OPERATIONS RESEARCH 2012
ENERGY, MARKETS AND MOBILITY

INTERNATIONAL ANNUAL CONFERENCE OF THE GERMAN OR SOCIETY

CONFERENCE GUIDE

September 4-7, 2012
Leibniz Universität Hannover

www.OR2012.de

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CONTENTS

WELCOME ADDRESS OF THE PRESIDENT OF LEIBNIZ UNIVERSITÄT HANNOVER

Erich Barke,
President of Leibniz Universität Hannover

Welcome to Leibniz Universität Hannover!

It is a pleasure and an honor to host the OR 2012 conference here in Hannover. Our university is named after Gottfried Wilhelm Leibniz, who lived and worked in Hannover for more than 40 years. The breadth of his scientific work is nicely reflected in the wide area of subjects you are addressing under the motto "Energy, Markets and Mobility". In dealing with these subjects, or any other operations research topic, you will almost certainly also build on his work, perhaps without even being aware of it. For example, Leibniz made important contributions to the dual number system, a foundation of the digital computers you use every day in your professional work.

Your discipline fits well to the place you have chosen for your conference. Leibniz Universität Hannover traces its roots back to 1831, when it was founded as a Higher Vocational School with a first student intake of 64. Over the years, it successfully developed into a Royal College of Technology, later a Technical University and finally a full university offering all established academic disciplines short of Medicine with more than 22,000 students today.

Inspired by Leibniz, we believe in research that crosses boundaries of established disciplines and addresses current and vital problems of society at large. Our university motto is "Theoria cum praxi": What is important for life is important for us. What you operations researchers do is clearly following this general principle and so I am more than happy to welcome you here on behalf of the university and to wish you a fruitful conference and a great time in Hannover. We are glad to have you here!

WELCOME ADDRESS OF THE ORGANIZING AND PROGRAM COMMITTEE

Stefan Helber,
Chair of the Organizing & Program Committee

Welcome to Hannover and the OR 2012 Conference!

On behalf of both the Program Committee and the local Organizing Committee I thank you for your interest and participation in the International Annual Conference of the German Operations Research Society 2012. It is a truly international conference, with more than 500 participants from more than 39 countries all over the world.

When we started to prepare this conference about two years ago, we tried to find a general motto that is not only attractive in its own right, but also related to both Operations Research and the hosting institution, Leibniz Universität Hannover (LUH). Clearly, the increasing energy consumption and mobility demands of a growing world population lead to numerous resource conflicts, with markets being one out of several instruments to reconcile competing demands. These resource conflicts tend to be both complicated and of a quantitative nature, which obviously calls for operations researchers. However, these topics also have crucial technical and engineering aspects that have to be thoroughly understood in any attempt of sound individual and social decision making.

For this reason, it is good to host this conference at LUH, one of Germany's leading technical universities, and in Hannover, the state capital of Lower Saxony. The German federal state of Lower Saxony does not only have a world-class automotive industry which is extremely important for the state's economy, but it is also an important energy producer, with a growing emphasis on renewable energy, in particular wind energy. We were able to attract highly competent speakers from academia and industry to address the complex interfaces of engineering and economics related to "Energy, Markets and Mobility", the conference's general motto.

In addition to a series of interesting plenary and semi-plenary presentations, we will also hear 344 contributed talks addressing either this general motto or other established or developing fields of Operations Research in 18 different streams, ranging from "Applied Probability" to "Traffic and Transportation".

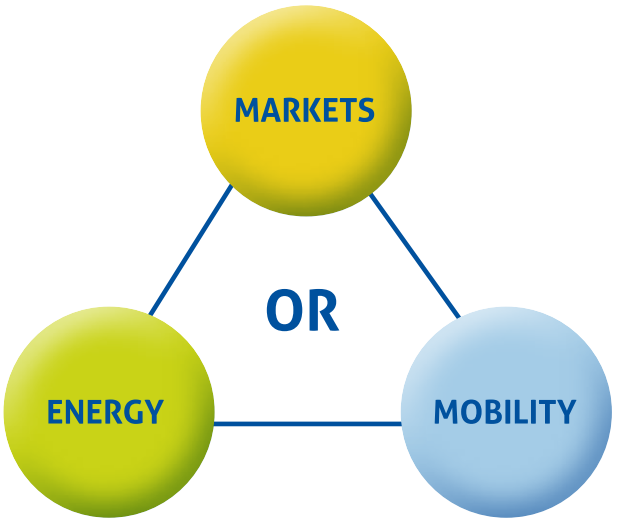
We are grateful to LUH for hosting the conference, to our donators and sponsors, and to the numerous helping hands that sacrificed their time and energy to make this conference possible. We hope that you will indeed find it interesting and enjoyable. We also hope that you will take some time to stroll around the many beautiful and interesting places Hannover has to offer as well as to socialize, to meet old friends and to make new ones.

We wish you a rewarding conference and an exciting time in Hannover!

OUR MOTTO: ENERGY, MARKETS AND MOBILITY

Special attention at the conference will be given to the three topics Energy, Markets and Mobility.

- Climate-neutral production, transportation, storage and use of energy lead to numerous new research questions for OR.
- Understanding and managing financial markets as well as markets for goods and services challenge OR experts.
- More and more people demand mobility, over both short and long distances. New mobility concepts that are both efficient and sustainable need to be understood and managed.



The OR 2012 conference in Hannover will address these topics from an OR perspective, treating them not only in isolation, but also with respect to their numerous and exciting interconnections, such as:

- New energy for new mobility concepts
- New market mechanisms for sustainable energy production

to name but a few. We will draw on the vast local expertise to organize an exciting and truly interdisciplinary conference in Hannover. As in former years, the conference will also provide ample opportunities to present OR-related research results in 18 different streams, representing both the many problem-oriented and the methodological aspects of Operations Research as a rich and vivid academic field.

STREAM AND STREAM CHAIRS

Applied Probability and Stochastic Programming, Forecasting
Prof. Dr. Karl-Heinz Waldmann
(Karlsruhe Institute of Technology)

Continuous Optimization
Prof. Dr. Mirjam Dür
(Universität Trier)

Decision Analysis and Multiple Criteria Decision Making
Prof. Dr. Jutta Geldermann
(Georg-August-Universität Göttingen)

Discrete and Combinatorial Optimization, Graphs and Networks
Prof. Dr. Matthias Müller-Hannemann
(Martin-Luther-University Halle-Wittenberg)

Energy and Environment
Prof. Dr. Grit Walther
(RWTH Aachen)

Financial Modeling, Banking and Insurance
Prof. Dr. Marc Gürtler
(TU Braunschweig)

Game Theory and Experimental Economics
Prof. Dr. Matthias Erlei
(Clausthal University of Technology)

Health Care Management
Prof. Dr. Axel Focke
(Neu-Ulm University)

Information Systems, Neural Nets and Fuzzy Systems
Prof. Dr. Natalia Kliewer
(Freie Universität Berlin)

Managerial Accounting
Prof. Dr. Katja Schimmelpfeng
(University of Hohenheim)

Production and Operations Management
Prof. Dr. Martin Grunow
(TU München)

Renewable Energy and New Mobility
Prof. Dr. Michael H. Breitner
(Leibniz Universität Hannover)

Revenue Management and Pricing
Prof. Dr. Alf Kimms
(University of Duisburg-Essen)

Scheduling and Project Management
Prof. Dr. Erwin Pesch
(University of Siegen)

Simulation and System Dynamics
Prof. Dr. Stefan Pickl
(Universität der Bundeswehr München)

Software Applications and Modeling Systems
Dr. Michael R. Bussieck
(GAMS Software GmbH)

Supply Chain Management, Logistics and Inventory
Prof. Dr. Herbert Meyr
(University of Hohenheim)

Traffic and Transportation
Prof. Dr. Knut Haase
(University of Hamburg)

PROGRAM COMMITTEE

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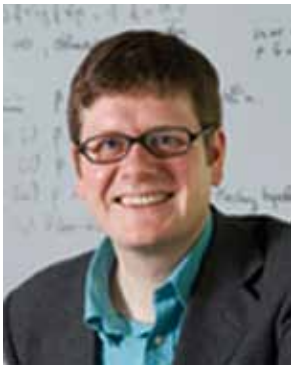


Stefan Weber
Institute of Probability and Statistics

CITY OF HANNOVER

There is scarcely any other city that can offer such diverse and attractive leisure amenities as Hannover, the capital of the State of Lower Saxony. You can stroll through the Royal Gardens of Herrenhausen or enjoy the unbridled greenery of the Eilenriede city forest; while the Maschsee Lake has a Mediterranean feeling that visitors revel in. And all these things are to be found right in the heart of the city.

Hannover's lively city center attracts shoppers with its extensive pedestrian zone, the new Ernst-August-Galerie and a series of elegant arcades and shopping malls.
In the Old Town quarter you can stroll through narrow medieval streets and relax on the banks of the River Leine or in one of the countless cafés.

Lovers of the arts from all over the world are drawn by Hannover's theaters and concerts, the outstanding offerings of its art galleries and its numerous museums and noted buildings.

As a city of trade fairs, events and sport, Hannover is a place of international encounter. Among the annual events that attract visitors in their thousands are the Maschsee Lake Festival and the biggest Marksmen's Funfair in the world.

Hannover is a state capital of great charm – why not come and discover its diversity?!

The Nanas designed by Niki de Saint Phalle

The Maschsee Lake Festival

The State Opera House at the Georgstraße

Photos & Texts: Hannover Marketing & Tourismus GmbH,
Photo of Maschsee Lake Festival: Stroetmann Verlag

MAP OF HANNOVER'S CITY CENTER

1 Leibniz Universität Hannover

2 Tram Station "Leibniz Universität"

3 Central Railway Station / Ernst-August-Platz

4 Brauhaus Ernst August

5 Ballhofplatz

6 Beginenturm

7 New Town Hall

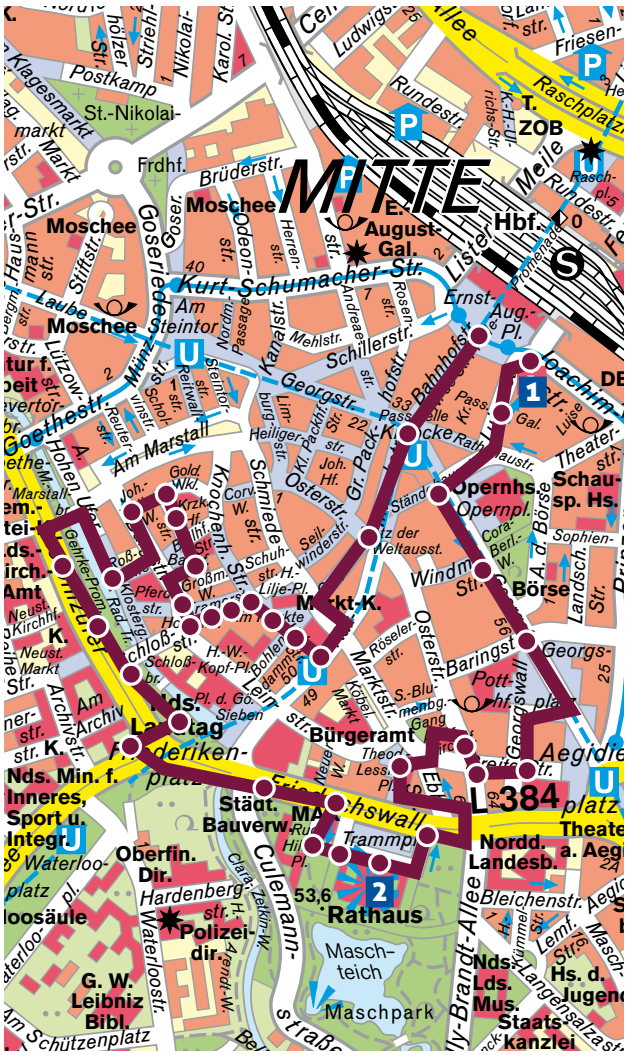
8 Sprengel Museum

Stadtkarte Hannover 1:20 000

PLACES OF INTEREST: THE RED THREAD

The Red Thread is a floorline visitors' guide of a different kind. The Red Thread is painted on the pavement, is 4200 meters long, and weaves its way through the inner city joining up 36 prime attractions. All you have to do is follow The Red Thread.

This "do it yourself" city tour is accompanied by an informative brochure which describes all of the interesting buildings and monuments you meet along the way, and is also full of interesting historical background. Furthermore the brochure describes a new "ExtraTour" which is a 45 minutes refreshing detour to the banks of Lake Maschsee.



Stadtkarte Hannover
©Landeshauptstadt Hannover, Geoinformation, 2010

Text & Photo: Hannover Marketing & Tourismus GmbH

You can purchase the brochure in German or English for 3 € at the Conference Desk.

Note: The brochure is available at the Tourist Information 1 and the Info-Counter in the New Town Hall 2 in Chinese, English, French, German, Italian, Japanese, Polish, Russian, Spanish, and Turkish.

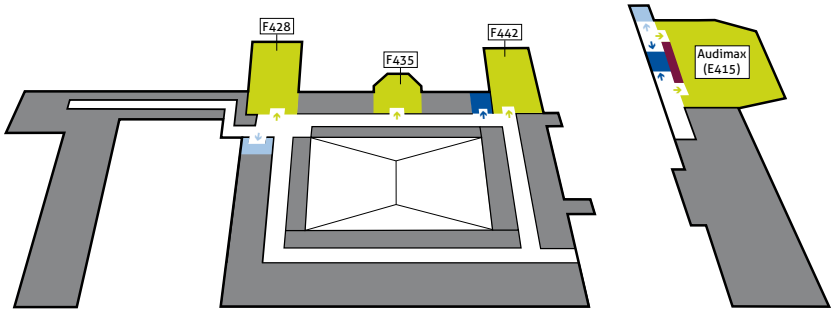
LEIBNIZ UNIVERSITÄT HANNOVER

With no more than 64 students to start with in 1831, there are roughly 22,000 students and nine faculties today. Students can choose from a wide variety of courses with 60 subjects and some 170 full-time and part-time courses in natural sciences, engineering, humanities and social sciences as well as in economics and management, and law.
In research, Leibniz Universität Hannover focuses on national and international competitive areas. Competence centers and two Clusters of Excellence (QUEST and REBIRTH) raise the profile of the university.
International contacts are part of everyday life at Leibniz Universität Hannover. In addition, international master's degree programs such as "Water Resources and Environmental Management" or "International Horticulture" are on offer. The fact that 12% of the students come from abroad is living proof of the international attractiveness of the university.

The heart of Leibniz Universität Hannover beats in the idyllic Welfenschloss, the Guelph Palace. The Welfenschloss has formed the center of the university since 1879. As a result of annexation by Prussia in 1866 the original plans for the building as the seat of the Kingdom of Hannover never came to fruition.

SITE PLAN

- CONFERENCE ROOMS
- STAIRS
- ELEVATORS
- RESTROOMS

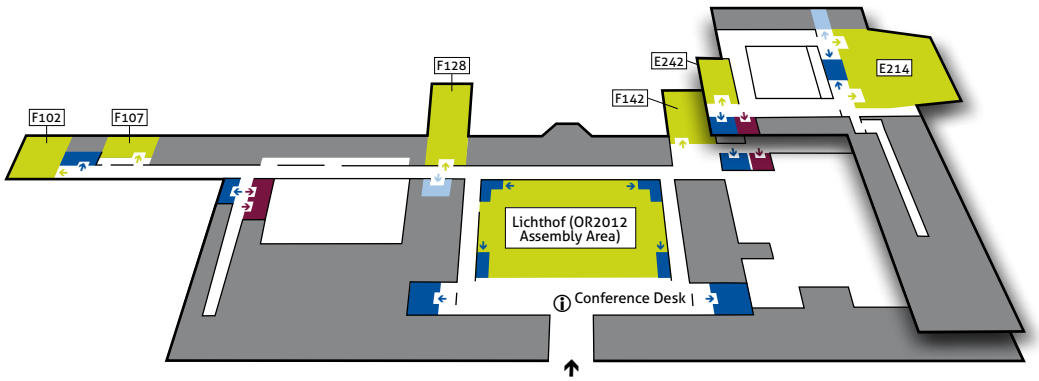


FOURTH FLOOR

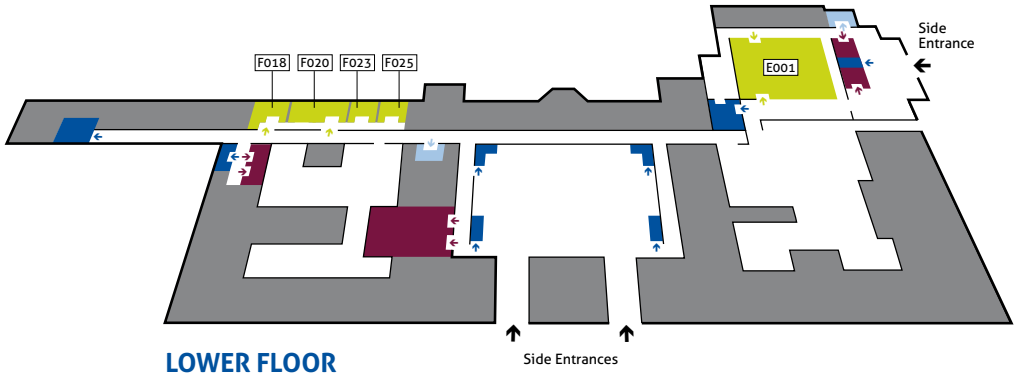
NOTE: You cannot walk directly from the rooms F428, F435 and F442 to the Audimax (E415). You first have to go down to the third floor and then back up.

THIRD FLOOR

(INTERMEDIATE) SECOND FLOOR



FIRST FLOOR



LOWER FLOOR

LUNCH AND COFFEE BARS NEARBY

We recommend the main dining hall of the university for lunch **1**. Lunch there is included using the allotted vouchers. It is a 5 to 10 minute walk from the Lichthof through the beautiful Welfengarten to the main dining hall. Please note that the food counters close at 14:10. You can download the menu at the following link: **www.studentenwerk-hannover.de/hauptmensa.html**

2 **Campus Suite** • Coffee Bar
3 **Cheers** • Restaurant for pizza, pasta and salad
4 **uni Biergarten** • Beer Garden

Many other restaurants and coffee bars can be found along the Engelbosteler Damm **5**.

CONFERENCE DESK

The Conference Desk is located at the Lichthof next to the main entrance.

Opening hours:
Tuesday, September 4 • 16:30 – 21:00
Wednesday, September 5 • 08:00 – 20:00
Thursday, September 6 • 08:00 – 17:30
Friday, September 7 • 08:00 – 14:00

Contact:
admin@or2012.de
+49 (0)511 762 4851

DOWNLOAD INFORMATION

You can download this book and other supplementary material at the following website: **www.OR2012.de/downloads**.

REMARKS FOR SPEAKERS

- Please arrive at the room at least 10 minutes before the session starts to check in with the session chair and test the provided technical equipment. There will be an assistant in each room who will help you if a technical problem occurs. Please note that due to time constraints, the use of your own computer for the presentation is unfortunately not possible.
- The software installed on the computers in the rooms is **Adobe Acrobat Reader** and **Microsoft Office 2007**. Please provide the assistant with a compatible version of your presentation on a USB memory-stick or on a CD-Rom before the first talk in the session starts.

  Note: You may test the technical adequacy of your presentation at the Speaker's Check-In in room C311. There will be IT-assistants available to help you in case of technical problems.
- Your presentation including the questions afterwards should take 30 minutes.
- Each room will be equipped with a laser-pointer.

REMARKS FOR SESSION CHAIRS

Thank you for supporting the conference by being a session chair! Your role is to coordinate the presentations and to ensure the smooth running of the session.

- Please arrive at the room at least 10 minutes before the session starts in order to verify whether all speakers appeared. Take care that the speakers prepare the technical equipment for their presentation before the first talk in this session starts. There will be an assistant in each room who will help you and the speakers if a technical problem occurs.
- Each presentation including the questions afterwards should take 30 minutes.
- We want to allow participants to change between sessions. Therefore, please begin and end each presentation on time and ensure that the presentations are held in the order shown in the program. If a speaker cancels or does not attend, you are free to allocate the time to the remaining presentations.
- At the beginning of each presentation, please introduce the speaker and the title of the presentation. If a presentation takes too long, produce visual warnings to the speaker on the remaining number of minutes by using the prepared cards in the conference room. At the end of each talk, chair the discussion on the presentation.

INTERNET ACCESS

Internet access via WLAN will be available at the whole conference venue. For internet access via WLAN please follow these steps:

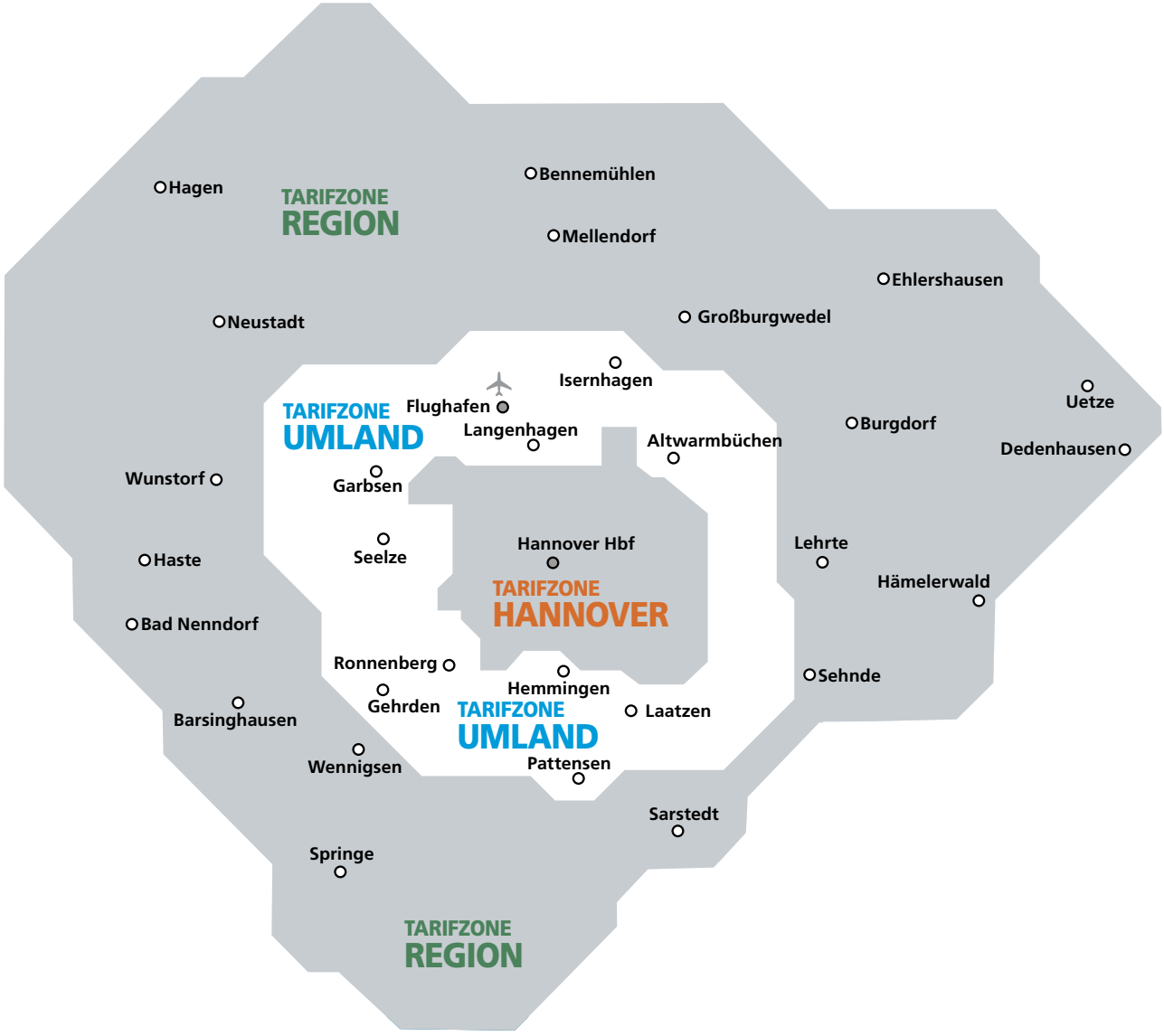
Note: Unfortunately we cannot provide the login information in the online version of the Conference Guide.

HANNOVER TOURISM DESK

A representative of the Hannover Marketing und Tourismus GmbH will be present on-site at the Lichthof on **Wednesday, September 5** from **11:00 to 17:00**, providing you with tourist information and answering any questions you may have about the city and region of Hannover.

PUBLIC TRANSPORTATION (GVH)

You can use your name tag as your public transportation ticket. It is valid from **Tuesday, September 4** to **Friday, September 7**. The ticket is valid in all areas displayed on the following map.



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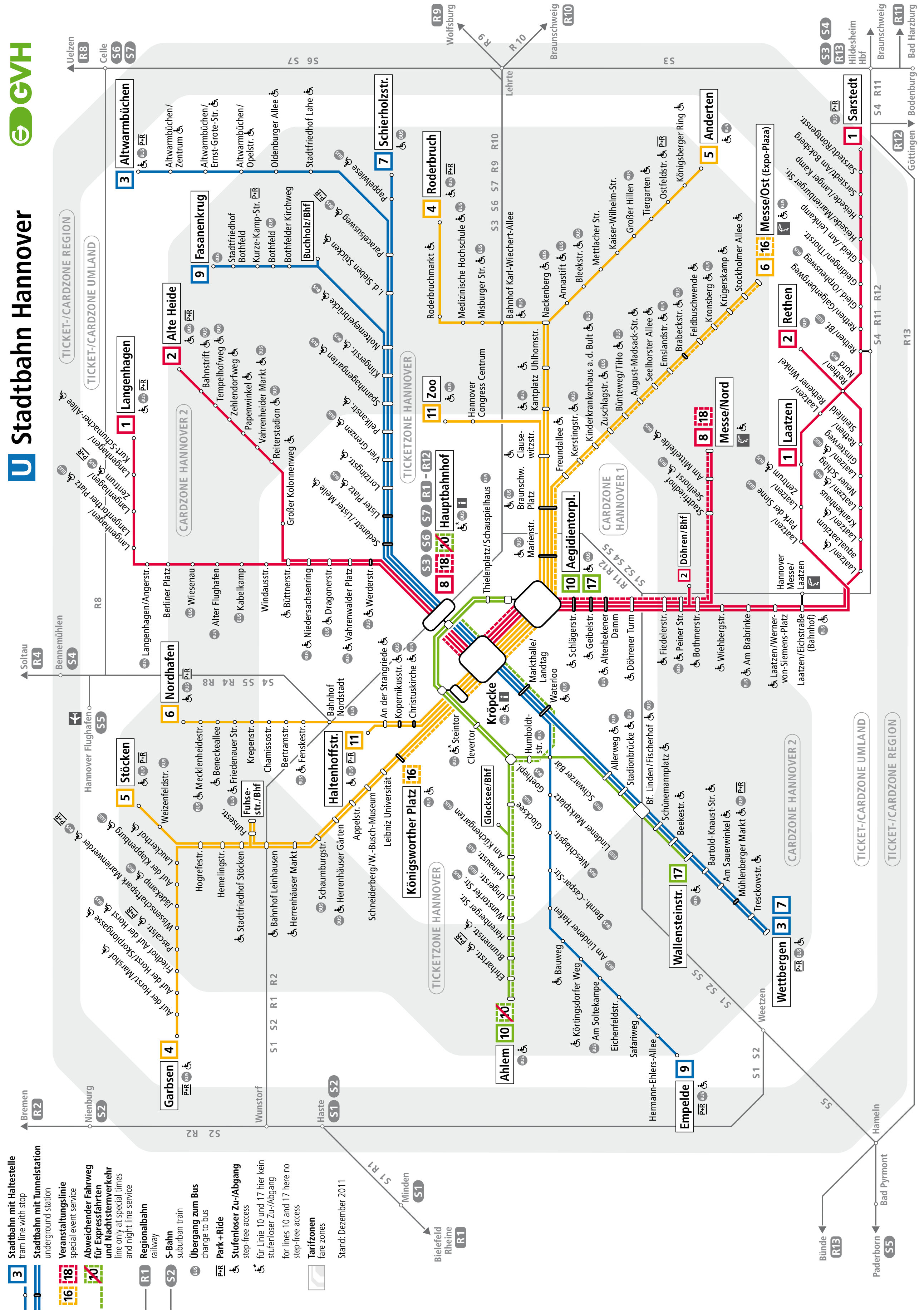

U Stadtbahn Hannover
GVH
Stadtbahn mit Haltestelle
tram line with stop
Stadtbahn mit Tunnelstation
underground station
Veranstaltungslinie
special event service
Abweichender Fahrweg für Expressfahrten und Nachtsternverkehr
line only at special times and night line service
Regionalbahn
railway
S-Bahn
suburban train
Übergang zum Bus
change to bus
Park+Ride
Stufenloser Zu-/Abgang
step-free access
für Linie 10 und 17 hier kein stufenloser Zu-/Abgang
for lines 10 and 17 here no step-free access
Tarifzonen
fare zones
Stand: Dezember 2011
TICKETZONE HANNOVER
CARDZONE HANNOVER 1
CARDZONE HANNOVER 2
TICKET-/CARDZONE UMLAND
TICKET-/CARDZONE REGION
Hauptbahnhof
Kröpcke
Aegidientorpl.
Langenhagen
Altwarmbüchen
Alte Heide
Fasanenkrug
Schierholzstr.
Roderbruch
Zoo
Anderten
Messe/Ost (Expo-Plaza)
Messe/Nord
Laatzen
Rethen
Sarstedt
Wettbergen
Wallensteinstr.
Empelde
Ahlem
Garbsen
Stöcken
Nordhafen
Haltenhoffstr.
Königsworther Platz
Bremen
Nienburg
Wunstorf
Haste
Minden
Bielefeld Rheine
Hameln
Bad Pyrmont
Paderborn
Bünde
Göttingen
Hildesheim Hbf
Braunschweig
Bad Harzburg
Wolfsburg
Lehrte
Celle
Uelzen
Soltau
Bennemühlen
Hannover Flughafen
Weetzen
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CONFERENCE SCHEDULE

	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
09:00		WA Opening Session & Plenary Speaker	TA Contributed Papers	FA Contributed Papers
10:00			TB Plenary Speaker	FB Semiplenary Speakers
11:00		Coffee Break	Coffee Break	Coffee Break
12:00		WB Contributed Papers	TC Contributed Papers TC GOR PhD Awards	FC Plenary Speaker & Closing Ceremony Farewell Lunch
13:00		Lunch	Lunch	
14:00		WC Contributed Papers WC GOR Master Awards	TD Contributed Papers	
15:00	GAMS Workshop AIMMS Workshop			
16:00		WD Semiplenary Speakers	TE Semiplenary Speakers	
17:00		Coffee Break WE Contributed Papers	Coffee Break Meeting of GOR Members	
18:00				
19:00	Welcome Reception	Evening Reception with Hannover's Mayor	Conference Dinner	

BUSINESS MEETINGS

MEETING OF THE MANAGEMENT BOARD OF THE GOR

Tuesday, September 4 • 08:30 – 12:30
Room: Senatssitzungssaal (F335)

MEETING OF THE ADVISORY BOARD OF THE GOR

Tuesday, September 4 • 14:00 – 18:00
Room: Senatssitzungssaal (F335)

MEETING OF THE OR SPECTRUM BOARD

Wednesday, September 5 • 14:00 – 15:30
Room: Senatssitzungssaal (F335)

MEETING OF THE ORGANIZERS OF OR 2013

Wednesday, September 5 • 14:00 – 15:30
Room: E242

WORKSHOP CONTENT-MANAGEMENT-SYSTEM OF THE GOR WORK GROUP LEADERS

Wednesday, September 5 • 17:00 – 18:30
Room: Senatssitzungssaal (F335)

MEETING OF THE GOR WORK GROUP LEADERS

Thursday, September 6 • 08:30 – 10:00
Room: Senatssitzungssaal (F335)

MEETING OF GOR MEMBERS

Thursday, September 6 • 17:00 – 18:30
Room: Audimax (E415)

SOCIAL PROGRAM

WELCOME RECEPTION

Tuesday, September 4 • 19:00

Enjoy an evening with a barbecue in the park behind the Welfenschloss. In case of rain, the Welcome Reception will be moved to the Lichthof inside the Welfenschloss.
The Welcome Reception is free for registered conference participants.

RECEPTION WITH HANNOVER'S MAYOR

Wednesday, September 5 • 19:00

You are invited by Hannover's Mayor to a festive evening in the Lichthof.
The Evening Reception is free for registered conference participants.

FAREWELL LUNCH

Friday, September 7 • 12:30

Bring the conference to a pleasant end by joining the Farewell Lunch in the Lichthof.
The Farewell Lunch is free for registered conference participants.

CONFERENCE DINNER IN HANNOVER'S ADVENTURE ZOO

Thursday, September 6 • 19:00

The festive Conference Dinner will take place at the Great Hall of the Maharajah of Hannover's Adventure Zoo.

Fee: 80 € per person

You can register and pay for the Conference Dinner at the Conference Desk, if tickets are still available.

MENU

STARTERS
Asian Noodle Salad with Yakitori Skewer
(Vegetable Skewer for Vegetarians)
•
Vegetarian Sushi-Crêpe with Avocado Sauce
•
Skewer with Cherry Tomatoes and Mozzarella

SOUP
Cream of Red Lentil Soup

MAIN COURSE
Roasted Corn-Fed Chicken Breast on a Tandoori Bed with Wok Vegetables and Saffron Pualo
or
Goat Cheese in a Wang-Tan Coat on Sesame Sauce with Wok Vegetables and Saffron Pualo

DESSERT
Maharajah Dessert Plate with a Selection of Exotic Fruits and Homemade Mango Sorbet in a Pastry Bowl
•
Marbled Chocolate Mousse on Fruit Sauce with Fine Fruit Decoration
•
Exotic Fruit Ratatouille with Lime Mousse on Cassis Sauce with a Chocolate Sail

TOURS & EXCURSIONS

WEDNESDAY, SEPTEMBER 5

SPRENGEL MUSEUM

Wednesday, September 5 • 11:30 – 12:30
Start/End: Sprengel Museum (Kurt-Schwitters-Platz)
Fee: 9 € per person

Enjoy a one-hour guided tour through the Sprengel Museum Hannover. With its comprehensive permanent collection and diverse temporary exhibitions it ranks among the most important museums of 20th and 21st century art.

Photo & Text: Sprengel Museum Hannover

Photo: Nik Barlo jr.; Text: Hannover Marketing & Tourismus GmbH

ROYAL GARDENS OF HERRENHAUSEN - GARDEN WONDER & FLOWER POWER

Wednesday, September 5 • 13:30 – 15:00
Start/End: Great Garden
Fee: 8 € per person

Wander through this remarkably well preserved Baroque garden – the Great Garden of Herrenhausen looks back over more than 300 years of history. Be inspired by the intricate patterns of carefully tended box trees, the contrasting effect of marble gravel and colourful flowerbeds. One of the garden's special and modern attractions is the delightful grotto featuring colourful glass mosaics designed by artist Niki de Saint Phalle. The Berggarten is equally worth a visit. This botanical garden is famous for its unique collection of plants gathered from the world over.

You can register and pay for the Tours and Excursions at the Conference Desk, if tickets are still available.

ON TOUR WITH THE "BRUCHMEISTER"

Wednesday, September 5 • 16:00 – 18:00
Start: New Town Hall (Trammplatz)
End: Brauhaus Ernst August (Schmiedestr. 13)
Fee: 6 € per person

Spend 2 hours accompanied by the "Bruchmeister", with top hats and white gloves. The "Bruchmeister" (or city steward) represents not only an interesting aspect of Hannover's history but also more than 700 years of the art of drinking. The tour culminates with a specialist teaching you how to drink Hannover's very own national drink, the "Lüttje Lage".

Photo: Collegium ehemaliger Bruchmeister e.V.; Text: Hannover Marketing & Tourismus GmbH

Photo & Text: Hannover Marketing & Tourismus GmbH

NIGHT-WATCHMAN MELCHIOR

Wednesday, September 5 • 21:00 – 22:30
Start: Beginenturm (Pferdestraße)
End: Ballhofplatz
Fee: 10 € per person

When all honourable citizens of Hannover lie asleep in their beds, that is when Night-Watchman Melchior takes you on a fascinating walk through the darkest alleys and corners of the city. As he walks, he tells of murders, of gangs and the everyday trials and tribulations of a night-watchman's life. He also knows a thing or two about the history of beer and the city's nightlife.

You can register and pay for the Tours and Excursions at the Conference Desk, if tickets are still available.

THURSDAY, SEPTEMBER 6

HANNOVER KEEPS RUNNING ...

Thursday, September 6 • 7:00 – 8:00
Start/End: Ernst-August-Platz
Fee: 10 € per person

A jogging city tour for sportive people. Discover the sights of Hannover in a guided tour lasting 1 hour. The track starts at Ernst-August-Platz, leads you via the New Town Hall, Maschsee Lake and the Old Town back to the starting point. Be inspired by this new and individual kind of getting to know Hannover!

Photo & Text: Hannover Marketing & Tourismus GmbH

Photo: Volkswagen AG

EXCURSION TO VOLKSWAGEN COMMERCIAL VEHICLES

Thursday, September 6 • 12:30 –15:30
Start/End: Conference Desk
(shuttle service to and from Volkswagen site)
Fee: free for registered conference participants

You will walk on foot through the production, seeing the fabrication of a vehicle from the pressroom to the final assembly, which takes about two hours. In addition you will get a brief presentation about the history of Volkswagen Commercial Vehicles.

You can register and pay for the Tours and Excursions at the Conference Desk, if tickets are still available.

HANNOVER ADVENTURE ZOO

Thursday, September 6 • 16:00 – 17:30
Start/End: Hannover Adventure Zoo
Fee: 23 € per person
(guided tour through the Zambezi, incl. day ticket to the zoo)

Independent of the guided zoo tour, you can purchase day tickets to the zoo for a reduced price of 18 € at the Conference Desk.

Enjoy an exciting day out in Hannover Adventure Zoo – Germany's most spectacular zoological garden, which thrills some 1.5 million visitors every year. The animals and the fascinating landscapes in which they live, make for an unforgettable day out for the whole family. See the more than 2,000 resident animals in the unique authentic theme worlds: real-life boat trip along the Zambezi; the magnificent ruins of the Indian Jungle Palace; the exciting Gorilla Mountain; and the old-world rural charm of Lower Saxony in Meyers Hof and Helme Heine's "Mullewapp" Children's Paradise. Not to mention many shows and feeding time specials every day, theme gastronomy, and numerous baby animals to round off a really entertaining day out. The Hannover Adventure Zoo is the perfect holiday attraction for grown-ups and children. For a really animally day out!

You can register and pay for the Tours and Excursions at the Conference Desk, if tickets are still available.

Photos & Text: Hannover Adventure Zoo

CONFERENCE SCHEDULE

	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
09:00		WA Opening Session & Plenary Speaker	TA Contributed Papers	FA Contributed Papers
10:00			TB Plenary Speaker	FB Semiplenary Speakers
11:00		Coffee Break	Coffee Break	Coffee Break
12:00		WB Contributed Papers	TC Contributed Papers TC GOR PhD Awards	FC Plenary Speaker & Closing Ceremony
13:00		Lunch	Lunch	Farewell Lunch
14:00		WC Contributed Papers WC GOR Master Awards	TD Contributed Papers	
15:00	GAMS Workshop AIMMS Workshop			
16:00		WD Semiplenary Speakers	TE Semiplenary Speakers	
17:00		Coffee Break WE Contributed Papers	Coffee Break Meeting of GOR Members	
18:00				
19:00	Welcome Reception	Evening Reception with Hannover's Mayor	Conference Dinner	

DETAILED DAILY SCHEDULE

WEDNESDAY, SEPTEMBER 5

STREAM	TRACK	ROOM	WA	WB · PAPERS 11:30 – 13:00	WC · PAPERS 14:00 – 15:30
GOR Awards			OPENING SESSION & PLENARY SPEAKER 09:00 – 11:00 Hämäläinen (Room: Audimax (E415))		GOR Master Awards (Room: B302)
Applied Probability & Stochastic Programming, Forecasting	08	F018		Applied Probability I	Applied Probability II
Continuous Optimization	10	F025		Nonsmooth & Conic Optimization	Nonlinear Programming
Decision Analysis & Multiple Criteria Decision Making	11	F107		Decision Processes & Strategic Management	Multi Criteria Decision Making & Social Responsibility
	12	F023			
Discrete & Combinatorial Optimization, Graphs & Networks	13	A310		Column Generation	Robustness & Uncertainty
	14	F435		Packing & Cutting	Combinatorial Optimization
Energy & Environment	16	B305		Planning Energy Systems I	Planning Energy Systems II
	17	F020		Sustainable Networks	Sustainable Measures
Financial Modeling, Banking & Insurance	12	F023		Risk Analysis	Pricing & Design of Financial Instruments
Game Theory & Experimental Economics	10	F025			
Health Care Management	08	F018			
Information Systems, Neural Nets & Fuzzy Systems	18	E242			
Managerial Accounting	20	B302		Managerial Accounting I	
Production & Operations Management	09	F102		Designing (Energy Efficient) Production Systems	Maintenance & Rework
	11	F107			
Renewable Energy & New Mobility	19	F309		Energy Production & Fossil Energy Saving	Optimization in Energy Usage
	18	E242			
Revenue Management & Pricing	21	F128		Revenue Management I	Revenue Management II
Scheduling & Project Management	15	F303		Project Scheduling I	Scheduling
	14	F435			
Simulation & System Dynamics	20	B302			
Software Applications & Modeling Systems	22	E001		Supply Chain Management	Modeling Applications in European Energy Markets
	23	F142		Algebraic Modeling Languages I	Learning Modeling & Optimization
	24	F428			
Supply Chain Management, Logistics & Inventory	26	E214		Diverse Issues I	Diverse Issues II
	27	F342		Inventory I	Inventory II
Traffic & Transportation	25	F442		Public Transport	Road Traffic
	24	F428		Routing I	Routing II

				WEDNESDAY, SEPTEMBER 5	THURSDAY, SEPTEMBER 6
STREAM	**TRACK**	**ROOM**	**WD**	**WE • PAPERS 17:00 – 18:30**	**TA • PAPERS 09:00 – 10:00**
GOR Awards			SEMIPLENARY SPEAKERS 15:45 – 16:30 Breitner (Room: F303) • Gershwin (Room: F102) • Gilg (Room: E001) • Walther (Room: B305)		
Applied Probability & Stochastic Programming, Forecasting	08	F018		Applied Probability III	
Continuous Optimization	10	F025			Continuous Optimization in Applications I
Decision Analysis & Multiple Criteria Decision Making	11	F107		Decision Processes in the Energy Sector	
	12	F023			
Discrete & Combinatorial Optimization, Graphs & Networks	13	A310		Networks	Scheduling & Linear Programming
	14	F435		Miscellaneous	Applications
Energy & Environment	16	B305		Managing Energy Systems	Gas Networks I
	17	F020		Water & Hydrothermal Systems	
Financial Modeling, Banking & Insurance	12	F023		Finance & Banking	
Game Theory & Experimental Economics	10	F025		Experimental Games	
Health Care Management	08	F018			Risk Management
Information Systems, Neural Nets & Fuzzy Systems	18	E242			Neural Networks & Fuzzy Systems
Managerial Accounting	20	B302		Managerial Accounting II	
Production & Operations Management	09	F102		Lotsizing	Ethics & Sustainability
	11	F107			Stocks & Inventories
Renewable Energy & New Mobility	19	F309		Electric Vehicles & Car Sharing	
	18	E242		Electricity Markets	
Revenue Management & Pricing	21	F128		Revenue Management III	
Scheduling & Project Management	15	F303		Project Scheduling II	Recent Results in Scheduling
	14	F435			
Simulation & System Dynamics	20	B302			Strategic Management & Innovation Processes
Software Applications & Modeling Systems	22	E001		Selected Algorithms & Applications I	Revenue Management
	23	F142		Stochastic Programming	Nonlinear Programming
	24	F428			Selected Algorithms & Applications II
Supply Chain Management, Logistics & Inventory	26	E214		Network Design I	Network Design II
	27	F342		Lotsizing	Contracts
Traffic & Transportation	25	F442		Traffic Estimation	Bike Sharing & Service Regulations
	24	F428		Routing III	

THURSDAY, SEPTEMBER 6

FRIDAY, SEPTEMBER 7

TB	TC · PAPERS 11:30 – 13:00	TD · PAPERS 14:00 – 15:30	TE	FA · PAPERS 09:00 – 10:00	FB	FC
PLENARY SPEAKER 10:15 – 11:00 Oehlschlaeger (Room: Audimax (E415))	GOR PhD Awards (Room: F128)		SEMIPLENARY SPEAKERS 15:45 – 16:30 Bichler (Room: F303) • Reuter (Room: F102) • Spengler (Room: E001)		SEMIPLENARY SPEAKERS 10:15 – 11:00 Fichtner (Room: F303) • Gatzert (Room: F102) • Henderson (Room: E001) • Skutella (Room: B305)	PLENARY SPEAKER & CLOSING CEREMONY 11:30 – 12:30 Company Award (Room: Audimax (E415))
				Continuous Optimization in Applications II		
	Risk Analysis & Assessment	Decision Analysis in Industrial Engineering		Data Envelopment Analysis (DEA)		
		Outranking Approaches for Sustainable Development				
	Facility Location	Routing		Graph Algorithms		
	Energy Storage Systems	Demand Side Management		Gas Networks II		
	Energy Management Systems	Electricity Markets				
	Portfolio Management					
	Applied Game Theory	Dynamic Processes in Economic Games				
		Location/Allocation of Health Care Facilities		Multiobjective Decision Making in Health Care Management		
	Information Systems & Neural Networks	Neural Networks				
	Airport Operations Management	Product Variety & Structure		Capacity Management & Contracts		
	Wind Energy & Other Energy Sources	Electric Mobility		Mathematics & New Energy		
		Revenue Management IV		Revenue Management V		
	Scheduling Applications I	Scheduling Applications II		Scheduling & Rostering		
	Scheduling Theory	New Scheduling Models & Algorithms		Scheduling & Practice		
	Energy Markets	Complex Systems				
	Software in Traffic Management	Applications in Logistics		Selected Algorithms & Applications III		
	Algebraic Modeling Languages II	MI(N)LP Software		Deploying Optimization Software		
				Selected Algorithms & Applications IV		
	Green Supply Chains	Transport		Humanitarian Logistics		
	Supply	Auctions				
	Shipping & Railway	Air Transport & Motorail				
	Synchronization in Vehicle Routing I	Synchronization in Vehicle Routing II				

PLENARY SPEAKERS

Wednesday • 09:00 – 11:00
Room: Audimax (E415)

Raimo P. Hämäläinen
Systems Analysis Laboratory, Aalto University School of Science, Finland

Raimo P. Hämäläinen received his masters and doctoral degrees in operations research from the Helsinki University of Technology which has recently merged with the Helsinki School of Economics to form the Aalto University. He is the founder and director of the Systems Analysis Laboratory and director of the National Graduate School of Systems Analysis, Decision Making and Risk Management and the Honorary President of the Finnish OR society.
His current research interests include decision modelling and risk analysis with energy-environmental applications. He is the designer of many widely used web based decision support software [www.decisionarium.hut.fi] and has also recently introduced the new concept of Systems Intelligence to improve human performance in problem solving. He has consulted widely for environmental and nuclear energy agencies as well as for the Finnish Air Force.
Prof. Hämäläinen has published extensively in major OR journals including Operations Research, Management Science, EJOR and the Journal of the Operational Research Society.

On the Need for Behavioral Operations Research

I call for research in Behavioral Operational Research (BOR) to advance the practice of OR. Our community has studied behavioral issues in decision making but they are also important and always present when supporting human problem solving by modeling. In the practice of OR behavioral effects can relate to problem framing, methodological anchoring, group interaction and communication as well as to the possibility of procedural mistakes and cognitive biases. A well known behavioral system dynamics study claims that people do not understand accumulation. We show how the results are critically dependent on the problem formulation.

Horst Oehlschlaeger
Development/Manager Concepts, Simulation, Product Data
Volkswagen Commercial Vehicles, Germany

Thursday • 10:15 – 11:00
Room: Audimax (E415)

Horst Oehlschlaeger studied Mechanical Engineering at the Technical University of Braunschweig, where in 1981 he received his PhD.
After two years as Branch Manager of the Fahrzeugtechnische Forschungs- und Beratungsgesellschaft in Braunschweig (Automotive Research and Consulting), he joined Volkswagen R&D in Wolfsburg. Starting as an engineer for numerical analysis at VW Commercial Vehicles in 1983, Horst Oehlschlaeger later worked for research and for chassis development. After acting as assistant to the Development Board Manager in 1983, he became head of the department Concepts and Simulation at VW Commercial Vehicles. As of 2001, he followed up to become its Division Manager, a division later also comprehending Product Data Management. In 2002 the Technical University of Braunschweig appointed him honorary professor at the Institute of Vehicle Technology in the field of design und numerical simulation of vehicle structures, a job parallel to his responsibilities at VW.
Through time Horst Oehlschlaeger published numerous papers and acted as a conference speaker primarily dealing with issues in numerical simulation, virtual product development and alternative drives.

Outlook on Low-Emission Light Commercial Mobility – New Energy for the Future

Ensuring the long-term future of commercial transport demands highly efficient vehicles that can be operated with alternative and renewable energy resources to an increasing extent. Electric drives (hybrid and battery-powered vehicles) offer great potential for reducing dependency on oil imports as well as for cutting CO2 and other pollution emissions.
For the transition phase, the optimisation of conventional powerplants needs further investigation. All this is encompassed by the Volkswagen fuel and powertrain strategy.
Light commercial vehicles in particular have their own typical application scenario and boundary conditions. Thus the electrification of the light commercial vehicle powertrain allowes and/or requires a different approach from passenger cars.

SEMIPLENARY SPEAKERS

Wednesday • 15:45 – 16:30
Room: F303

Michael H. Breitner
Information Systems Institute (ISI), Leibniz Universität Hannover, Germany

Michael H. Breitner received his Diploma in Mathematics and Management from the TU München and pursued his PhD in the group of Prof. Dr. Dr. h.c. mult. Roland Bulirsch working on Numerical Optimization, Optimal Control and Dynamic Games. In 1995 he accepted an assistant professor position at the TU Clausthal and earned his PhD in 1995. He became tenure in 1997 and earned his venia legendi (Habilitation) in 2001 working on Aerospace, Management and Economics problems. Since the mid 1990s he is also interested in Information Systems, High Performance Computing, Artificial Neural Networks and Software Engineering, e.g. for the neurosimulator FAUN.

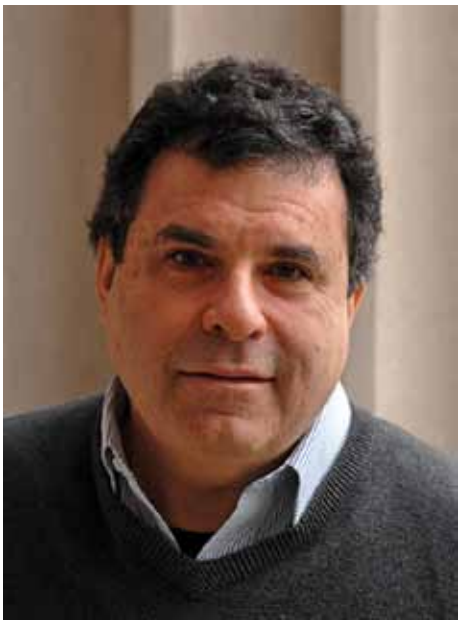
In 2002 Michael H. Breitner became full professor at the Leibniz Universität Hannover and head of the Information Systems Institute (ISI). His research topics today include intelligent power networks, the transformation of the energy system to renewable energy sources and new mobility, e.g. car sharing and new fuels. He is a member of the directorial board of the Leibniz Research Center "Transformation of the Energy System 2050" in Hannover and earned various grants and funding in the last decade.

Modeling the Transformation of the German Energy System until 2050 – A Multi-Criteria, Long Term Optimization Problem with Many Constraints

Today only 10% of Germany's energy demand of 2500 TWh per year for living, traffic and electricity is met with renewable energy sources. Total energy costs exceed 300 billion Euro per year. For the next decades Germany needs a careful and cost-efficient transformation to a reliable and affordable energy system with a rapidly increasing share of renewable energy sources. Trillions of Euro investments are necessary to build up cost-efficient renewable energy generation, storage, transformation and transportation. Power plants, vehicles, heating/cooling facilities etc. must be replaced step by step in the long run. For holistic, techno-economic scenario analyses and optimization a multi-criteria, long term simulation and optimization model with many constraints is developed and discussed which forms the basis of an interdisciplinary research project.

Stanley B. Gershwin
Department of Mechanical Engineering, Massachusetts Institute of Technology (MIT), USA

Wednesday • 15:45 – 16:30
Room: F102



Stanley B. Gershwin is a Senior Research Scientist at the MIT Department of Mechanical Engineering. He received the B.S. degree in Engineering Mathematics from Columbia University; and the M.A. and PhD degrees in Applied Mathematics from Harvard University.
He has worked at the Bell Telephone Laboratories and at the C. S. Draper Laboratory, and he was Professor of Manufacturing Engineering at Boston University.
His research interests include real-time scheduling and planning in manufacturing systems; hierarchical control; decomposition methods for large scale systems; approximation techniques. His major research goal is the development of an engineering theory of manufacturing systems control. He has published papers in Annals of Operations Research, IEEE Transactions on Automatic Control, IIE Transactions (which awarded Best Paper Awards to two of his papers), International Journal of Production Economics, International Journal of Production Research, Operations Research, Operations Research Spectrum, and other journals. Dr. Gershwin is the author of Manufacturing Systems Engineering (Prentice-Hall, 1994).

Analysis, Control, and Design of Stochastic Flow Systems with Limited Storage

We present a class of network models that can be used to analyze and control the flow of material in a stochastic network with limited storage space, and we describe the design of such networks. These models have been primarily applied to manufacturing systems. Material enters the system and flows from processing stations (machines) to storage areas (buffers) to other processing stations and then it exits the system. The machine time is random, possibly because of machine failure. The class of systems that can be analyzed has grown from two-machine, one-buffer systems with very restricted machine models, to very large systems, with a general set of machine behaviors. Tokens, as well as material, flow in these systems, and the flow of tokens can be used to control the flow of material. Unlike Jackson networks, exact analytical solutions of the flow dynamics are not available, but very accurate approximate methods are available. Efficient optimization methods exist which allow the simultaneous optimization of the system and its control policy. We survey important results and we describe open research problems.

Wednesday • 15:45 – 16:30
Room: E001

Albert B. Gilg
Corporate Research and Technologies, Siemens AG, Germany

Albert Gilg studied Mathematics and Computer Science at the Technical University of Munich (1976-84, Diploma 1981 and Dissertation 1984). He started his industrial career at Corporate Technology of Siemens AG in Munich. There he initiated and conducted the setting up of a Computer-Aided Electronics Engineering suite covering process, device and circuit simulation. Dr. Gilg took over further research manager positions gaining expertise in an extraordinary broad field of industrial applications.
1991 Albert Gilg was promoted to the senior management level. At the time he is heading the Global Technology Field "Modeling, Simulation and Optimization" at Siemens Corporate Research and Technologies in Munich.
Albert Gilg has been a member of several academic evaluation teams, scientific advisory and editorial boards. In 1988 and 2001 he assumed visiting professorship positions at the Mathematics Department of the University of California at San Diego. Since 1997 he has held an honorary professorship at Technical University of Munich. In 2006 Albert Gilg was awarded the honorary engineering doctorate by the Institute of Electrical Engineering and Information Technology of the University of Armed Forces at Munich for his pioneering work in Mathematical Engineering.

Optimizing Design and Operations – An Industrial Viewpoint

Simulation and optimization methods and tools have been established in industry as drivers for speedup and quality. They became key methodologies for model-based prediction and planning in computer-based virtual work spaces. We see shifts in importance and even new challenges driven by industrial trends like bridging product and system life-cycle phases and supporting business decision making and management of full life cycles. This also addresses modelling topics to find more intelligent ways to deal with exploding complexity and impacts of uncertainty.

Ursula Walther
Karl Friedrich Hagenmüller Professor of Financial Risk Management, Frankfurt School of Finance & Management, Germany

Wednesday • 15:45 – 16:30
Room: B305

Ursula Walther is a professor of financial risk management at Frankfurt School of Finance and Management since 2007.
Her areas of research and teaching are financial risk management, investment strategies, corporate finance and banking. She is the academic head of "Master in Risk Management & Regulation", which is offered in cooperation with the Frankfurt Institute of Risk Management (FIRM).
Ursula Walther graduated from the University of Bonn in Mathematics and from the FernUniversität in Hagen in Business Administration. She holds a doctorate in Mathematics from University of Giessen. Prior to her current position she was a postdoc and an assistant professor for financial services management at TU Bergakademie Freiberg (2001-2007) and worked as an asset & liability manager at Envia Energie Sachsen Brandenburg AG (2000-2001) and as a portfolio manager at Allianz Asset Management GmbH (1998-2000).
Her publications have appeared in journals such as the Journal of Banking Law and Banking, Corporate Finance biz and Transition Studies Review.

Performance Analysis of Investment Strategies – Pitfalls and Surprises

Active investment strategies are a subject of endless debates. Myriads of studies have been conducted to proof performance potential - or to reject previous studies due to flaws or misinterpretations. The presentation will address three specific aspects which often are disregarded when performance is measured. Firstly, we will discuss the role of backtests and show that this instrument – even when used carefully and skilled – may lead to biased and misleading results. Secondly, we give an example that the concepts of performance and forecast power must be strictly distinguished. Finally, we demonstrate that implementation details, while largely neglected, may strongly impact and bias a strategy's performance.

Thursday • 15:45 – 16:30
Room: F303

Martin Bichler
Decision Sciences & Systems, Department of Informatics, TU München, Germany

Martin Bichler received his MSc in Information Systems from the Technical University of Vienna, and his Ph. D. as well as his Habilitation (2000) from the Vienna University of Economics and Business Administration, where he was Associate Professor at the Department of Information Systems. Since 2003 he is full Professor at the Department of Informatics of the TU München, and also a faculty member at the TUM School of Management.
He is currently vice chair of the IS Section of the German Informatics Society (GI FB Wirtschaftsinformatik).
He has contributed to different areas in computer science, information systems, and operations research. In particular he is interested in the design of multi-object markets and in computational methods to solve managerial decision and planning problems.
He has published in journals such as INFORMS ISR, IEEE TSC, EJOR, IEEE Computer, CACM, DSS, ITM, Information Systems Frontiers and is on the editorial board of a number or journals such as ACM TWEB, BISE and POM. He recently received an HP Labs eAward, the IBM Faculty Award 2008, and the INFORMS ISS Design Science Award, and holds several patents.

Discrete Optimization and Market Design

Discrete optimization has played an increasingly important role in modern market design. Examples include the design of combinatorial auctions for selling spectrum as they have been used in the recent years worldwide, as well as multi-lot auctions in procurement and in transportation. Discrete optimization, game theory, lab experiments, and behavioural studies all play a role in the design of such optimization-based markets. In this talk, I will introduce market design goals and provide examples of specific auction formats as they are being used for the sale of spectrum licenses, as well as in industrial procurement. I will discuss some of the central optimization problems, game-theoretical properties of these new auction formats, and empirical observations.

Andreas Reuter
Fraunhofer IWES, Bremerhaven and Institute of Wind Energy Systems, Leibniz Universität Hannover, Germany

Thursday • 15:45 – 16:30
Room: F102

Andreas Reuter works as professor for wind energy technology at the Leibniz Universität Hannover and managing director of the Fraunhofer Wind Energy & Energy Systems Technologies Institute (IWES) with a total of 250 scientific employees and a well established testing infrastructure.
His education is in aviation and space technology, after completing his doctoral thesis on fatigue of wind turbines at the Technical University of Berlin he has worked in the wind industry for 15 years for companies such as aerodyn, GE Energy and Bharat Forge as project engineer, director of engineering and managing director before returning into the scientific community in 2010.
The main focus of his current work is the structural analysis and design of large components of offshore support structures and rotor blades.

Industrialization of Manufacturing Processes for Developing the Offshore Wind Market

The use of offshore based wind is planned to have a major role within the new energy system in Germany and also on the European level. Within the next eight years about 2000 turbines are supposed to be installed in German waters only. New turbine technologies have been developed in the last years for this purpose.
But on the manufacturing side of this upcoming industry, processes based on manual labour and small series are still predominant, resulting in high costs and quality risks. Currently the labour content of rotor blades sums up to about 40% of the product costs, structures with a length of about 80 m are built using technologies developed for 20 m blades. On the project side, wind farms worth one billion Euros each and involving expertise from the wind environment, from logistics companies and marine experts are executed using standard desktop computer software tools.
All these deficits result in cost structures, which are endangering the growth of this industry. In order to achieve the aggressive installation targets of the next years, an industrialization of manufacturing and logistic processes is required. Fraunhofer IWES is working together with the offshore wind industry on several projects aiming for closing this technology gap. Some examples of automated blade manufacturing technologies under development and integrated logistic concepts will be presented, also highlighting the benefits for cost reduction and volume increase.

Thursday • 15:45 – 16:30
Room: E001

Thomas S. Spengler
Institute of Automotive Management and Industrial Production, Chair of Production and Logistics, TU Braunschweig, Germany

Thomas S. Spengler holds a diploma in Industrial Engineering (1989) and a PhD in Business Administration (1994) from the University of Karlsruhe (TH). In 1998 he received the Habilitation degree (venia legendi) for Business Administration from the University of Karlsruhe (TH). Since 1998 he is Full Professor of Production and Logistics and Head of the Institute of Automotive Management and Industrial Production at the Technische Universität Braunschweig. From 2003 to 2008 he was board member and from 2007 to 2008 President of the German Operations Research Society (GOR). Since 2008 he is Vice President for Research and Technology Transfer of the Technische Universität Braunschweig and board member of the Automotive Research Centre Niedersachsen (NFF).
His main fields of research are the conceptual development and implementation of technoeconomic models and quantitative methods for decision support in the fields of production, logistics and environmental management.
He has published over 40 refereed papers in international journals, including European Journal of Operational Research, International Journal of Production Economics, International Journal of Production Research, OR Spectrum, Business Research, Zeitschrift für Betriebswirtschaft, and System Dynamics Review.

The Transition to Electric Vehicles: Simulation Based Analysis of the Automotive Market

Meeting 21st century's challenges of climate change and scarcity of crude oil requires a better understanding of the forces that ensure a successful market introduction of electric vehicles. Against this background, we discuss how the application of system dynamics and agent-based simulation can contribute to analyze the transition processes in the automotive market. The discussion is based on real-world examples that stem from a series of studies we have carried out in cooperation with a large German automotive manufacturer. The examples comprise modeling and validation issues as well as main results of our computational experiments. We also reflect the use of the presented simulation models in praxis, both from an industry and a policy perspective.

Wolf Fichtner
Institute for Industrial Production, Karlsruhe Institute of Technology (KIT), Germany

Friday • 10:15 – 11:00
Room: F303

Wolf Fichtner studied business engineering at the Universität Karlsruhe (TH). In 1998, he received a PhD in Economics. From 1999 to 2004 he was head of the research group Energy and the Environment of the Institute for Industrial Production (IIP), University of Karlsruhe. With his habilitation in 2004 at the University of Karlsruhe, he received the venia legendi in business administration.
In 2005 he worked for Energie Baden-Württemberg AG, analysing the concept of emissions trading. From October 2005 to November 2008 he was full professor and holder of the Chair of Energy Economics at the Institute for Energy Technology at the Technical University of Cottbus. Since November 2008 he holds the Chair of Energy Economics at Karlsruhe Institute of Technology (KIT) and is Director of the IIP and the French-German Institute for Environmental Research.
His main areas of research are Energy System Modelling and the Techno-economic Analysis of Energy Technologies. Prof. Fichtner published more than 200 articles, including 35 papers in reviewed journals like EJOR and OR Spectrum.

New Challenges in Energy System Modeling

Energy systems are undergoing substantial structural changes, due to the fact that the share of renewable energies in energy supply will increase drastically within the coming years. This requires the transportation of large amounts of electricity from windy regions to the large load centres, for example, and the feed-in of electricity produced in decentralized installations (e.g. PV) in lower voltage power grids. These developments could lead to congestion at different voltage levels, illustrating the increasing importance of considering grid constraints within energy system models. This contribution will highlight modelling approaches allowing an adequate consideration of power grids and illustrate their application for decision support.

Friday • 10:15 – 11:00
Room: F102

Nadine Gatzert
Chair for Insurance Economics, Friedrich-Alexander-University of Erlangen-Nuremberg, Germany

Nadine Gatzert studied mathematics and economics at the University of Ulm, Germany, and at the University of Southern California in Los Angeles, USA, majoring in mathematical finance and actuarial science. She received her doctoral degree in 2007 and her postdoctoral qualification (Habilitation) in 2009 from the University of St. Gallen, Switzerland. Since 2009, she holds the Chair for Insurance Economics at the Friedrich-Alexander-University of Erlangen-Nuremberg. Her main research interests include enterprise risk management, embedded options and financial guarantees in life insurance contracts, alternative risk transfer, and regulation in the financial services industry. She has published articles in numerous peer-reviewed journals, such as the Journal of Risk and Insurance, Journal of Banking & Finance, Insurance: Mathematics and Economics, and Journal of Risk.

The Impact of Natural Hedging on a Life Insurer's Risk Situation

Besides financial market risks, demographic risk, i.e. the risk of unexpected changes in mortality and survival rates, can substantially impact a life insurers' risk and solvency situation. By using the "natural hedge" between life insurance providing a death benefit and annuities with lifelong survival benefit, insurance companies have an effective tool for reducing their net-exposure. The aim of this paper is to analyze this risk management tool and to quantify its effectiveness in hedging against changes in mortality with respect to default risk measures. To achieve this goal, we model the insurance company dynamically as a whole over the complete lifetime of the contracts, taking into account the interaction between assets and liabilities. We demonstrate that a holistic and dynamic approach that includes the asset side is vital to obtain deeper insight into the impact of natural hedging on an insurer's risk situation and show how to reach a desired safety level while simultaneously immunizing the portfolio against changes in mortality rates.

Shane G. Henderson
School of Operations Research and Information Engineering, Cornell University, USA

Friday • 10:15 – 11:00
Room: E001

Shane G. Henderson is a professor in the School of Operations Research and Information Engineering at Cornell University. He received his PhD from Stanford University in 1997, and has held academic positions in the Department of Industrial and Operations Engineering at the University of Michigan and the Department of Engineering Science at the University of Auckland.
His research interests include discrete-event simulation, simulation optimization, and emergency-services planning, and he has published papers in leading journals including Operations Research, Management Science, Mathematics of Operations Research, the ACM Transactions on Modeling and Computer Simulation, Stochastic Models, and the Electronic Journal of Statistics.
He is the current chair of the INFORMS Applied Probability Society, the past simulation area editor for Operations Research, and an associate editor for both Management Science and Stochastic Systems.

Real-Time Control of Ambulance Fleets through a Combination of Statistics, Approximate Dynamic Programming, and Simulation Optimization

Ambulance organizations everywhere face increasing call volumes, increasing traffic congestion, and shrinking budgets. To keep response times small, many employ some kind of system-status management (SSM). SSM is the practice of real-time control of the ambulance fleet, using Global Positioning System (GPS) units on the ambulances to track location, and information from the ambulance crews to track status. Available ambulances are carefully stationed to ensure coverage, while not requiring too many moves of the ambulance crews. I'll describe my work in this area, using a combination of statistics to model inputs, approximate dynamic programming (ADP) to make stationing decisions in real time, simulation optimization to "tune" the ADP algorithm and bounding techniques to determine what response times might be achievable in a given city.

Friday • 10:15 – 11:00
Room: B305

Martin Skutella
Combinatorial Optimization & Graph Algorithms, Department of Mathematics, TU Berlin, Germany

Martin Skutella is a full professor of mathematics at TU Berlin and at the DFG research center Matheon "Mathematics for key technologies" in Berlin. He received his Ph.D. in Mathematics from TU Berlin in 1998.
He spent one year at the Center for Operations Research and Econometrics (CORE) in Belgium, one semester at the Research Institute for Discrete Mathematics in Bonn and half a year at the Operations Research Center at M.I.T. in Cambridge, USA. From 2003 to 2004 he was associate professor at Max-Planck Institute for Computer Science before he moved to Dortmund University where he held the chair of Discrete Optimization until 2007.
His main research interests lie in the area of Combinatorial Optimization, in particular in Network Optimization and Scheduling. He is associate editor of the journals Mathematics of Operations Research, Operation Research Letters (until 2008), Mathematical Programming B, Networks, and Journal of Scheduling. He is editor in chief of the Notices of the German Mathematical Society "Mitteilungen der DMV".

Flows Over Time: Modeling Network Routing Problems Including a Temporal Dimension

In many real-world routing problems time plays a vital role. Network flows over time include a temporal dimension and therefore provide a more realistic modeling tool than classical "static" network flow models. While flows over time have already been introduced by Ford and Fulkerson in the 1950s, several more sophisticated models have been studied later on. After giving a general introduction to network flows over time, we are going to present recent work in this area.

GOR AWARDS

GOR MASTER AWARDS

Wednesday, September 5 • 14:00 – 15:30
Room: B302

Stefan Bonk
Solving School Class Assignment Problems Using Subgradient Optimization and Network Simplex Methods

Philipp von Falkenhausen
Design of Mechanisms for Good Equilibria

Pascal Lutter
Product Line Design with Pricing Kits

Matthias Walter
Sparsity of Lift-and-Project Cutting Planes

GOR PHD AWARDS

Thursday, September 6 • 11:30 – 13:00
Room: F128

Tobias Buer
Multicriteria Winner Determination in Combinatorial Transport Auctions

Thomas Schlechte
Railway Track Allocation - Simulation, Aggregation, and Optimization

Marie Schmidt
Integrating Routing Decisions in Network Problems

Guido Voigt
Supply Chain Coordination in Case of Asymmetric Information – Information Sharing and Contracting in a Just-in-Time Environment

PRE-CONFERENCE WORKSHOPS

AIMMS PRE-CONFERENCE WORKSHOP

Tuesday, September 4 • 15:30 – 17:00
Room: F435

Robust Optimization with AIMMS

As part of its extensive support for modeling optimization problems under uncertainty, AIMMS offers a specialized Robust Optimization (RO) add-on, developed in closed cooperation with Professor A. Ben-Tal of Technion - Israel Institute of Technology. The current set-up within AIMMS allows you to generate and solve linear and mixed integer programming (LP/MIP) models under uncertainty, without the need to reformulate the underlying deterministic models. In general, any LP/MIP solver can be used for solving the resulting RO models. For some specific classes (i.e. when the uncertainty is defined as an ellipsoid), solvers like CPLEX or MOSEK are required, as the so-called robust counterpart becomes a Second Order Cone Program (SOCP). The AIMMS RO add-on is included at no charge in the free AIMMS Academic licenses (and so are also the CPLEX, GUROBI and MOSEK solvers).

In this workshop we explain and illustrate what the AIMMS RO add-on specifically offers, how to use it within your AIMMS project and how it can help you in building Robust Optimization models fast and efficiently.
In particular, AIMMS is able to generate automatically the robust counterpart of a model in case the uncertain data belongs to uncertainty sets such as box, ellipsoid, polyhedron or the convex hull of a number of scenarios. The automatic generation extends to adjustable variables following Linear Decision Rules (LDR), as well as to safe robust approximations of Chance Constraints. For supporting all these, AIMMS offers tailor made modeling concepts, such as: uncertain parameters, uncertainty regions, dependencies, uncertainty constraints, adjustable variables, LDR mappings, random parameters, chance constraints, and approximation types.
We show how these intuitive, effective modeling concepts in AIMMS allow for fast, flexible experiments and comparison of results based on various uncertainty sets. We also illustrate the usage of the AIMMS RO add-on based on several example models, such as power system expansion, portfolio selection, systems design for manufacturing process flexibility or unit commitment and energy dispatch.

GAMS PRE-CONFERENCE WORKSHOP

Tuesday, September 4 • 15:00 – 17:00
Room: F309

In this workshop we will demonstrate two features which were recently introduced and improved respectively in the General Algebraic Modeling System (GAMS): Stochastic Programming and the object oriented GAMS API.

Stochastic Programming in GAMS

With a few changes uncertainty can be added to an existing deterministic model. For this, the Extended Mathematical Programming (EMP) framework is used to replace parameters in the model by random variables. This way multi-stage recourse problems and chance constraint models can be formulated.

Object Oriented GAMS API using the example of .NET

GAMS offers a low level application programming interface (API) to certain central libraries for various programming languages. Recently we added a DLL for Microsoft's .NET framework. This offers a seamless integration of GAMS into .NET based IT systems. The API extends the capabilities of GAMS by the addition of the rich features provided by the .NET framework. The in-memory representation of a GAMS model can increase performance when solving a model multiple times with slightly changed data significantly. Convenient data structures allow random access to data as well as data iteration.

SESSIONS AND TALKS DAY BY DAY

SESSIONS AND TALKS DAY BY DAY

Wednesday, 9:00 - 11:00

WA-01: Opening Session and Plenary Speaker: Raimo Hämäläinen (Audimax (E415)) - Chair: *Stefan Helber*

1. On the need for Behavioral Operations Research
   Raimo P. Hämäläinen 34

Wednesday, 11:30 - 13:00

WB-08: Applied Probability I (F018) - Chair: *Karl-Heinz Waldmann*

1. On worst case trees in multistage stochastic programming
   Georg Pflug 81
2. Sojourn Times in the Longest Queue System with Exchangeable Items
   Rachel Ravid 81
3. Rational and Floating Point Random Numbers for Computer Algebra Systems
   Thomas Morgenstern 81

WB-09: Designing (Energy Efficient) Production Systems (F102) - Chair: *Philipp Hungerländer*

1. Development of Analytical Models for Energy Consumption and Roughness in Inner Layer Scrubbing Process in PCB Manufacturing
   You-Jin Park 143
2. Optimizing cost efficiency and energy efficiency in batch production for strategic planning
   Christian A. Hochmuth 143
3. A Semidefinite Optimization Approach for Complex Facility Layout Structures
   Philipp Hungerländer 144

WB-10: Nonsmooth and Conic Optimization (F025) - Chair: *Mirjam Duer*

1. A nonsmooth Newton method for disjunctive optimization problems
   Stephan Buetikofer 84
2. Aubin Property and Uniqueness of Solutions in Cone Constrained Optimization
   Diethard Klatte 84
3. Infinite dimensional semidefinite programming
   Mirjam Duer 84

WB-11: Decision Processes and Strategic Management (F107) - Chair: *Anne Chwolka*

1. Value-focused thinking enhances the quality of decisions
   Johannes Siebert 88

2. Overconfidence vs. Planning Competence in Entrepreneurial Ventures
Matthias G. Raith 88

3. Selection Of Photovoltaic Panels In Solar Energy Systems Using Fuzzy Vikor
Onur Yilmaz 88

WB-12: Risk Analysis (F023) - Chair: *Ashok Banerjee*

1. Vector Risk Functions
Raquel Balbás 122

2. Measuring Risk in Risk Factor Models
Steffi Höse 122

3. Impact of information arrival on volatility of intraday stock returns
Ashok Banerjee 122

WB-13: Column Generation (A310) - Chair: *Marco Lübbecke*

1. Packing Cuts with Column Generation
Martin Bergner 96

2. Large Neighborhood Search and Diving Heuristics in Column Generation Algorithms
Christian Puchert 96

3. A branch-and-price algorithm for rearranging a matrix into doubly bordered block-diagonal form
Michael Bastubbe 96

WB-14: Packing and Cutting (F435) - Chair: *Pawel Zielinski*

1. New Heuristic For The Integrated Problem Of Cutting And Sizing Of 3d-bins
Mariem Baazaoui 97

2. A Discretized Invasive Weed Optimization algorithm for the bin packing problem
Medily Villamayor 97

3. Deepest Dual Optimal Inequalities for Cutting Stock and Bin Packing
Stefan Irnich 97

WB-15: Project Scheduling I (F303) - Chair: *Carolin Kellenbrink*

1. Numerical Experiments of Randomized Approximation Scheme for Calculating Expected Length of Critical Path in Stochastic PERT Network
Jun Hioki 168

2. A Facility Layout Model for Resource Constraint Project Scheduling Problem
Hassan Taheri 168

3. First results on resource-constrained project scheduling with model-endogenous decision on the project structure
Carolin Kellenbrink 168

WB-16: Planning Energy Systems I (B305) - Chair: *Bo Hu*

1. Optimal control models of renewable energy production under fluctuating supply
Elke Moser 108

2. Investment decisions in electricity markets from the perspective of control theory
Jessica Raasch 108

Wednesday, 14:00 - 15:30

WC-06: GOR Master Awards (B302) - Chair: *Katja Schimmelpfeng*

WC-08: Applied Probability II (F018) - Chair: *Georg Pflug*

WC-09: Maintenance and Rework (F102) - Chair: *Ralf Gössinger*

WC-10: Nonlinear Programming (F025) - Chair: *Mirjam Duer*

WC-16: Planning Energy Systems II (B305) - Chair: *Valentin Bertsch*

WC-17: Sustainable Measures (F020) - Chair: *Magnus Fröhling*

WC-19: Optimization in Energy Usage (F309) - Chair: *Christian Hinrichs*

WC-21: Revenue Management II (F128) - Chair: *Claudius Steinhardt*

WC-22: Modeling Applications in European Energy Markets (E001) - Chair: *Olaf Syben*

WC-23: Learning Modeling and Optimization (F142) - Chair: *Hans Achatz*

WC-24: Routing II (F428) - Chair: *Julia Rieck*

WC-25: Road Traffic (F442) - Chair: *Matthias Ehrgott*

WC-26: Diverse Issues II (E214) - Chair: *Svenja Lagershausen*

WC-27: Inventory II (F342) - Chair: *Gudrun Kiesmüller*

SESSIONS AND TALKS DAY BY DAY

Wednesday, 15:45 - 16:30

WD-02: Semiplenary Speaker: Michael H. Breitner (F303) - Chair: *Cornelia Schoen*

1. Modeling the Transformation of the German Energy System until 2050 - a Multi-Criteria, Long Term Optimization Problem with Many Constraints
   Michael H. Breitner 36

WD-03: Semiplenary Speaker: Stanley B. Gershwin (F102) - Chair: *Stefan Helber*

1. Analysis, Control and Design of Stochastic Flow Systems with Limited Storage
   Stan Gershwin 37

WD-04: Semiplenary Speaker: Albert B. Gilg (E001) - Chair: *Stefan Pickl*

1. Optimizing Design and Operations - An Industrial Viewpoint
   Albert Gilg 38

WD-05: Semiplenary Speaker: Ursula Walther (B305) - Chair: *Daniel Roesch*

1. Performance Analysis of Investment Strategies - Pitfalls and Surprises
   Ursula Walther 39

Wednesday, 17:00 - 18:30

WE-08: Applied Probability III (F018) - Chair: *Stefan Lessmann*

1. Statistical mechanics of Innovation Diffusion: model development, estimation, and forecasting.
   Christos J. Emmanouilides 83
2. Sequencing Protocols and Cut Consolidation for the Parallel Hybrid-Cut Nested L-Shaped Method
   Christian Wolf 83
3. A Robust Reliability Modeling in Series-Parallel Systems with Redundancy Allocation
   Ali Ghafarian Salehi Nezhad 83

WE-09: Lotsizing (F102) - Chair: *Stefan Bock*

1. Dynamic capacitated lot-sizing problem with parallel common setup operators and time windows
   Karina Copil 145
2. Linear programming models for the stochastic dynamic capacitated lot sizing problem
   Timo Hilger 146
3. A Real-time Approach for the Capacitated Lot-sizing and Scheduling Problem with Sequence-dependency and Backorders
   Rudolf Bauer 146

WE-10: Experimental Games (F025) - Chair: *Ulrike Leopold-Wildburger*

WE-11: Decision Processes in the Energy Sector (F107) - Chair: *Gonçalo Pereira*

WE-12: Finance and Banking (F023) - Chair: *Daniel Roesch*

WE-13: Networks (A310) - Chair: *Matthias Müller-Hannemann*

WE-14: Miscellaneous (F435) - Chair: *Stefan Irnich*

WE-15: Project Scheduling II (F303) - Chair: *Julia Rieck*

Thursday, 9:00 - 10:00

TA-11: Stocks and Inventories (F107) - Chair: *Markus Siepermann*

1. A Production-Inventory System with both Patient and Impatient Demand Classes
   Mohsen Elhafsi 148
2. How to deal with alternative cutting lengths in a one-dimensional cutting stock problem
   Markus Siepermann 148

TA-13: Scheduling and Linear Programming (A310) - Chair: *Christina Büsing*

1. An improved polynomial relaxation-type algorithm for linear programming
   Sergei Chubanov 103
2. A tight analysis of Smith's rule for nonlinear cost
   Wiebke Höhn 103

TA-14: Applications (F435) - Chair: *Axel Werner*

1. Generation System of a timetable
   Rabah Kassa 104
2. Simultaneous Optimization of Berth Allocation, Quay Crane Assignment and Quay Crane Scheduling Problems in Container Terminals
   Necati Aras 104

TA-15: Recent Results in Scheduling (F303) - Chair: *Nicole Megow*

1. Models and bounds for preemptive project scheduling with generalized precedence relationships
   Christoph Schwindt 171
2. Nearly optimal solutions for universal sequencing problems
   Nicole Megow 172

TA-16: Gas Networks I (B305) - Chair: *Marc Steinbach*

1. Mixed-Integer Nonlinear Optimization of Gas Compressor Stations
   Martin Schmidt 115
2. Capacity determination of gas networks
   Bernhard Willert 116

TA-18: Neural Networks and Fuzzy Systems (E242) - Chair: *Joachim Vierling*

1. A Hybrid Method for Task Flow Control in a GRID-System
   Vlad Kucher 136
2. Fuzzy data analysis for mixed type data
   Joachim Vierling 136

TA-20: Strategic Management and Innovation Processes (B302) - Chair: *Bo Hu*

1. System Dynamics und Agenten-basierte Modellbildung im strategischen Personalmanagement
   Joachim Block 180
2. A business simulation game in innovation management education: Lessons learnt
   Markus Günther 180

Thursday, 10:15 - 11:00

TB-01: Plenary Speaker: Horst Oehlschlaeger (Audimax (E415)) - Chair: *Stefan Helber*

1. Outlook on low-emission light commercial mobility — new energy for the future
   Horst Oehlschlaeger 35

Thursday, 11:30 - 13:00

TC-07: GOR PhD Awards (F128) - Chair: *Leena Suhl*

1. Multicriteria Winner Determination in Combinatorial Transport Auctions
   Tobias Buer 79
2. Railway Track Allocation - Simulation, Aggregation, and Optimization
   Thomas Schlechte 79
3. Integrating Routing Decisions in Network Problems
   Marie Schmidt 80
4. Supply Chain Coordination in Case of Asymmetric Information — Information Sharing and Contracting in a Just-in-Time Environment
   Guido Voigt 80

TC-09: Airport Operations Management (F102) - Chair: *Jens Brunner*

1. A model for the transfer baggage problem at airports
   Torben Barth 149
2. Comparison of solution approaches for multiskilled workforce scheduling at airport check-in counters
   Emilio Zamorano de Acha 149
3. A new linear integer formulation for the ground delay program with misconnections
   Jens Brunner 149

TC-10: Applied Game Theory (F025) - Chair: *Francesc Carreras*

1. Does SFE correspond to expected behavior in the uniform price auction?
   Alexander Vasin 128
2. Two-stage Market with a Random Factor
   Ekaterina Daylova 129
3. A new allocation method for simple bargaining problems: the Shapley rule
   Francesc Carreras 129

TC-11: Risk Analysis and Assessment (F107) - Chair: *Jonas Ide*

1. Competitive Ratio as Coherent Measure of Risk
   Esther Mohr 91
2. Price acceptability and decision-making process model after the earthquake disaster
   Yumi Asahi 91

3. Concepts of robustness in multi-objective optimization
Jonas Ide 92

TC-12: Portfolio Management (F023) - Chair: *Maximilian Wimmer*

1. About the existence of good deals in capital markets: Theoretical and empirical approaches
Beatriz Balbas 125
2. Multi-Asset Portfolio Optimization and Out-of-Sample Performance: An Evaluation of Black-Litterman, Mean Variance and Naïve Diversification Approaches
Dominik Wolff 125
3. Computing the Nondominated Surface in Tri-criterion Portfolio Selection
Maximilian Wimmer 126

TC-13: Facility Location (A310) - Chair: *Stefan Ruzika*

1. Impact of utility function to servic center location in public system
Michal Kohani 105
2. An extended formulation for the survivable hop constrained connected facility location problem
Mohsen Rezapour 105
3. A genetic algorithm for the unequal area facility layout problem
Udo Buscher 105

TC-14: Scheduling Theory (F435) - Chair: *Nicole Megow*

1. A New Approach to Online Scheduling: Approximating the Optimal Competitive Ratio
Elisabeth Günther 172
2. Robust Appointment Scheduling
Sebastian Stiller 172
3. Non-Preemptive Speed Scaling
Antonios Antoniadis 173

TC-15: Scheduling Applications I (F303) - Chair: *Sigrid Knust*

1. A genetic algorithm for the slab scheduling problem
Matthias Wichmann 173
2. Two Dedicated Machines Scheduling Problem in Two-Sided Assembly Lines
Evgeny Gafarov 174
3. Tabu Search and Lower Bounds for a Combined Production-Transportation Problem
Sigrid Knust 174

TC-16: Energy Storage Systems (B305) - Chair: *Stefan Minner*

1. Optimizing storage placement in electricity distribution networks
J.m. van den Akker 116
2. Managing Energy Storages — Lessons from Inventory Theory
Stefan Minner 116
3. Optimal Underground Pumped Hydroelectric Storage Design
Amir José Daou Pulido 117

TC-17: Energy Management Systems (F020) - Chair: *Milad Ziaeian*

TC-18: Information Systems and Neural Networks (E242) - Chair: *Hans Georg Zimmermann*

TC-19: Wind Energy and Other Energy Sources (F309) - Chair: *Anne Bechtel*

TC-20: Energy Markets (B302) - Chair: *Grit Walther*

TC-22: Software in Traffic Management (E001) - Chair: *Karl Nachtigall*

TC-23: Algebraic Modeling Languages II (F142) - Chair: *Robert Fourer*

1. CMPL - Coliop — Coin Mathematical Programming Language
   Mike Steglich 195
2. Tools to increase model quality and knowledge sharing
   Wietse Dol 195
3. Alternatives for Scripting in Conjunction with an Algebraic Modeling Language for Optimization
   Robert Fourer 195

TC-24: Synchronization in Vehicle Routing I (F428) - Chair: *Michael Drexl*

1. Combined flow of goods, vehicles and packaging in logistics networks
   Siegfried Jetzke 224
2. Route Feasibility Testing and Branch-and-Price Algorithms for the Pickup and Delivery Problem with minimum and maximum Ride Times
   Timo Gschwind 224
3. Branch-and-Cut-and-Price for the Vehicle Routing Problem with Trailers and Transshipments
   Michael Drexl 225

TC-25: Shipping and Railway (F442) - Chair: *Dominique Feillet*

1. An extended formulation for allocating classification tracks in hump yards
   Florian Dahms 225
2. Liner Shipping Fleet Repositioning with Cargo Flows
   Kevin Tierney 226
3. Column generation for the container relocation problem
   Elisabeth Zehendner 226

TC-26: Green Supply Chains (E214) - Chair: *Kathrin Fischer*

1. Evaluating Management Approaches In Green Supply Chain Using Extended Vikor Method
   Betül Özkan 209
2. Business Analytics with AIMMS: optimizing demand & supply allocation of energy efficient systems for buildings
   Ovidiu Listes 209
3. Closed-Loop Supply Chain (CLSC) Management: Analysis and classification of existing approaches, and future research prospects
   Leena Steinke 209

TC-27: Supply (F342) - Chair: *Rainer Kleber*

1. A discrete time approach to analyze the behavior of Milkrun supplied inventories
   Justus Arne Schwarz 210
2. Supply strategies for a fashion retailer
   Miriam Kießling 210
3. Single vs. dual sourcing: the strategic impact of stock-keeping on supply strategies
   Rainer Kleber 210

Thursday, 14:00 - 15:30

TD-08: Location/Allocation of Health Care Facilities (F018) - Chair: *Walter Gutjahr*

TD-09: Product Variety and Structure (F102) - Chair: *Martin Grunow*

TD-10: Dynamic Processes in Economic Games (F025) - Chair: *Kensaku Kikuta*

TD-11: Decision Analysis in Industrial Engineering (F107) - Chair: *Gábor Lovics*

TD-12: Outranking Approaches for Sustainable Development (F023) - Chair: *Simon Hirzel*

Thursday, 15:45 - 16:30

TE-02: Semiplenary Speaker: Martin Bichler (F303) - Chair: *Alf Kimms*

1. Discrete Optimization and Market Design
   Martin Bichler 40

TE-03: Semiplenary Speaker: Andreas Reuter (F102) - Chair: *Michael H. Breitner*

1. Industrialization of Manufacturing Processes for Developing the Offshore Wind Market
   Andreas Reuter 41

TE-04: Semiplenary Speaker: Thomas S. Spengler (E001) - Chair: *Stefan Nickel*

1. The Transition to Electric Vehicles: Simulation based Analysis of the Automotive Market
   Thomas Spengler 42

Friday, 9:00 - 10:00

FA-08: Multiobjective Decision Making in Health Care Management (F018) - Chair: *Katja Schimmelpfeng*

1. A Three-Objective Optimization Approach to Cost Effectiveness Analysis Under Uncertainty
   Walter Gutjahr 134
2. Decision Support for Rehabilitation Hospital Scheduling — Ideas for Heuristic Algorithms
   Steffen Kasper 135

FA-09: Capacity Management and Contracts (F102) - Chair: *Kei Takahashi*

1. Optimal Capital and Labor Investment in Price Regulated Service Firms Facing Cyclical Demand
   Mustafa Akan 151
2. The Newsvendor Problem as a Real Option Game
   Kei Takahashi 151

FA-10: Continuous Optimization in Applications II (F025) - Chair: *Mirjam Duer*

1. A Bi-Objective MIP Model for Robust Facility Layout Problem
   Mohammad Hassan Salmani 87
2. Energy Utility Fuel Allocation Model for Non-Linear Revenue
   Balram Avittathur 87

FA-11: Data Envelopment Analysis (DEA) (F107) - Chair: *Andreas Kleine*

1. Comparing two methods of ranking interval efficiencies for fuzzy DEA models
   Somayeh Tabatabaee 95
2. From central scaling to efficiency change - a new interpretation of u
   Andreas Dellnitz 95

FA-13: Graph Algorithms (A310) - Chair: *Matthias Müller-Hannemann*

FA-14: Scheduling and Practice (F435) - Chair: *Sigrid Knust*

FA-15: Scheduling and Rostering (F303) - Chair: *Marco Lübbecke*

FA-16: Gas Networks II (B305) - Chair: *Marc Steinbach*

FA-19: Mathematics and New Energy (F309) - Chair: *Vladimir Tsurkov*

FA-21: Revenue Management V (F128) - Chair: *Waldemar Grauberger*

FA-22: Selected Algorithms and Applications III (E001) - Chair: *Tuukka Puranen*

FA-23: Deploying Optimization Software (F142) - Chair: *Bjarni Kristjansson*

1. Cloud Solver Service
   Toni Thenhausen 199
2. Deploying MPL Optimization Models on Servers and Mobile Platforms
   Bjarni Kristjansson 199

FA-24: Selected Algorithms and Applications IV (F428) - Chair: *Adiwijaya*

1. Hybrid Algorithm For Blind Equalization Of Qam Signals
   Abdenour Labed 200
2. Multiple Watermarking on Digital Medical Image for Mobility and Authenticity
   Adiwijaya 200

FA-26: Humanitarian Logistics (E214) - Chair: *Kathrin Fischer*

1. An Analysis of Lateral Transshipment Opportunities for Humanitarian Relief Facility Location in Istanbul
   Serhan Duran 213
2. Decision making in humanitarian logistics — A multi-objective optimization model for allocating relief goods during disaster recovery operations
   Beate Rottkemper 214

Friday, 10:15 - 11:00

FB-02: Semiplenary Speaker: Wolf Fichtner (F303) - Chair: *Cornelia Schoen*

1. New Challenges in Energy System Modeling
   Wolf Fichtner 43

FB-03: Semiplenary Speaker: Nadine Gatzert (F102) - Chair: *Stefan Weber*

1. The Impact of Natural Hedging on a Life Insurer's Risk Situation
   Nadine Gatzert 44

FB-04: Semiplenary Speaker: Shane G. Henderson (E001) - Chair: *Stefan Helber*

1. Real-Time Control of Ambulance Fleets through a Combination of Statistics, Approximate Dynamic Programming, and Simulation Optimization
   Shane Henderson 45

FB-05: Semiplenary Speaker: Martin Skutella (B305) - Chair: *Marc Steinbach*

1. Flows Over Time: Modeling Network Routing Problems including a Temporal Dimension
   Martin Skutella 46

Friday, 11:30 - 12:30

FC-01: Plenary Speaker and Closing Ceremony: Company Award (Audimax (E415))
Chair: *Stefan Weber*

1. Company Award

ABSTRACTS SORTED BY STREAMS AND TIMES

GOR AWARDS

■ WC-06

Wednesday, 14:00 - 15:30, Room B302

GOR Master Awards

Chair: *Katja Schimmelpfeng*, Lehrstuhl für Beschaffung und Produktion, Universität Hohenheim

1 - Solving School Class Assignment Problems Using Subgradient Optimization and Network Simplex Methods

Stefan Bonk, University of Cologne

This thesis presents an approach to solve a transportation problem with additional sideconstraints. The problem is to find a good assignment of students to school classes taking into account additional sideconstraints. These constraints were developed together with the administration of an elementary school in order to meet their requirements in such an assignment. A problem formulation as an integer linear program is presented, the transportation problem being a relaxation of this linear program. The Lagrangian relaxation is approximately solved with subgradient optimization. In each step, the Lagrangian heuristic provides feasible solutions and the subproblem, a transportation problem, has to be solved. This is done efficiently by a primal network simplex method. The performance of the solution of the subproblems is important for the total runtime. Thus, the network simplex method is presented and analyzed and additionally extensive computational results with regard to different strategies and arguments are presented. The Lagrangian heuristic (together with subgradient optimization) is able to find good feasible solutions, but mostly not optimal solutions. Hence, a branch and bound algorithm is presented to find optimal solutions. The corresponding lower bounds are provided by the subgradient optimization and equal those of an LP relaxation. The hybrid strong/pseudocost branching rule is used and a further strategy concerning the choice of the variable is briefly presented. Furthermore two different branching methods are explained. Computational results of the branch and bound algorithm with some instances of the elementary school and some artificial instances are presented. The thesis concludes with further applications of the methods presented.

2 - Design of Mechanisms for Good Equilibria

Philipp von Falkenhausen, Institut für Mathematik, Technische Universität Berlin

Joint use of resources with usage-dependent cost raises the question: Who pays how much? We study cost sharing protocols in congestion games with the goal to minimize the efficiency loss caused by the users' selfish behavior. While in some applications the protocol can optimize globally, in other settings the protocol needs to work in a distributed way. This motivates a classification of mechanisms which I will introduce in the first part of the talk. In the second part, I will present mechanisms from three such classes that are optimal with respect to the price of anarchy and price of stability.

3 - Product Line Design with Pricing Kits

Pascal Lutter, Faculty of Management and Economics, Ruhr University Bochum

In the context of growing requests of individualization and increasing propagation of modularization and mass customization it is necessary to accommodate the opportunities of the product individualization with an appropriate pricing. In contrast to patterns of pure product line pricing, the new concept of pricing kits provide a concept which transfers the flexibility of product configurations to the price setting. A pricing kit is an innovative pricing system in terms of list prices for modular product components which can be offered as a complete product in the market. Applications are discovered in the configuration of personal computers as well as in the automotive sector. Previous demonstrations in the literature did not focus on price setting. Hence, we propose a mixed—integer model to determine an optimal pricing system for all components. The model is extended for a combined use of product line pricing and design with pricing kits. All presented models are analyzed by case studies and can be solved within a short period of time using standard solvers. It is shown that the proposed approaches are superior to established methods of pure product line design, especially in cases of uncertain parameters.

4 - Sparsity of Lift-and-Project Cutting Planes

Matthias Walter, Otto-von-Guericke Universität Magdeburg

It is well-known that sparsity (i.e. having only a few nonzero coefficients) is a desirable property for cutting planes in mixed-integer programming. We show that on the MIPLIB 2003 problem instance set, using only 10 very dense cutting planes (compared to thousands of constraints in a model), leads to a run time increase of 25% on average for the LP-solver. We introduce the concept of dual sparsity (a property of the row-multipliers of the cut) and show a strong correlation between dual and primal (the usual) sparsity. Lift-and-project cuts crucially depend on the choice of a so-called normalization, of which we compared several known ones with respect to their actual and possible sparsity. Then a new normalization is tested that improves the dual (and hence the primal) sparsity of the generated cuts.

■ TC-07

Thursday, 11:30 - 13:00, Room F128

GOR PhD Awards

Chair: *Leena Suhl*, DS&OR Lab, University of Paderborn

1 - Multicriteria Winner Determination in Combinatorial Transport Auctions

Tobias Buer, Department of Business Studies & Economics, Chair of Logistics, University of Bremen

Shippers, like industrial enterprises or retail businesses, often procure their required transport services from carriers by means of a transport auction. In a real world transport auction, the procurement volume can sum up to several million dollars. Transport auctions exhibit two specific features: On the one hand, there are economies of scope between the tendered transport contracts. For a given carrier, the costs of executing a transport contract depend on the other contracts the carrier wins (e.g. whether they are well combinable in a single tour). On the other hand, shippers usually trade off cost savings for an increase in transport quality. Transport quality is affected by the way carriers cope with heterogeneous transport requirements which may arise from characteristics of the goods to be transported (e.g. fragile, hazardous) or from different customer needs (e.g. time windows). In the transportation procurement literature, approaches considering both economies of scope and transport quality are missing mostly. To close this gap to some extent, we focus on the winner determination problem. This problem has to be solved by a shipper after all carriers have submitted their bids; the task is to decide which bids should be accepted as winning bids. The proposed model extends the well-known set covering problem and has two objective functions (minimize transport costs, maximize transport quality). In order to solve the model, Pareto optimizers based on branch-and-bound and metaheuristic-hybrids have been developed and evaluated. All procedures compute a set of non-dominated solutions. Therefore, the shipper can apply the procedures to calculate the realizable trade-off between transport costs and transport quality without analyzing his or her preferences a priori.

2 - Railway Track Allocation - Simulation, Aggregation, and Optimization

Thomas Schlechte, Optimization, Zuse-Institute-Berlin

This talk is about mathematical optimization for the efficient use of railway infrastructure. We address the optimal allocation of the available railway track capacity - the track allocation problem. This track allocation problem is a major challenge for a railway company, independent of whether a free market, a private monopoly, or a public monopoly is given. Planning and operating railway transportation systems is extremely hard due to the combinatorial complexity of the underlying discrete optimization problems, the technical intricacies, and the immense sizes of the problem instances. Mathematical models and optimization techniques can result in huge gains for both railway customers and operators, e.g., in terms of cost reductions or service quality improvements. We tackle this challenge by developing novel mathematical models and associated innovative algorithmic solution methods for large scale instances. We made considerable progress on solving track allocation problems by two main features - a novel modeling approach for the macroscopic track allocation problem and algorithmic improvements based on the utilization of the bundle method. This allows us to produce for the ?rst time reliable solutions for a real world instance, i.e., the Simplon corridor in Switzerland.

3 - Integrating Routing Decisions in Network Problems

Marie Schmidt, Institut für Numerische und Angewandte Mathematik, Georg-August-Universität Göttingen

To model and solve optimization problems arising in public transportation, data about the passengers is necessary and must be included in the models in any phase of the planning process. Many solution approaches assume a two-step procedure: firstly, the data about the passengers is distributed over the public transportation network using traffic-assignment procedures. Secondly, the actual planning of lines, timetables, etc. is done. This approach ignores that for most passengers there are many possible ways to reach their destinations, thus the actual connections the passengers take depend strongly on the decisions made during the planning phase. We aim at integrating the traffic assignment procedure in the optimization process in public transportation problems, in particular in line planning, timetabling and delay management, where our objective is the minimization of the passengers' overall travel time. In this talk we concentrate on the delay management problem. After formulating suitable network models for the considered problem with integrated routing, we investigate the computational complexity of the integrated problem. We prove NP-hardness results and derive polynomial algorithms for special cases and investigate the approximability of some of the considered problems. For solving the integrated problems, we present integer programming approaches and a heuristic approach which alternates traffic assignment and optimization steps.

4 - Supply Chain Coordination in Case of Asymmetric Information — Information Sharing and Contracting in a Just-in-Time Environment

Guido Voigt, Operations Management, Otto-von-Guericke University Magdeburg

Information sharing is frequently discussed as a main enhancer for supply chain cooperation. This holds particularly true for environments that are characterized by asymmetrically distributed information concerning, e.g., cost parameters or end-customer demand. Yet, if the supply chain parties are profit-maximizing and fully rational, credible information sharing might not be established due to misaligned incentives. In this context, non-linear contract schemes are intensively discussed in the supply chain coordination literature, since they coordinate the supply chain to a second-best outcome. The present work applies methods of non-linear optimization in order to obtain optimal contracting schemes (so-called screening contracts) in a strategic lot sizing framework. The validity of the applied theory is tested via laboratory experiments. This approach allows for identifying the main critical assumptions within the theory while showing that non-predicted behavior leads to a deterioration of supply chain performance. Interestingly, the experiments reveal that — in contrast to standard assumptions - the impact of information sharing is ambiguous and dependent on several factors, such as contract flexibility and complexity. The experimental results form the basis for a behavioral principal-agent model. The model gives valuable insights on how the interaction of information sharing and information processing impacts the supply chain performance.

APPLIED PROBABILITY AND STOCHASTIC PROGRAMMING, FORECASTING

■ WB-08

Wednesday, 11:30 - 13:00, Room F018

Applied Probability I

Chair: *Karl-Heinz Waldmann*, Institut für Operations Research, KIT

1 - On worst case trees in multistage stochastic programming

Georg Pflug, Department of Statistics and Decision Support Systems, University of Vienna

We consider a multistage stochastic program, which is defined on a scenario tree. For incorporating model error into the optimization problem, we define a set of tree models and optimize the worst case among all tree models as a minimax problem. The set of tree models is defined by a ball around a baseline tree using the nested distance between trees. This distance extends the Kantorovich trnasportation distance to the multistage case. The distance appears as the minimal transportation effort from one tree to the other, where the tree structures have to be respected in the transportation plan. The method is illustrated for multistage decision models for hydro as well as thermal electricity production.

2 - Sojourn Times in the Longest Queue System with Exchangeable Items

Rachel Ravid, Industrial Engineering and Management, Ort Braude College

We consider a repair facility that consists of one server and two arrival streams of failed items. The two arrival streams are independent Poisson processes with different rates that emerge from two sources; bases 1 and 2. The service times are independent, exponential random variables with equal rates. The items are exchangeable in the sense that customers who arrive with a broken item can be satisfied by any repaired item. The arriving customers generate two separated lines and each customer is admitted to his own line; namely, the customers are marked according to their sources (bases). As a result, a backorder is created in the lines at each arrival. Within the lines the issuing policy is FIFO, but the repaired items are delivered to the longest queue. In case that the lines are of the same length, the item will be delivered to either base 1 or base 2 with probability 0.5. In this talk we will focus on the law of the sojourn time in steady state.

3 - Rational and Floating Point Random Numbers for Computer Algebra Systems

Thomas Morgenstern, IWI Informatik und Wirtschaftsinformatik, Hochschule Karlsruhe — Technik und Wirtschaft

The analysis of special stochastic simulation studdies, e.g. for energy signals, show that the higher precision of computer algebra systems through symbolic computations allows to detect effects not visible with conventional floating point environments. In order to solve these problems a rational and a floationg point random number generator for two computer algebra systems is constructed and tested. The computational efficiency for the two generators are compared and differences in the simulation results investigated.
Key words: random number generation, stochastic simulation, stochastic programming, computer algebra systems

Applied Probability and Stochastic Programming, Forecasting (WC-08)

■ WC-08

Wednesday, 14:00 - 15:30, Room F018

Applied Probability II

Chair: *Georg Pflug*, Department of Statistics and Decision Support Systems, University of Vienna

1 - Estimating resale prices in the used car market: The relevance of forecasting method and model granularity

Stefan Lessmann, Institute of Information Systems, University of Hamburg

The paper is concerned with estimating resale prices in the used-car market. In this setting, forecasting is useful to inform sellers and support pricing decisions. Previous research has concentrated on explanatory modeling approaches. Compared to predictive modeling, explanatory models allow testing the influence of, e.g., car features or economic condition on market prices, but sacrifice some accuracy. This paper focuses on predictive modeling to study the extent to which market prices are actually predictable. Using a collection of real-world data sets from a leading German car manufacturer, a large empirical benchmarking study is undertaken to contrast the predictive power of alternative modeling techniques. These include several individual prediction methods and different regimes for forecast combination. Furthermore, the study sheds light on the specificity of resale price forecasting models. On the one hand, one can build a single model for all vehicles. Alternatively, individual models for different brands or different car models can be built. Forecasting at lower granularity is likely to improve forecast accuracy but at the cost of multiplying the number of models and thus the effort of creating and monitoring these models. It is therefore important to appraise the trade-off between accuracy and specificity to clarify the marginal utility of forecasting at lower granularity and provide recommendation how the forecasting task should be approached in corporate practice.

2 - Segmenting electrical load time series for forecasting - An empirical evaluation of daily UK load patterns

Sven F. Crone, Department of Management Science, Lancaster University Management School

Forecasting future electricity load represents one of the most prominent areas of electrical engineering, in which artificial neural networks (NN) are routinely applied in practice . A common approach to overcome the complexity of building NNs for high-frequency load data is to segment the time series into homogeneous subclasses of simpler subseries, often a constant hour of the day or day of the week, which are forecasted independently using a separate NN model, and which are recombined to provide a complete forecast of the next days ahead. Despite the empirical importance of load forecasting, and the high operational cost associated with forecast errors, the potential benefits of segmenting time series into subseries have not been evaluated in an empirical comparison. This paper assesses the empirical accuracy of segmenting empirical hourly load data taken from the UK into daily subseries versus forecasting the original, continuous time series with NNs. Empirical accuracy is provided in comparison to statistical benchmark algorithms and across multiple rolling time origins, which indicates the superior performance of NN on continuous, non-segmented time series, in contrast to best practices.

3 - Value-at-risk Forecasts Using Time Varying Evt-copulas

Theo Berger, Empirical Economics and Applied Statistics, University of Bremen

We combine elliptical copulas with time varying Dynamic Conditional Correlation (DCC) matrices to forecast Value at Risk (VaR). When applied to various financial portfolios consisting of German Stocks, market indices and FX-rates, with a data sample covering both calm and turmoil market times, the approach turns out to be feasible even for higher order portfolios. Using Extreme Value Theory (EVT) based models for the marginal return distributions, the overall performance of this hybrid DCC-Copula approach is highly reasonable with respect to several backtesting criteria. An additional simulation exercise allows to control for the influence of the marginals. Again, dependency modeling via the DCC-Copula approach is supported. Hence, the use of time varying EVT-Copulas can be recommended as a feasible and reliable tool for VaR forecasts. Due to the broad scope of the empirical analysis, this recommendation is not limited to particular asset classes or specific market phases.

■ WE-08

Wednesday, 17:00 - 18:30, Room F018

Applied Probability III

Chair: *Stefan Lessmann*, Institute of Information Systems, University of Hamburg

1 - Statistical mechanics of Innovation Diffusion: model development, estimation, and forecasting.

Christos J. Emmanouilides, Department of Economics, Aristotle University of Thessaloniki

Statistical mechanics concepts are used to model the interaction process among users and potential users of a new product - innovation, who are located in a network defined over a multivariate set of characteristics and spatial structures. The market is modeled as a multi-agent system where individuals maximize their adoption utility that is affected by product attributes, individual characteristics, marketing actions and structural network characteristics. Aggregate diffusion equations are then derived under simplifying distributional assumptions for the utility components. These are Mean Field type equations for the temporal evolution of the adoption probabilities' distribution, whose dynamics are assessed with simulations. Reduced (i.e. homogenized to some degree) model forms that are estimable under a variety of data availability scenarios (e.g. with macro-level aggregate diffusion data, individual level panel or cross-sectional data) are then obtained. Preliminary results on the properties of available estimators are discussed. Finally, the forecasting performance of the simpler (i.e. fully homogenous) model form is compared to that of established aggregate innovation diffusion models using a large number of diffusion series, for a number of forecast origins and lead times. When empirically supported, this model forecasts better or equally well than standard diffusion models, thus providing a preferable alternative.

2 - Sequencing Protocols and Cut Consolidation for the Parallel Hybrid-Cut Nested L-Shaped Method

Christian Wolf, Decision Support & OR Lab, University of Paderborn, *Achim Koberstein*

The Nested L-shaped method can be accelerated by the use of alternative sequencing protocols, the removal of inactive optimality cuts from the subproblems and a parallel implementation. We implemented a parallel nested L-shaped method within the well-known COIN-OR framework with the capability of scenario aggregation. We devise a new dynamic sequencing protocol for traversing the scenario tree and a cut consolidation strategy to reduce the number of optimality cuts in the master problem. We present computational results which indicate that both techniques can lead to significant reductions in running time on some test porblems.

3 - A Robust Reliability Modeling in Series-Parallel Systems with Redundancy Allocation

Ali Ghafarian Salehi Nezhad, Department of Industrial Engineering, Sharif University of Technology, *Abdolhamid Eshragh*, *Mohammad Hassan Salmani*, *Fereshte Ghasemi*

Redundancy Allocation Problem (RAP) is a combinatorial problem to maximize system reliability by discrete selection from available components. The main purpose of this study is to prove the effectiveness of robust optimization to solve RAP. Generally, robust optimization is a field of optimization theory where robustness is sought against uncertainty and/or variability of parameters' values. In this study it is assumed to have Erlang distribution density for components' failures where to implement robust optimization. We suppose that failure rate attains dynamic values instead of exact and fixed values. Another assumption is that each subsystem can have one of cold-standby or active redundancy strategies.

CONTINUOUS OPTIMIZATION

■ WB-10

Wednesday, 11:30 - 13:00, Room F025

Nonsmooth and Conic Optimization

Chair: *Mirjam Duer*, Mathematics, University of Trier

1 - A nonsmooth Newton method for disjunctive optimization problems

Stephan Buetikofer, Institute of Data Analysis and Process Design, Zurich University of Applied Sciences, *Diethard Klatte*

In recent works of the authors [1,2] a nonsmooth Newton method was developed in an abstract framework and applied to certain finite dimensional optimization problems with C1,1 data. Such problems arise from general semi-infinite optimization problems (GSIP) under suitable assumptions. Recent results show that under some weaker assumptions there is a reformulation of a GSIP as a disjunctive optimization problem. We will apply this method to disjunctive optimization problems. For this we reformulate stationary points of a disjunctive optimization problem [3] as a zero of a suited nonsmooth function F. The authors already presented preliminarily results about this at the OR 2011 conference in Zurich. The weakness in the reformulation from there (equivalence of stationary points and zeros of F, assumptions for local convergence) could be eliminated. We will work out in detail the concrete Newton schemes from [1,2] for disjunctive optimization problems and discuss the (local) convergence properties of the Newton scheme. References [1] S. Buetikofer, Globalizing a nonsmooth Newton method via nonmonotone path search, Mathematical Methods of Operations Research 68 No. 2, (2008) 235 - 256 [2] S. Buetikofer, D. Klatte, A nonsmooth Newton method with path search and its use in solving C1,1 programs and semi-infinite problems, SIOPT 20, (2010) 2381-2412 [3] H.T. Jongen, J.J. Rückmann, O. Stein, Disjunctive Optimization: Critical Point Theory, JOTA 93 No.2, (1997) 321-336

2 - Aubin Property and Uniqueness of Solutions in Cone Constrained Optimization

Diethard Klatte, IBW, Universität Zürich, *Bernd Kummer*

In this talk, we discuss conditions for the Aubin property of solutions to perturbed cone constrained programs, by using and refining known results of this type. In particular, we show that constraint nondegeneracy and hence uniqueness of the multiplier is necessary for the Aubin property of the critical point map. Moreover, we give conditions under which the critical point map has the Aubin property if and only if it is locally single-valued and Lipschitz.

3 - Infinite dimensional semidefinite programming

Mirjam Duer, Mathematics, University of Trier

Semidefinite programming has proved a highly useful tool in numerous applications. Among others, it provides very strong bounds for many combinatorial optimization problems. A well studied example is the theta-number which is a bound on the stability number of a finite graph. Recent work by Bachoc and Vallentin (2008) generalizes this to infinite graphs, i.e. graphs with an infinite number of vertices. This motivates our study of infinite dimensional semidefinite programming. We introduce the primal and dual infinite "semidefinite cones" and discuss several of its properties which will result in the formulation of a primal/dual pair of infinite SDPs.

■ WC-10

Wednesday, 14:00 - 15:30, Room F025

Nonlinear Programming

Chair: *Mirjam Duer*, Mathematics, University of Trier

1 - A unifying approach to solve some classes of rank-three d.c., multiplicative and fractional programs involving linear and quadratic functions

Claudio Sodini, Statistics and Applied Mathematics, University of Pisa, *Riccardo Cambini*

The aim of this paper is to propose a solution algorithm for solving a class of low-rank programs involving linear and quadratic functions and having a polyhedral feasible region. In particular, the proposed solution method solves in an unifying approach some classes of rank-three d.c., multiplicative and fractional programs. The algorithm is based on the so called optimal level solutions method. Some optimality conditions are used to improve the performance of the proposed algorithm.

2 - Global Optimization by Range Approximation of Multivariate Polynomials with the help of Bernstein Polynomials

Martin Stöcker, Fakultät Mathematik, Professur Wirtschaftsmathematik, Technische Universität Chemnitz

We consider polynomials in an arbitrary number of variables which frequently occur in all kinds of optimization problems. Even though the properties of polynomials are well understood, it can be hard to find the minimizer of an polynomial of high order. A common problem is to determine bounds for the range of polynomials. These bounds can be used for optimization (e.g. as relaxation of a direct search method) or they can help to identify regions of the feasible set where the function values satisfy certain conditions (e.g. function value above or below a certain level). For those problems we introduce two approaches which generate lower and upper bounds of multivariate polynomials over an n-dimensional box. These strategies differ in accuracy and complexity of calculation. The first method is based on the estimation of the contribution of the polynomial's summands, while the second one uses an expansion into Bernstein polynomials to obtain a convex envelope which yields the desired bounds. Two hyperplanes which enclose the polynomial's graph can be derived from the convex envelope. They increase the quality of the bounds. The mentioned approaches work both for univariate and multivariate polynomials and are enhanced to rational polynomials. We apply the method to a real-world problem which occurs in the development process of vehicle transmissions. In this example, a system of equations with inherent parameters is transformed into a polynomial and the obtained description is optimized with the help of lower and upper bounds.

3 - Random Projection Of Polytope

Rahul Paul, Computer Science, International Institute Of Information Technology, Bangalore, *Kundan Kumar*, *G. N. Srinivasa Prasanna*

Random projections are a powerful method of dimensionality reduction of N-Dimensional Polytopes. We provide practical results relating to using random projections to solve a volume computation problem (which is otherwise computationally intractable), as well as theoretical results relating to various error guarantees they provide. We also prove several new results relating to projections of polytope that is of interest when trying to apply them in practice, such as analysis on the orthogonality of the created subspace guarantees, and the error incurred on the dot-product. We present experimental results on using random projection as a dimensionality reduction tool in volume computation. In the random projection method (RP), the original high-dimensional data is projected onto a lower-dimensional subspace using a random matrix. RP has been found to be a computationally efficient, yet sufficiently accurate method for dimensionality reduction of high-dimensional data sets. Dimensionality reduction of polytope with the help of random projection can help to calculate the volume of higher dimension using the estimates of the volume in the lower dimension. Our methods can be used to quantify information content and uncertainty, in constraint regions, in a robust optimization framework. We show its applications in supply chain management, under conditions of future uncertainty.

■ TA-10

Thursday, 9:00 - 10:00, Room F025

Continuous Optimization in Applications I

Chair: *Mirjam Duer*, Mathematics, University of Trier

1 - The Linear Sum-of-ratios Optimization Problem: A Pso Based Algorithm

João Paulo Costa, Faculty of Economics, University of Coimbra / INESC-Coimbra, *Maria João Alves*

Problems modeled as a sum-of-ratios arise naturally when several rates (objectives) are to be optimized simultaneously. The numerators and denominators of the ratios are affine functions that may represent profits, capital, time, etc. The linear sum-of-ratios problem is also used for computing nondominated solutions in multiobjective linear fractional programming problems when weighted-sums are applied. We previously developed a Branch & Cut (B&C) algorithm for computing solutions for this kind of problems. The solutions that individually optimize each ratio (which turn out to be linear programs) are firstly computed. These solutions provide upper or lower bounds in the objective space that are used to delimit the search region The search region is further divided and the sub-regions are analyzed in order to be able to discard some of them. The incumbent solution is used to define some cuts (linear constraints) and to trim the current search region. The process is repeated with the remaining regions, ending when these regions are "so small' that the differences among their individual optimum solutions are lower than a pre-defined error. The algorithm has a good performance for problems of medium dimensions (less than roughly ten ratios) even considering a small pre-defined error. The integration of particle swarm optimization (PSO) techniques improves performance for problems of higher dimensions. PSO is applied after running the B&C technique considering a big pre-defined error, for which a reasonable computing time is enough. The swarm is then built upon the computed solutions of the remaining regions. New incumbent solutions are used to redefine cuts to further trim the search regions. We will report on the followed approach and on some computational results.

2 - The OR of Stochastic Hybrid Dynamical Systems and Their Role in Finance, Economics and Science

Gerhard-Wilhelm Weber, Institute of Applied Mathematics, Middle East Technical University, *Azar Karimov*, *Büsra Temocin*, *Aysegul Iscanoglu Cekic*

We represent dynamics in finance, but also economics and science, under uncertainty and covariance. An emerging representation tool for this is Stochastic Differential Equations. Is has become acknowledged that additionally an impulsive part is needed, together amounting for Levy processes. Even these are often composed piecewise with changes happening at thresholds. We present several classes of these Hybrid Systems, discuss problems of identification, keeping them between barriers and optimizing portfolios with regard to them, discussing approaches of Hamilton-Jacobi-Bellman and Maximum Principle. During the presentation we discuss sound interpretations, and we conclude with an outlook.

■ FA-10

Friday, 9:00 - 10:00, Room F025

Continuous Optimization in Applications II

Chair: *Mirjam Duer*, Mathematics, University of Trier

1 - A Bi-Objective MIP Model for Robust Facility Layout Problem

Mohammad Hassan Salmani, Industrial Engineering, Sharif University of Technology, *Kourosh Eshghi*, *Hossein Neghabi*

Facility Layout Problem (FLP) is one of the classical and important problems in real world problems in the field of industrial engineering in which efficiency and effectiveness are very important factors. To have an effective and practical layout, the deterministic assumptions of data should be changed. In this study, it is supposed that we have dynamic and uncertain values for departments' dimensions. Therefore, we consider that each dimension changes in a predetermined interval. Due to this assumption, two new parameters are introduced which are called length and width deviation coefficients. According to these parameters, a robust layout is defined and a Mixed Integer Programming (MIP) model is developed. Moreover, two new objective functions are presented and their lower and upper bounds are calculated with four different approaches. It is worth to mention that one of the objective functions is used to minimize the total areas, which is an appropriate criterion to appraise robust layout. Finally, we solve some benchmarks in literature to test the proposed model and then according to their results, a sensitivity analysis is also presented.

2 - Energy Utility Fuel Allocation Model for Non-Linear Revenue

Balram Avittathur, Operations Management, IIM Calcutta

The motivation for this paper is the coal allocation challenge faced by an energy firm that has six coal-fired thermal power plants. The tariff entitled to a particular plant of the firm is decided by a regulatory authority and comprises of a capacity component and an energy component. The former is a function of the plant utilization and the fixed costs associated with the plant among others. The energy component of tariff is independent of plant utilization and is a function of coal cost. This coal cost is based on the prices of a bundle of different types of coal and the utility firm could improve its profitability by using a higher proportion of cheaper coal. The optimization model is one of maximizing the surplus of the firm. The surplus function comprises of a (i) revenue component, (ii) coal cost component, (iii) coal freight cost component and (iv) other variable costs component. The decision variable is the amount of power that should be generated at a particular plant using coal of a particular coal source. The revenue component is a non-linear function up to given plant utilization level. The various cost components described above and constraints are linear. Objective function representing the surplus of the firm is a non-linear function. The non-linearity of the objective function results in difficulty to estimate the global optima. We develop a heuristic approach to solve the problem by introducing an additional constraint. The heuristic improves the functioning of the firm significantly. The paper can be looked at as a contribution to the body of knowledge on heuristic approaches to solve non-linear optimization problems.

DECISION ANALYSIS AND MULTIPLE CRITERIA DECISION MAKING

■ WB-11

Wednesday, 11:30 - 13:00, Room F107

Decision Processes and Strategic Management

Chair: *Anne Chwolka*, OvGU

1 - Value-focused thinking enhances the quality of decisions

Johannes Siebert, Business Administration, University of Bayreuth

Normally, decisions are based on given alternatives that are evaluated with high methodological effort (alternatives-focused thinking) but not scrutinized themselves. However, since alternatives are only means to achieve the decision makers (DMs) objectives these and not the alternatives should be the starting point in any decision situation. Value focused thinking, first introduced by Keeney (1), postulates a paradigm shift in the thinking of the DM. Based on the values of the DM her objectives were identified and structured to develop systematically better alternatives. Instead of solving decision problems the DM the DM should identify proactively decision opportunities to gain more control about her decisions. In a recent study (2), students used value-focused thinking to identify the objectives and to generate systematically alternatives for the title of (2). Three groups - experts, students who have created the alternatives with value-focused thinking, and students who have not used value-focused thinking - were given an identical decision problem and asked to rank 12 alternatives for the title of (2). The ranking provided by the first group can be considered as optimal. The ranking provided by the second group was by far closer to the ranking by experts than that provided by the third group. This result shows that value-focused thinking enhances the quality of decisions. (1) Keeney RL (1992) Value-focused thinking?: a path to creative decisionmaking, Cambridge Mass.: Harvard University Press. (2) Keeney RL, Siebert J Proaktive Entwicklung besserer Alternativen mit Value-focused Thinking. Submitted.

2 - Overconfidence vs. Planning Competence in Entrepreneurial Ventures

Matthias G. Raith, Otto-von-Guericke Universität Magdeburg, *Anne Chwolka*

In their attempt to capture the leading characteristics of entrepreneurial behavior, researchers are often quick to abandon the assumption of rationality. Instead, entrepreneurs are typically regarded as being overconfident in their investment decisions and driven by hubris when as-sessing their own abilities to start a new venture. In this paper we challenge this view and argue in favor of a more rational entrepreneurship paradigm, which emphasizes the rationale of entrepreneurial decisions, rather than just observing their outcomes. We first show that observations of entrepreneurial behavior, which have often been attributed to overconfidence, can just as well be motivated by rational decision making. However, rather than dismissing the relevance of overconfidence, we defend rational behavior, as it provides a sound theoretical basis for understanding the logic of entrepreneurship. We then propose a framework for stud-ying the rationality of an overconfident entrepreneur. We study the properties of relevant entrepreneurial decision contexts and derive implications for entrepreneurship policy and education.

3 - Selection Of Photovoltaic Panels In Solar Energy Systems Using Fuzzy Vikor

Onur Yilmaz, INDUSTRIAL ENGINEERING, YILDIZ TECHNICAL UNIVERSITY, *Bahadir Gulsun*, *Musa Demirok*

Renewable energy sources have gained increasing interest by people and governments all over the world, and the sun turned out to be one of the most common renewable energy sources. Photovoltaics panels are used to convert light into electricity and three of the most common photovoltaic panel types in solar energy sector are monocrystalline, policrystalline and thin film panels. These panel types all have different specifications in terms of some criteria, which turns the selection which panel to use to a multiple criteria decision making problem. Our study focuses on selecting the optimal photovoltaic panel for a solar energy system by using fuzzy VIKOR method. VIKOR is a relatively new multiple criteria decision making method introduced by Opricovic. Experts from the sector contributed in the study by helping in forming the criteria and rating the alternatives with respect to those criteria. In the end, we determine the most suitable photovoltaic panel for solar energy utilization.

■ WC-11

Wednesday, 14:00 - 15:30, Room F107

Multi Criteria Decision Making and Social Resposibility

Chair: *Verónica Cañal*, Applied Economics, University of Oviedo

1 - Building a Yesable Proposal to Multiple Stakeholders in Social-Business Planning

Christoph Starke, Chair of Entrepreneurship, Otto-von-Guericke-University Magdeburg, *Matthias G. Raith*

When planning for social-value creation, entrepreneurs generally need to consider multiple stakeholders with conflicting views of organizational effectiveness. By employing a scoring procedure often used for the analysis of multiple-issue negotiations, we show how the quantitative assessment of stakeholders' preferences results in a one-dimensional subjective measure of organizational effectiveness for each stakeholder. Our approach complements recent research by contributing to a quantitative discussion of organizational effectiveness. Due to typical structural features of the employed scoring template, we are also able to derive general propositions resulting from the conflict structure and the interaction of multiple stakeholders. We find that an increase in the number of stakeholders required for an agreement tends to decrease the perceived organizational effectiveness of initial negotiation parties. On the other hand, the multitude of possible agreements is also reduced, thereby sharpening the focus on acceptable proposals to the stakeholders involved.

2 - Selection of Socially Responsible Portfolios using Hedonic Prices

Verónica Cañal, Applied Economics, University of Oviedo, *Amelia Bilbao-Terol*, *Mar Arenas-Parra*, *Celia Bilbao*

This paper presents a novel framework for selecting Socially Responsible Investment(SRI) portfolios. The Hedonic Price Method (HPM) is applied to obtain an evaluation of SRI criteria that is integrated into a multi-objective mathematical programming model. The HPM breaks away from the traditional view that goods are the direct object of utility; on the contrary, it assumes that utility is derived from the properties or characteristics of the goods themselves. As far as the investment decision is concerned, we assume that socially responsible investment mutual funds (SRI funds)constitute heterogeneous goods. Our approach allows us to obtain a portfolio the financial performance of which is similar to that which the investor would have reached if he or she had not taken into account social, ethical and environmental (SEE) considerations when making his or her investment decisions. This is achieved by designing a two-stage multi-objective mathematical programming procedure. In the first stage, we achieve the maximum level of financial satisfaction that the investor can receive. In the second stage, the portfolio with the best financial-social behaviour is built. For the purpose of this second stage, the first stage portfolio is used as a benchmark for the financial performance of a socially responsible portfolio. To apply this methodology, we use portfolios composed of socially responsible and conventional mutual funds domiciled in Spain.

3 - Solving strongly cross-linked problems: How to reach goals in complex cases?

Olaf Tietje, FHO-Hochschule Rapperswil

There is a huge number of cases in which we don't know how to reach our goals because the available options have only indirect impacts on the goals. Before an effect of an option occurs, the option has impacts on a set of mutually interdependent factors. In many cases, the overall impact of a proposed measure on the final goal is very small, if it occurs at all, or it even is counter-effective. For a certain class of cases there is a procedure — called feedback analysis — that pre-estimates the overall impact of measures on indirectly affected goals. All important mutual impact factors are represented in an impact matrix. The impact matrix includes all impacts that are relevant for the direct or indirect influence on the goals. Thus, the impact matrix sufficently represents the system for which the goals are defined. Some of the impact factors are directly influenced by the options or measures, other impact factors are utility indicators that indicate to which degree or to which extent the goals are achieved. The feedback analysis combines scenarios for the assessment of options and measures, a system model to assess the effects, and a set of utility attributes to evaluate the system state with respect to the goals. It is used to evaluate measures to enhance farmers' benefits and overall costs within the maize production chain and to improve the tourism organization for a small region in the alps.

■ WE-11

Wednesday, 17:00 - 18:30, Room F107

Decision Processes in the Energy Sector

Chair: *Gonçalo Pereira*, MIT Portugal Program, IST - Instituto Superior Técnico

1 - Main drivers for the Iberian market price and energy storage in Portugal

Gonçalo Pereira, MIT Portugal Program, IST - Instituto Superior Técnico, *Susana Vieira*, *Carlos Santos Silva*

Electricity generated from renewable sources has shown a remarkable growth worldwide. In the majority of the renewable technologies, immediate response to demand is not possible since they do not deliver a regular supply adjustable to consumption needs. This problem has led to the emergency of storage technologies and to their field implementation. Initial results on large scale storage using reversible hydro dams in Portugal showed an increase in the share of renewable energies going into the Portuguese electric system. It also showed that Wind production and the Iberian electricity market price, translated into electricity imports, have a very important role in the energy storage charge decision by the grid operator and the duration of the charge period. During the discharge period, the only relevant factor is the overall system's demand. This work proposes to evaluate how the Portuguese and Spanish electricity production influences the charge phase/decision in large scale storage systems in Portugal. What are the production sources that drive the Iberian Market price and, therefore, energy storage? The proposed methodology consists in applying a feature selection based algorithm to the collected historical data, reducing the number of variables used to predict the energy storage charge decision. The methodology is applied to the collected historical data which is composed by: • Iberian Market prices and transacted quantities; • Portuguese and Spanish pump storage consumption, demand and production by production source. By gaining further knowledge on how the Iberian market works and what are the main drivers it is possible to achieve more accurate models for energy planning and forecasting.

2 - Portfolio model as a support decision to combinatorial auctions

Elisa Bastos Silva, Energy Department, Unicamp - State University of Campinas, *Paulo Correia*

The operation of power plants in Brazil is granted through public auctions. These auctions can be sequential, simultaneous, combinatorial or hybrids. On the one hand the Government designs the auction to reduce the price of energy to consumers; on the other hand the investors are looking for opportunities to extract higher profits, and to be successful in these type of auction the interests of both must be contented. The design of combinatorial auction complies with the objective of the Government increasing the competition and reducing the energy price making it attractive to investors, since they are inclined to offer better values for two or more products together rather than individual products. This strategy is good for investors because the goods are complementary and together can generate more revenue. For this reason, understanding the seasonality of the energy sources encourage the investors to acquire different power plants due to one venture minimizing the risk of another, and consequently it increasing the revenue. Therefore, this paper aims to assist the choice of the investor to participate in a combinatorial auction in order to identify an optimal portfolio of power plant projects, considering their complementary features. Thus, a decision support tool was developed and it uses the portfolio theory, combinatorial auction theory, multiobjective optimization and Brazilian energy trading processes.

3 - Binomial lattice model: application on carbon credits market

Natália Addas Porto, Energy, University of Campinas, *Paulo Correia*

The increasing concern over the greenhouse gas emissions and the consequent global energy market transformation are evident, along with the necessity of economic value allocation into environmental resources, which are incorporated into market dynamics to decrease, at least partially, the environmental impacts on economic growth. The Clean Development Mechanism (CDM) is inserted in this context to provide mitigation through the practice of sustainable development in developing countries, either by transfer of investments or technologies coming from developed countries or other stakeholders. Given the perspective of economic and environmental concerns, the present paper presents a model based on that developed by Cox and Rubinstein (1979), known as Lattice Binomial Model. It is known from literature that many models of financial mathematics are based on the assumption of normality returns. However, the normal distribution may underestimate the probability of extreme events due to having a very sharp decay of their tails. Thus, it is very important to consider alternative kinds of probability distributions that are able to model the effects caused by asymmetric data. The Lattice Binomial Model is discussed in this paper in order to represent the random parameters behavior in the contracts of Certified Emission Reductions (CERs), which are carbon credits generated by CDM projects. Then, after establish the probability distribution of data, pricing are done. However, the model is not implemented analytically, the parameters are adjusted in accordance to information obtained from the distributions. Finally, the model is applied to a representative example, showing the ability of the approach as a decision tool for investors in CDM projects.

■ TC-11

Thursday, 11:30 - 13:00, Room F107

Risk Analysis and Assessment

Chair: *Jonas Ide*, Fakultät für Mathematik, Georg-August-Universität Göttingen

1 - Competitive Ratio as Coherent Measure of Risk

Esther Mohr, Information and Technology Management, Saarland University, *Iftikhar Ahmad*, *Guenter Schmidt*

A risk measure determines the quantity of an asset that needs to be kept in reserve in order to make the risk taken by an investor acceptable. In the last decade so-called coherent measures of risks meeting a set of four desirable properties gain in importance. Inherently online algorithms fell short to provide any mechanism for risk management. In this paper we prove the competitive ratio to be coherent as it satisfies all the required axioms of a coherent measure of risk. We explain risk management in online conversion problems, and show how the competitive ratio can be used to manage the risk for online algorithms. Inherently these algorithms are designed for worst-case scenarios. But in a real world scenario, an investor would like to take risk in order to gain a higher reward.

2 - Price acceptability and decision-making process model after the earthquake disaster

Yumi Asahi, Department of engineering, Management of business, Shizuoka University

In Japan, needs of domestic vegetable have risen because consumers have become increasingly aware of problem related to safety of food. On the other hand, the amount of imported vegetable has increased, and the price of imported vegetables is cheaper than domestic ones. This paper analyzed purchasing behaviors of domestic vegetables and imported vegetables through a face to face interviews survey of 50 housewives at super-market in Japan. Also, the author investigated what kind of purchasing action change of consumers there was after an earthquake disaster. The author compared it how consciousness such as the "safety" "interest in meal" "price consideration" "simple and easy cooking" changed after an earthquake disaster. It followed that the consumers made much of quality than a price. From this survey, the author build brand switching behavior model with pride acceptability. Keywords: safety of food, price acceptability, domestic vegetable

3 - Concepts of robustness in multi-objective optimization

Jonas Ide, Fakultät für Mathematik, Georg-August-Universität Göttingen, *Anita Schöbel*

Many practical problems suffer from inaccurate, missing, or unreliable input data. This is a severe problem, since even small changes can make an optimal solution completely useless for practice. Robust optimization approaches try to hedge against uncertain data. The goal is to find solutions which are good for all scenarios contained in some given uncertainty set. Due to various applications, many different interpretations of optimality for such uncertain problems exist. So far, these only apply to single-objective functions. Hence, the question arises, if these concepts are useful in a multi-objective context and if so, how to extend them to multi-objective optimization. In this talk we present three concepts on how to define robustness in multi-objective optimization problems. These are the following: - A solution is called flimsy robust efficient if there exists a scenario for which it is efficient, - A soluton is called highly robust efficient, if it is efficient for all scenarios. - We also generalize the concept of strict robustness to multicriteria problems. The differences and usefulness of these definitions will be demonstrated with an example, and the relations between the concepts will be analyzed. We furthermore investigate the resulting optimization problems for finite and polyhedral uncertainty sets. In particular we identify cases in which we receive problems of the same type as the original problem. Furthermore, algorithms for computing highly, flimsy and strictly robust efficient solutions will be presented.

■ TD-11

Thursday, 14:00 - 15:30, Room F107

Decision Analysis in Industrial Engineering

Chair: *Gábor Lovics*, Budapest University of Technology and Economics

1 - A method to approximate the whole Pareto-optimal set of the Markowitz model

Gábor Lovics, Budapest University of Technology and Economics, *Tibor Illés*

In economic and engineering application of mathematics sometimes we need to optimize more than one objective function at the same time. In this type of problems we need to find solutions, where one of the objectives can not be improved without worsen the other. These solutions are called Pareto-optimal solutions, and in since 1950's such methods are known that compute one of the Pareto-optimal solutions.

Recently, for unconstrained mulitobjective optimization problems such algorithm has been developed by Oliver Schütze at al. (2003) that try to approximate the whole set of the Pareto-optimal solutions at the same time. In this talk we generalize the subdivision algorithm of Schütze and others for linearly constrained multiobjective problem. The objective functions in our case need to be differentiable convex functions. Further generalization of the more general class of problems (convex constrained and convex objective function for mineralization problem) seems to be possible. The main idea of the method to find joint decreasing direction, for the all objective function at the same time. Practical applicability of the new algorithm has tested on the Markowitz portfolio optimization problem.

2 - Optimization Methodologies for Interface Design

Mehmet Burak Şenol, Industrial Engineering, Gazi University-Ankara TURKEY, *Metin Dagdeviren*, *Mustafa Kurt*

The dialog between the user and system is provided by an interface. Poor interaction between an interface and users can result in human errors and accidents. Although a general reason for aircraft accidents are improper displays, relatively few studies have been conducted on interface layout design except usability evaluations. Subjectivity within most usability evaluation techniques can cause challenges in different applications. Here cockpit interface design problem is evaluated objectively, because the methods we have developed and applied, are all analytical. We present different techniques for panel modifications and for new designs. Multi Criteria Decision Making, Card Sorting and Unified design approaches are offered and applied for modifications; because as layout planning is done on a two-dimensional plane, a priori knowledge about indicator's possible locations is available due to structure (e.g. electrical wiring, mechanical structure, etc.) of the panel. However when this information is unavailable as in continuous facility layout problems, we have devised a new optimization model, namely, Relative Layout Design. Besides to flow values, interractions between the items may affect their locations relatively. By including "Relative Criteria' constraints, layout problems for 2,3-D designs like engines, circuits, etc can be solved in a more realistic manner.

3 - A Fuzzy Analytic Hierarchy Process Model for Selecting the Best Tunnel Boring Machine for Excavation of Subway

Ali Asghar Anvary Rostamy, Management, Tarbiat Modares University (TMU), *Meysam Shaverdi*, *Amin Mikhak Beiranvand*, *Farideh Bakhishi Takanlou*

Today regarding to increasing of cities population and traffic, construction of subways is a solution. There are different methods for construction of subways. Extraction with full face machine or Tunnel Boring Machine (TBM) is a general method. This method has advantages and problems. Faster penetration rate than other methods is an important benefit of TBM. The high primal value of TBM is a problem. Therefore many economic & technical studies should be make before project start. If we result that we should use TBM, the next step is best TBM selection. According to variety of TBM types and effective parameters on excavation, the selection is difficult. For Shiraz subway, the Fuzzy Analytic Hierarchy Process (FAHP) model is used. There are four alternatives and five criteria. The best type is selected by previous excavation experiments, zone position and tunneling aspects. After the calculations, weight of Earth Pressure Balance Shields (EPB Shields) is maximized and this machine is selected.

■ TD-12

Thursday, 14:00 - 15:30, Room F023

Outranking Approaches for Sustainable Development

Chair: *Simon Hirzel*, Fraunhofer Institute for System and Innovation Research

1 - Sustainability Assessment of Concepts for Energetic Use of Biomass - A Multi-Criteria Decision Support Approach

Nils Lerche, Chair of Production and Logistic, Georg-August-Universität Göttingen, *Meike Schmehl*, *Jutta Geldermann*

The use of biomass for energy production is gaining attention among policy-makers, energy suppliers and the public. There are several reasons why the energetic use of biomass is often associated with sustainability, e.g., the less contribution to climate change or the preservation of fossil energy reserves. Nevertheless, the public perception of the energetic use of biomass has recently been characterized by decreasing acceptance. Major concerns are that monocultures will increase due to a higher demand for energy crops, which would result in massive land-use changes and affect biodiversity. In addition, an increase in transport activity is expected in rural areas, aggravating air pollution and disturbance. Moreover, the designation of areas for energy crop production is a highly controversial issue from an ethical perspective, especially in cases where areas are used for food production, nature conservation or grassland. Hence, it becomes apparent that the assessment of potential concepts for the energetic use of biomass is of multidimensional nature and should not only imply economic, but also environmental, social and technical aspects. For that reason, methods of Multi-Criteria Decision Analysis (MCDA) seem to be suitable for assessing potential concepts of biomass-usage. An approach, based on the multi-criteria method PROMETHEE, has been developed, which allows an assessment of three different concepts: Small-scale and large-scale biogas plants, as well as bioenergy villages. In this paper the developed approach will be presented and applied exemplarily for a rural area in southern Lower Saxony, with a focus on further potential enhancements.

2 - Comparison of two visualisation methods for decision support in MCDM problems

Bastian Schmidtmann, Institute of Controlling, University of Hannover, *Genoveva Uskova*, *Harald Uhlemair*

By using MCDM methods like PROMETHEE, it is possible to include the alternatives, the rele-vant criteria and preferences for each decision maker in his decision process. Visualisation methods make the impact of each single criterion and its weight on every single alternative visible. In this paper, we present a new method of visualising and interpreting MCDM prob-lems and a comparison of the method with the GAIA method which is used in the Outranking approach PROMETHEE. The method introduced in this paper is based on the classical Multi-dimensional Scaling (MDS). MDS is extended by the property fitting to integrate each single criterion into the visualisation aspects. The comparison is drawn in two ways. Firstly, we compare visualisation of the two methods and their interpretability to show which one gives a better and easier understanding of the MCDM problem. Also, differences concerning po-tential interpretations and losses of information are investigated. Secondly, the methodolog-ical approaches of the two methods are compared. In order to compare and evaluate the two visualisation methods, we use a data set from the electronic vehicle research area to calculate and visualise the PROMETHEE results. Human mobility behaviour in everyday life needs to be aligned to economic as well as ecological and social objectives. To achieve those objectives, several innovative and conventional types of vehicles exist, such as electric vehi-cles, hybrid vehicles, fuel cell vehicles. In order to select one of those vehicles, the decision maker has to evaluate several criteria. In addition to the price and the engine performance, the decision maker also needs to keep criteria like CO2-emission, charging-time and range for each type of vehicle in mind.

3 - Evaluation of energy efficiency measures: An integrated approach for compressed air systems

Simon Hirzel, Fraunhofer Institute for System and Innovation Research, *Grit Walther*

Industrial compressed air systems are usually important contributors to energy demand and energy costs. Thus, numerous measures to increase energy efficiency in compressed air systems have been proposed. Yet it often remains difficult for decision-makers to thoroughly evaluate the large variety of conceivable measures at hand. These difficulties arise from the heterogeneous character of efficiency improvement measures, from existing interrelations between different measures and from uncertainties concerning costs and benefits. Furthermore, aspects such as the flexibility and the complexity of the measures need to be taken into consideration as well, and there are often diverging interests within a company that have to be carefully balanced against each other. Against this background, the aim of this paper is to develop an integrated approach for modelling and evaluating energy efficiency measures of compressed air systems to support the decision-making process in industry. The developed approach combines a techno-economic model with a multi-criteria decision support system. Within the techno-economic model, different modules representing the compressed air system are specified and are then combined to analyze air and energy flows of alternative system layouts. The applied multi-criteria method is based on an extended fuzzified PROMETHEE method. It explicitly allows both: handling of uncertainties with regard to investments, energy demand and energy costs, as well as accounting for differing results in the decision-making of miscellaneous actors. For illustration, the method is applied to a case study, and results are contrasted with results from classical economic calculus.

■ FA-11

Friday, 9:00 - 10:00, Room F107

Data Envelopment Analysis (DEA)

Chair: *Andreas Kleine*, Faculty of Economics, University of Hagen

1 - Comparing two methods of ranking interval efficiencies for fuzzy DEA models

Somayeh Tabatabaee, mathematics, Azad university of firoozabad, *Zahra Tabatabaee*

Data envelopment analysis is a non-parametric technique for evaluating the relative efficiencies of a set of entities. In fact in a real evaluation problem input and output data of entities evaluated often fluctuate. This fluctuating data can be represented as linguistic variables characterized by fuzzy numbers for reflecting a kind of general feeling. For this purpose some researchers have proposed several models to deal with the efficiency evaluation problem with the given fuzzy input and output data. One of these methods is changing fuzzy models in to interval models by using alpha cuts. As we may face with some interval efficiency of several entities that should be compare with each other and ranked,In this paper we compare two methods of ranking interval efficiencies that is obtained from interval models. A sensitive difference between these two methods will be shown by a numerical example.

2 - From central scaling to efficiency change - a new interpretation of u

Andreas Dellnitz, Operations Research, University of Hagen, *Wilhelm Rödder*, *Andreas Kleine*

Already in their pioneering work Banker et al. (1984) considered the free variable u of the BCC multiplier model and interpreted it correctly, as a qualitative characteristic of the DMU's returns to scale. In the envelopment form, on the other hand, u is the dual shadow price of the convexity constraint. Besides all these mathematical well known properties a profound economic interpretation of this shadow price is still missing. This contribution provides a deeper economic insight by infinitesimal changes of the right hand side in the convexity constraint. These changes give rise either to a transformation of the technology or by a transformation of the DMU under assessment. Both such transformations are called centric scaling. These considerations yield a new understanding of the importance of the variable u: u is an exact measure for efficiency change under such centric scaling. Numerical example and respective illustrations complement all theoretical considerations.

DISCRETE AND COMBINATORIAL OPTIMIZATION, GRAPHS AND NETWORKS

■ WB-13

Wednesday, 11:30 - 13:00, Room A310

Column Generation

Chair: *Marco Lübbecke*, Operations Research, RWTH Aachen University

1 - Packing Cuts with Column Generation

Martin Bergner, Operations Research, RWTH Aachen University, *Marco Lübbecke*

In our talk, we propose an exact algorithm for the cut packing problem in general graphs via a column generation approach. It is known that packing cuts in general graphs is NP-hard and cannot be approximated better than with a factor of O(n/logn) in general graphs. Cut packing has applications in both network design and, via its dual formulation as a cycle packing problem, in computational biology. For our approach, we discuss both combinatorial algorithms and a mixed-integer linear programming (MIP) formulation for solving the pricing problems. In order to further improve the dual bound, cutting planes from the literature are separated during the solution process and their integration in the pricing problems is explained. Furthermore, we highlight a novel application for detecting structures in constraint matrices of MIPs and use heuristics tailored to this application for finding solutions during the branch-and-price algorithm. Finally, we present computational results both on graphs from the literature as well as from our application and discuss the peculiarities of these instance.

2 - Large Neighborhood Search and Diving Heuristics in Column Generation Algorithms

Christian Puchert, Operations Research, RWTH Aachen University, *Marco Lübbecke*

In many MIP applications, a problem with a particular structure is to be solved. For those problems, the Branch-and-Price scheme using the Column Generation procedure has proven to be a successful approach, which relies on the Dantzig-Wolfe decomposition. The performance of this scheme may be improved by supplying it with additional features such as primal heuristics. We present heuristics that are specially tailored for Column Generation and exploit a given problem structure, but are still generic in that they are not restricted to any particular problem. In particular, we lay focus on two special kinds of heuristics, namely Large Neighborhood Search and Diving Heuristics. The former explore a MIP neighborhood of one or more given feasible (or at least LP feasible) solutions. The latter perform a depth-first search on the branch-and-bound tree, where they may branch either on the original variables or the master variables. We will investigate the impact of these heuristics and give a comparison to classical heuristic approaches.

3 - A branch-and-price algorithm for rearranging a matrix into doubly bordered block-diagonal form

Michael Bastubbe, Operations Research, RWTH Aachen University, *Martin Bergner*, *Alberto Ceselli*, *Marco Lübbecke*

We consider rearranging the rows and the columns of a matrix into doubly bordered block-diagonal (a.k.a. arrowhead) form. For a given number of blocks and some given balance condition on the blocks, this becomes an optimization problem in which the total number of border rows and border columns is to be minimized. In this talk we present an exact branch-and-price algorithm to this optimization problem. For us, this matrix form is particularly interesting because it may help us applying a Dantzig-Wolfe decomposition of the underlying mixed integer program. We extend a naive assignment IP formulation (that has a weak LP relaxation) by an exponentially number of block pattern variables to strengthen the LP relaxation. Our branch-and-price algorithm first solves the pricing problem heuristically by exploiting its special structure. If the heuristic solution of the pricing problem does not yield variables with negative reduced costs the pricing problem is solved exactly by an IP. We present the improvement of the LP relaxation and discuss the practicability of the algorithm.

■ WB-14

Wednesday, 11:30 - 13:00, Room F435

Packing and Cutting

Chair: *Pawel Zielinski*, Institute of Mathematics and Computer Science, Wroclaw University of Technology

1 - New Heuristic For The Integrated Problem Of Cutting And Sizing Of 3d-bins

Mariem Baazaoui, méthodes quantitatives, FSEG Sfax, *Habib Chabchoub*, *Racem Mellouli*

Cutting and packing problems are numerous and have a wide range of practical applications. In our research, we are interested in the cutting of mousse blocks in SOTIM industrial company. Indeed, we present a general optimization problematic of integrated cutting and sizing of the 3D-mousse bins by defining a new type of cutting and packing problem. The latter is a combination of the assembly problem and the cutting problem in 3D. This is an NP-hard problem for which it is difficult to find the optimal solution. So, it would be better to use heuristic methods to find a good solution in a reasonable lap time. We propose a new heuristic made in three steps for the case of SOTIM. In the first step, taking into consideration the rotation of pieces, we classify the items into similar sets called clusters in such a way that the lengths of all pieces in the same cluster are close. In the second step, we sort the clusters according to the largest cardinality and the pieces in each cluster according to the decreasing height. While in the third step, we reconstruct the mousse blocks with fictitious manner by placing the pieces in the predefined order. For this, we use an overlap of 2D-heuristic packing procedure generating a succession of layers whose boundaries are eligible to delimit the blocks (the sizing part). To implement and evaluate our heuristic, we test random, SOTIM and some literature instances. We conduct a sensitivity analysis while taking into account the variation in the number of pieces and changing the nature of the pieces.

2 - A Discretized Invasive Weed Optimization algorithm for the bin packing problem

Medily Villamayor, University of the Philippines Mindanao, *Giovanna Fae Oguis*, *Ruben Jr. Idoy*

This study employed first fit and best fit heuristics to enhance a Discretized Invasive Weed Optimization Algorithm with an optional Mutation Algorithm (DIWO) as an additional tool to improve the solution quality of an Offline One-dimensional Bin Packing Problem (BP). Mutation will be utilized if the optimal solution is not reached upon completion of DIWO Algorithm. Comparison of results of six (6) DIWO parameter sets and two (2) Modified Shuffled Frog Leaping Algorithm (MSFLA) parameter sets tested on twenty (20) BP data sets with items of four (4) different sizes were done. Results showed that DIWO parameter sets outperformed the MSFLA parameter sets, with DIWO parameter sets exhibiting various and inconsistent behaviors on the four data sizes. In general, however, the DIWO parameter sets with lower weed but higher seed population gave better results. Statistical analysis also showed that the execution of mutation improved the algorithms solution quality. In future studies, it is recommended to test more parameter sets with lower weed and higher seed population involving different number of iterations as this was constant in this study.

3 - Deepest Dual Optimal Inequalities for Cutting Stock and Bin Packing

Stefan Irnich, Chair of Logistics Management, Gutenberg School of Management and Economics, Johannes Gutenberg University Mainz, *Timo Gschwind*

One successful method for solving the cutting stock (CS) and bin packing problem (BP) is branch-and-price. The column generation master program is a set covering problem where columns correspond to feasibly filled bins that cover a subset of the items. It is known that standard column generation suffers from slow convergence (tailing off). For CS, valid inequalities on the dual prices of the covering constraints, so-called dual optimal inequalities, were identified to be helpful to mitigate the tailing off effect. Our presentation addresses three issues: First, the standard approach is the a priori construction of dual optimal inequalities before solving the master program. We show that the most violated inequalities can be easily identified in the column generation process and so be added dynamically. For standard benchmark problems, computation times were approximately halved. Second, for BP not all CS inequalities are dual optimal, i.e., fulfilled by at least one optimal solution of the LP-relaxation of the master program. We present a way to handle these cases and to reconstruct primal feasible solutions needed in the branch-and-bound process. Third, we generalize our results to the BP with conflicts.

■ WC-13

Wednesday, 14:00 - 15:30, Room A310

Robustness and Uncertainty

Chair: *Marie Schmidt*, Institut für Numerische und Angewandte Mathematik, Georg-August-Universität Göttingen

1 - Approximating combinatorial optimization problems with uncertain costs and the OWA criterion

Adam Kasperski, Wroclaw University of Technology, Institute of Industrial Engineering and Management, *Pawel Zielinski*

In this paper the following class of combinatorial optimization problems is discussed. We are given a finite set of elements and a set of feasible solutions composed of some subsets of the element set. In the deterministic case, each element has a nonnegative cost and we seek a feasible solution whose total cost is minimal. This formulation encompasses a large class of problems, in particular the important network problems such as the shortest path, minimum spanning tree or minimum assignment. In real life the precise values of the element costs are often not known in advance. To model this uncertainty, we can introduce a scenario set which contains a finite number of distinct cost vectors, called scenarios. Thus each scenario represents a possible realization of the element costs which may appear with a positive but perhaps unknown probability. In order to choose a solution the ordered weighted averaging aggregation operator (shortly OWA), introduced by Yager in 1988, is used. In particular, the OWA operator contains the max, min, average, median and Hurwicz criteria as special cases. Unfortunately, for most problems, for example the basic network problems, minimizing OWA is NP-hard even for two scenarios. In this paper we provide some general positive and negative approximation results for the considered problem. Namely, we show that if the weights of the scenarios are nonincreasing, then the problem has a simple approximation algorithm with a guaranteed performance bound. On the other hand, if the weights of the scenarios are nondecreasing, then the problem is not at all approximable. Furthermore, we show that if the number of scenarios is constant, then the problem can be solved in pseudopolynomial time and admits an FPTAS.

2 - Recoverable robust combinatorial optimization problems

Pawel Zielinski, Institute of Mathematics and Computer Science, Wroclaw University of Technology, *Adam Kasperski*, *Adam Kurpisz*

In the paper, we investigate two Recoverable Robust (RR) models for combinatorial optimization problems with uncertain element costs proposed by Busing in 2012. In the traditional robust approach to combinatorial optimization problems, a scenario set which contains all possible vectors of the element costs is given. This set contains a number of distinct scenarios or is the Cartesian product of interval costs of the elements. The RR approach extends the concept of robustness by incorporating limited recovery actions after the element costs are revealed. In the first model (k-dist RR) after a solution is determined and the costs are known, at most k elements of the solution can be replaced in the second stage. In the latter one (Rent RR) the number of elements which can be replaced in the second stage is not limited, but deviating from previous choice results in an extra cost. Up to now, only few RR problems were investigated - RR Shortest Path and RR Knapsack (Busing 2011). In this paper, we provide new results on the RR model which are valid for a class of combinatorial optimization problems. For Rent-RR model with discrete scenario set, we prove some inapproximability results for the class of network problems containing Minimum Spanning Tree, Minimum Assignment and allocation problems. Furthermore, we show that the approximation algorithm for Rent-RR Shortest Path with discrete scenario set and the polynomial algorithm for Rent-RR Shortest Path with interval costs, proposed by Busing, can be extended to the above class of combinatorial optimization problems. For the k-dist-RR model, we focus on a particular network problem, namely on Minimum Spanning Tree, and prove hardness and inapproximability results for both discrete and interval uncertainty representations.

3 - Robust Optimization under Multi-Band Uncertainty

Christina Büsing, Operations Research, RWTH Aachen University, *Fabio D'Andreagiovanni*

"The Price of Robustness' by Bertsimas and Sim [BS04] represented a breakthrough in the development of a tractable robust counterpart of a Linear Programming problem. However, the central modelling assumption that the deviation band of each uncertain parameter is single may may be too limitative in practice. Experience indeed suggests that the deviations distribute also internally to the single band. Breaking the band into multiple sub-bands thus looks advisable. This observation was first captured by Bienstock and used to develop a Robust Optimization framework for the special case of Portfolio Optimization [Bi07]. Nevertheless, no theoretical study of a general multi-band model has yet been done. The aim of our investigations is to bridge such gap. In this work, we study the robust counterpart of a Linear Programming Problem with an uncertain coefficient matrix and we model these uncertainties through a multi-band set. We show that i) the robust counterpart corresponds to a compact Linear Programming formulation and that ii) the separation of cuts imposing robustness can be operated efficiently by solving a min-cost flow problem. Finally, we present computational experiments comparing the performance of solving the compact formulation versus a cutting plane approach on realistic wireless network design instances. REFERENCES [BeSi04] D. Bertsimas, M. Sim, The Price of Robustness, Operations Research, 52 (1), 35—53, 2004 [Bi07] D. Bienstock, Histogram models for robust portfolio optimization, Journal of Computational Finance, 11, 1—64, 2007 [BuDA12] C. Büsing, F. D'Andreagiovanni, New Results about Multi-band Uncertainty in Robust Optimization, to appear in Proceedings of SEA 2012, LNCS 7276, 63-74, 2012

■ WC-14

Wednesday, 14:00 - 15:30, Room F435

Combinatorial Optimization

Chair: *Filipa Duarte Carvalho*, Matematica, ISEG/UTL; CIO

1 - Relevant Network Distances for Approximate Approach to the p-Median Problem

Jaroslav Janacek, Transportation Networks, University of Zilina, *Marek Kvet*

A public service system structure is usually formed by deployment of limited number of service centers and the associated objective is to minimize social costs, which are proportional to network distances between serviced objects and the nearest service centers. Mathematical models of the public service system design problem are often related to the p-median problem, where the numbers of serviced customers and possible service center locations take the value of several thousands. The number of possible locations impacts the computational time for solving the associated mathematical programming problem. The necessity of solving large instances of the p-median problem has led to the approximate approach based on a set-covering formulation, which enables to solve bigger instances in admissible time making use of a universal IP-solver. This approach pays for shorter computational time or smaller demanded computer memory by a loss of accuracy. The accuracy can be improved by a more suitable determination of dividing points, which are used for a network distance approximation. This contribution deals with the idea that some network distances from customer to possible center locations can be considered relevant. These distances are expected to belong to the optimal solution. The p-1 largest distances from a customer to all possible service center locations represent an example of non-relevant distances. We suggested a formalization of the outlined notion of relevancy and based the dividing point selection on it. In this contribution, we study an impact of dividing point distribution on effectiveness of the approximate approach. Numerical experiments were performed to demonstrate the expected impact and the associated results are reported at the end of the paper.

Discrete and Combinatorial Optimization, Graphs and Networks (WC-14)

2 - A Multi-Dimensional Multi-Commodity Covering Problem with Application in Logistics

Alexander Richter, TU-Berlin, *Felix G. König*, *Jannik Matuschke*

In this talk, we study a multi-commodity multi-dimensional covering problem which we encountered as a subproblem in optimising large scale transportation networks in logistics. The problem asks for a selection of containers for transporting a given set of commodities, each commodity having different extensions of properties such as weight or volume. Each container is specified by a fixed charge and capacities in the relevant properties and can be selected multiple times. The task is now to find a cost minimal collection of containers and a feasible assignment of the demand to all selected containers. From theoretical point of view, by exploring similarities to the well known set cover problem, we derive NP-hardness and see that the non-approximability result known for set cover also carries over to our problem. For practical applications we need very fast heuristics to be integrated into a meta-heuristic framework that — depending on the context - either provide feasible near optimal solutions or only estimate cost value of an optimal solution. Thus, in a second part we develop and analyse a flexible family of greedy algorithms that meet these challenges. In order to find best-performing configurations for different requirements of the meta-heuristic framework, we provide an extensive computational study on random and real world instance sets obtained from our project partner 4flow. We outline a trade-off between running times and solution quality and conclude that the proposed methods achieve the accuracy and efficiency necessary for serving as a key ingredient in more complex meta-heuristics.

3 - Reference Point Methods and Approximation in Multicriteria Optimization

Kai-Simon Goetzmann, Institut für Mathematik, Technische Universität Berlin, *Christina Büsing*, *Jannik Matuschke*, *Sebastian Stiller*

Applications of combinatorial optimization often feature several contradicting objectives, e.g. cost and duration of a transport. The basic concept in multicriteria optimization is Pareto optimality: a solution is Pareto optimal if improving one objective is impossible without worsening another. In general, however, the number of Pareto optimal solutions is exponential. We study a concept called reference point methods. A reference point solution is the solution closest to a given reference point in the objective space. This method is widely spread in practice and gives a single Pareto optimal solution balancing the criteria. By changing the norm in the objective space each point in the Pareto set can become the reference point solution, thus maintaining the full variability of multicriteria problems. Despite its apparent virtues only few theoretical and even less algorithmic results are known for reference point methods. We establish an algorithmic link to approximate Pareto sets: finding an approximate reference point solution is equivalent to approximating the set of Pareto optimal solutions. With our techniques we further show that the Pareto set has a constant approximation factor if and only if the single-criteria problem has a constant factor. We give several and some general techniques to obtain solutions for reference point methods. The main algorithmic result is an LP-rounding technique that achieves the same approximation factors as in the single-criteria case for many classical combinatorial problems, including set-cover and several machine scheduling problems. By the established link our algorithmic results also give a short alternative proof for the existence of an FPTAS to Pareto set in the case of linear optimization over convex sets.

■ WE-13

Wednesday, 17:00 - 18:30, Room A310

Networks

Chair: *Matthias Müller-Hannemann*, Computer Science, Martin-Luther Universität Halle-Wittenberg

1 - Minimization of energy consumption in IP-over-WDM networks

Axel Werner, Optimization, Zuse Institut Berlin (ZIB), *Christian Raack*, *Christoph Lange*, *Andreas Betker*, *Dirk Kosiankowski*, *Heiko Lehmann*

The operation of telecommunication infrastructure consumes a lot of energy. Given that the energy consumption scales with the ever increasing demand for capacity and network speed, there is a growing interest in strategies for a sustainable network management. It is a well-known fact that traffic demands vary significantly over time, most notably in day/night- and in weekly cycles. This provides the main potential for an energy-sensible traffic engineering and network management. We formulate mixed integer programming models for the corresponding optimization problems, taking various requirements and side constraints into account. Based on realistic nation-wide IP-over-WDM networks, we apply the models, using predictions for traffic matrices, as well as state-of-the-art hardware and energy models. We evaluate the results of our computations: How much energy is spent in the core and in metro regions of the network and how big are the savings in low-demand scenarios? What is the influence of bandwidth or different hardware on the overall energy consumption? How much do different routing schemes or protection scenarios restrict potential energy savings?

2 - MILP Formulation for Blackout Prevention by Deliberate Islanding of Power Networks

Andreas Grothey, School of Mathematics, University of Edinburgh, *Waqquas Ahmed Bukhsh*, *Paul Trodden*, *Ken McKinnon*

Deliberate islanding of power networks can be used as a last resort strategy to prevent wide-area blackouts. In this talk we present a mixed-integer programming (MILP) formulation for the islanding of power networks. Given an area of uncertainty in the network, the proposed approach uses mixed integer linear programming to isolate uncertain components and create islands, by intentionally (i) cutting lines, (ii) shedding loads and (iii) switching generators, while maximizing load supply. A key feature of the new method is that network constraints are explicitly included in the MILP problem, resulting in balanced, steady-state feasible DC solutions. A subsequent AC optimal load shedding optimization on the islanded network model provides a feasible AC solution. Numerical simulations on the 24-bus IEEE reliability test system and larger systems demonstrate the effectiveness of the method.

3 - Link replacement scheduling in fiber optic communication networks

Andreas Bley, TU Berlin, *Fabio D'Andreagiovanni*, *Daniel Karch*

We consider the problem of scheduling the replacement of the WDM transmission technology on the links of a fiber optic communication network in such a way that service disruptions are minimized. Given an optical network consisting of fiber links and switching nodes, unprotected and protected virtual connections of single paths or pairs of disjoint paths, respectively, and a discretized planning horizon, the task is to decide when to replace the technology of each link. Replacing a link requires several technicians at the repeaters and terminal nodes of this link. The number of technicians available per period is limited. Since the old and the new technology are incompatible, a path will be non-operational from the period its first link is replaced until all its links are replaced, which leads to the disruption of the corresponding virtual connections. An unprotected virtual connection is disrupted when its only path is non-operational. A protected virtual connection is non-operational when both its paths are non-operational, while it is operational but unprotected when only one paths is operational. The objective is to minimize the overall time that virtual connections are disrupted or unprotected. We present two integer linear programming formulations for this problem, discuss its relation to the linear arrangement problem and the complexity of some special cases, and finally report on computational results for real world instances.

■ WE-14

Wednesday, 17:00 - 18:30, Room F435

Miscellaneous

Chair: *Stefan Irnich*, Chair of Logistics Management, Gutenberg School of Management and Economics, Johannes Gutenberg University Mainz

1 - Integer Models for Network Cluster Problems

Filipa Duarte Carvalho, Matematica, ISEG/UTL; CIO, *Maria Teresa Almeida*

Computational biology, design of telecommunication systems and social network analysis are examples of fields where it is necessary to identify groups of entities (proteins, individuals, companies or other social actors) whose interactions take place mainly inside the group. In this talk we present new integer programming models to identify maximal cardinality clusters defined by reachability conditions and to determine sets of disjoint clusters that maximize node covering of a network. We discuss the tightness of the models from the linear programming standpoint and their contribution to enhance neighbourhood search-based heuristics.

2 - How does the topology determine the synchronization threshold in the network of oscillators?

Lubos Buzna, Department of Transportation Networks, University of Zilina, *Sergi Lozano*, *Albert Diaz-Guilera*

Reliable functioning of electrical power grid is dependent on the proper interaction between many of its elements. Of critical importance is its ability to keep the frequency across the entire system stable. Considering simple mathematical model, representing a network of coupled oscillators, we study the stability of the frequency synchronization. This model can be interpreted as a dynamical model of frequency synchronization among power producing and power consuming units. Assuming a uniform network we analytically derive the formula estimating the relation between the minimum coupling strength required to ensure frequency synchronization and the network parameters. This minimum value can be efficiently found by solving a binary optimization problem, even for large networks, using universal solver XPRESS. The accuracy of the analytical estimation we validate by comparing it with numerical simulations on a realistic network describing the European interconnected high-voltage electricity system, finding good agreement. Repeatedly solving the binary optimization problem we can test the stability of the frequency synchronization with respect to link removals. As the threshold value changes only in few cases we conclude that the network is resilient in this regard. Since the synchronization threshold depends on the network partition representing the synchronization bottleneck, we also evaluate which network areas become critical for synchronization when removing single links.

3 - Efficient ant colony algorithm for unidirectional flow path design

Julie Rubaszewski, LOSI, Université de Technologie de Troyes, *Alice Yalaoui*, *Lionel Amodeo*, *Sylvain Fuchs*

The flow path design is the determination of each segment direction and the paths used for automated vehicles in production units. The organization of these roads directly influences the performance of the system. This problem is one of the most important issues in designing an AGV (automated guided vehicles) system. This work deals with flow path design problem for a conventional unidirectional network. An efficient optimization method based on ant colony algorithm is developed in order to solve the case of minimizing the total travel distance considering both loaded and empty travels. For this algorithm, each ant constructs a solution moving into the graph. A displacement is allowed only if the nodes are linked and if the segment is not oriented yet. In this case, going from a node i to a node j fixes the segment orientation from i to j. When an ant arrives on a node which all segments linked are already oriented, it is moved on another node to finish his path. Two local searches are applied to the best solution. The first one consists in creating new solutions reversing for each one the direction of one segment of the solution considered. The second one consists in randomly selecting a node linked with at least 4 segments and testing all combinations of the segment direction for this node. If a better solution is found, it will replace the best current solution. To ensure the efficiency of the proposed optimization method, computational experiments are carried out and results are compared with the work of Guan et al. (2011). For all cases tested, the algorithm found optimal solution when it is known, with smaller time of resolution. When it is not the case, it improves the result of the literature with smaller time of resolution or equivalent.

■ TA-13

Thursday, 9:00 - 10:00, Room A310

Scheduling and Linear Programming

Chair: *Christina Büsing*, Operations Research, RWTH Aachen University

1 - An improved polynomial relaxation-type algorithm for linear programming

Sergei Chubanov, University of Siegen

To find a solution of a system of linear inequalities, the classical relaxation method projects the current point, at every iteration, either exactly onto a hyperplane defined by a violated constraint or into a point lying at some distance from the hyperplane, depending on the so-called relaxation parameter. The constructed sequence converges to a feasible solution, provided that the relaxation parameter is chosen appropriately. It is well known that the method is not polynomial. One of the reasons for this is that each iteration considers only one violated constraint among the original constrains of the system. Unlike the relaxation method, each iteration of our algorithm considers an appropriate nonnegative linear combination of the inequalities. The algorithm runs in O(n3L_min) time where n is the number of variables and L_min is the minimum binary size of a feasible solution. In particular, the algorithm either finds a nonnegative solution of a system of linear equations or proves that there are no 0,1-solutions in O(n4) time. This theoretical estimate is less by the factor of n2 than that of our previous algorithm.

2 - A tight analysis of Smith's rule for nonlinear cost

Wiebke Höhn, Institut für Mathematik, Technische Universität Berlin, *Tobias Jacobs*

We consider the problem of scheduling jobs on a single machine. Given some non-decreasing cost function, we aim to compute a schedule minimizing the weighted total cost, where the cost of each individual job is determined by the cost function value at the job's completion time. This problem is closely related to scheduling a single machine with nonuniform processing speed. We show that for piecewise linear cost functions it is strongly NP-hard. The main contribution is a tight analysis of the approximation guarantee of Smith's rule under any particular convex or concave cost function. More specifically, for these wide classes of cost functions we reduce the task of determining a worst case problem instance to a continuous optimization problem, which can be solved by standard algebraic or numerical methods. For polynomial cost functions with positive coefficients it turns out that the tight approximation ratio can be calculated as the root of a univariate polynomial. To overcome unrealistic worst case instances, we also give tight bounds that are parameterized by the minimum, maximum, and total processing time.

■ TA-14

Thursday, 9:00 - 10:00, Room F435

Applications

Chair: *Axel Werner*, Optimization, Zuse Institut Berlin (ZIB)

1 - Generation System of a timetable

Rabah Kassa, mathematique, Universite Bejaia algerie, *Abdelmalek Boudries*, *Mahdi Djelouah*, *Djamila Boukredera*

The artificial intelligence is this part of the computer science which is concerned with taking in charge, by computer, the intellectual tasks of the man. It is a discipline which comes to satisfy the human desire to produce machines reproducing its intellectual faculties. Since its birth, the artificial intelligence caused a significant passion in the professional environments and specializes in many fields such as the voice recognition, the pattern recognition, the computer-assisted learning, the expert systems, etc. In our work we have conciliated the artificial intelligence and the operations research whose the major concern is the generation of the timetables in a university institute. The problem of the timetables is known as being a strongly combinative problem, because it is characterized by its significant volume of data, its various constraints, its frequent changes (modifications being able to affect the coding of the modules, changes likely in the levels number of a teaching cycle, etc.) and finally the concern of the pedagogue to optimize the output of teaching (to avoid the hollow hours, the restoration constraint, satisfaction of the teachers, etc). In this work we have studied some methods which tried to solve the problem of timetables and we have proposed a resolution by using the techniques of the artificial intelligence and operations research. For the establishment of this system and to make the work clearer, we have divided it into three steps: assignment of the modules to the teachers, seances programming and buildings programming. The results obtained of the developed system are satisfactory. The only disadvantage is that if the number of input data increases the probability of the combinative explosion risk increases.

2 - Simultaneous Optimization of Berth Allocation, Quay Crane Assignment and Quay Crane Scheduling Problems in Container Terminals

Necati Aras, Industrial Engineering, Bogazici University, *Yavuz Turkogullari*, *Z. Caner Taşkın*, *I. Kuban Altinel*

There has been a dramatic increase in the world's container traffic during the last thirty years. As a consequence, the efficient management of the operations in seaport container terminals has become a crucial issue. In this work, we focus on the integrated planning of the following problems faced within the context of seaside operations at container terminals: berth allocation, quay crane assignment, and quay crane scheduling. First, we formulate a new binary integer linear program for the integrated solution of the berth allocation and quay crane assignment problems called BACAP. Then we extend it by incorporating the crane scheduling problem as well, which is named BACASP. Computational experiments performed on problem instances of various sizes indicate that the model for BACAP is very efficient and even large instances up to 60 vessels can be solved to optimality. Unfortunately, this is not the case for BACASP and only small instances can be solved optimally. To be able to solve large instances, we present a necessary and sufficient condition for generating an optimal solution of BACASP from an optimal solution of BACAP using a postprocessing algorithm. We also develop a cutting plane algorithm for the case where this condition is not satisfied. This algorithm solves BACAP repeatedly by adding cuts generated from the optimal solutions at each trial until the aforementioned condition holds. This method proves to be viable and enables us to solve large BACASP instances as well. To the best of our knowledge, these are the largest instances that can be solved to optimality for this difficult problem.

■ TC-13

Thursday, 11:30 - 13:00, Room A310

Facility Location

Chair: *Stefan Ruzika*, Department of Mathematics, University of Kaiserslautern

1 - Impact of utility function to servic center location in public system

Michal Kohani, Transportation Networks, University of Zilina, *Lubos Buzna*, *Jaroslav Janacek*

To design public service systems, as fire brigade system or emergency medical system, various types of location and allocation models can be used. In general, this problem can be seen as an example of resource allocation problem, with a central planner. Although the costs for system construction and its operation are typically shared by everybody, not all citizens have not the same access to the service. When it is possible to estimate the satisfaction level of citizens by a utility function, various fairness schemes can be used to compare corresponding allocation strategies. There are two different ways how to evaluate the resulting quality of the system structure. The utilitarian approach, preferring solutions, which maximize the system utility and the fair approach, which takes into account individual users and their rights to have an equal access to provided services. Although, there is no general agreement on what is fair, various basic fairness schemes can be used to decide on the resulting allocation of resources. In this paper we focus on the impact of used utility funcion on location of service centers, we compare the form of distribution of located centres in comparision with other approaches and we explore its impact on the price of fairness. Numerical experiments will be made using the large-scale topological data.

2 - An extended formulation for the survivable hop constrained connected facility location problem

Mohsen Rezapour, Institute for Mathematics, TU Berlin, *Andreas Bley*, *S. Mehdi Hashemi*

We consider a generalization of the rooted Connected Facility Location problem (ConFL) which occurs in planning of local access networks considering both survivability and hop-length constraints. In addition to choosing facilities to open and assigning clients to open facilities we need to find a minimum cost subgraph connecting all open facilities to the root, in which there are at least L arc-disjoint paths, each containing at most H edges, between the root and each open facility. We first present a flow based integer programming formulation for the problem using the layered representation. To reduce the integrality gap of the formulation, we then extend the formulation by using the concept of the solution level introduced by Mahjub et al. Afterwards, to solve the problem in practice, we project out the flow variables and generate Benders cuts within a branch-and-cut framework. Finally, we report computational results

3 - A genetic algorithm for the unequal area facility layout problem

Udo Buscher, Industrial Management, TU Dresden, *Birgit Mayer*, *Tobias Ehrig*

In this paper we apply a genetic algorithm for solving the single-floor facility layout problem. The focus is on departments of unequal sizes. The objective is primarily to minimize material flow factor cost. In addition, the shape ratio factor is taken into account. The chosen genetic method based on an implemented space-filling curve which continuously connects each unequal area department in order to ensure disjoint areas. Thereby, the selection of the right space-filling curve is critical. In contrast to the existing literature which applies sweeping, spiral or Hilbert-type patterns, we propose Peano-type patterns. Comparable with Hilbert-type patterns the original Peano-curve has to be adjusted in order to be applicable to the facility layout problem considered. We describe the generation of the Peano-curve and the applied genetic search. Further, we provide results from several test problems that demonstrate the very good suitability of modified Peano-curves for the unequal area facility layout problem.

■ TD-13

Thursday, 14:00 - 15:30, Room A310

Routing

Chair: *Andreas Bley*, TU Berlin

1 - Integration of Combinatorial Dispatching and Trajectory Planning for Welding Robots

Wolfgang A. Welz, Mathematics, Technische Universität Berlin, *Martin Skutella*

In welding cells a certain number of robots performs spot welding tasks on a workpiece. The movements of the welding robots have to be planned in such a way that all weld points on the component are visited and processed within the cycle time of the production line. During this operation, the robot arms must not collide with each other or the component. This problem consists of two major parts, namely, the nonlinear trajectory planning and the combinatorial assigning and sequencing of weld points. On the basis of these specifications, we show an approach how the path planning can be efficiently integrated in the solving process of the collision-aware routing problem so that computational expensive calculations can be kept to a minimum. While the routing problem is solved as an Integer Linear Program by Column Generation techniques, we use exact nonlinear path planning methods within the generation process to verify promising tours and to find new non-conflicting arcs. This technique allows us to find optimal solutions for real-world instances of the original problem.

2 - An extended formulation for the Shortest Path Routing Polytope

Daniel Karch, TU Berlin, *Mikael Call*, *Andreas Bley*

Routing in current communication networks is often based on shortest path routing protocols, such as OSPF or IS-IS. Shortest path routing problems arise as subproblems in many network optimization problems. An fundamental question is to decide if for a given set of end-to-end paths in a directed graph there exist arc weights such that the paths are unique shortest paths to their respective destinations. In a Branch-and-Cut context, this is done by solving a separation problem over a suitable polytope, thereby generating cutting planes that prohibit infeasible routings. The standard formulation for the Shortest Path Routing Polytope based on arc variables, however, is highly symmetric: It happens frequently that a single structural conflict will yield several weak cutting planes, thereby inflating the size of the LP relaxation. A classical approach to tackle this issue is by the use of an extended formulation. We show how some of these symmetries can be broken by the addition of a moderate number of new variables representing subsets of arcs. We also show how to obtain stronger cutting planes that would be difficult to find in the original variable space, by considering a node packing problem on the new variables.

3 - The Quickest Path Problem — Extensions and Algorithms

Stefan Ruzika, Department of Mathematics, University of Kaiserslautern, *Markus Thiemann*

The quickest path problem generalizes the shortest path problem in dynamic networks in which flow units are assumed to take time to traverse an arc. Given an amount of flow U and two nodes s and t, the goal of the quickest path problem is to find an s-t-path with minimum transmission time, that is the sum of the travel times from s to t of this path and the number of repetitions to send all U flow units along this path. Applications of this problem can be found in communication networks, transportation networks, and evacuation modeling. In this talk we address extended topics related to the quickest path problem. We consider min-max variants, the restricted and reliable quickest path problems, the k-min capacity quickest path problem and address sensitivity issues briefly.

■ FA-13

Friday, 9:00 - 10:00, Room A310

Graph Algorithms

Chair: *Matthias Müller-Hannemann*, Computer Science, Martin-Luther Universität Halle-Wittenberg

1 - Analysis of Economical Networks by Regular Equivalence

Stefan Wiesberg, Institut für Informatik, Universität Heidelberg, *Gerhard Reinelt*

In network analysis, an established way to obtain structural information is to partition the vertices into so-called regular equivalence classes. In such a partitioning, two nodes u and v belong to the same class if for every neighbor of u, there is a neighbor of v in the same class, and vice versa. Thus, for any two classes C and D, either every or no member of C has a neighbor in D. The relationships between the classes can hence be visualized by a graph, the so-called role graph. It is of interest in several fields, for example in sociology, economy, or consumer research. An NP-hard problem in this context is the following one: Given a network G and a finite set R of role graphs, which element of R represents the role structure of G in the best possible way? We present one of the first exact algorithms for this problem. It is based on an IP formulation with a quadratic objective function and solved by branch-and-cut. Significant running-time improvements compared to currently used methods are reported.

2 - An efficient adaptive algorithm for the graph partitioning problem

Frank Schneider, INFORM -GmbH

We describe a lean and efficient implementation of a memetic algorithm for the graph partitioning problem, which is based on the recently published algorithm MAGP by Galinier, Boujbel and Fernandes. It uses a pool of candidate solutions, an AP-based crossover-operator to create offspring and a tabu-search operator to improve candidate solutions. Our implementation generalizes MAGP by making it parameter-free and applicable to instances with 0% imbalance, and improves the original algorithm with respect to initialisation, pool-management and selection of tabu-search moves. It was tested on the well known instances from Walshaw's Graph Partitioning Archive and found new best known solutions to 385/816 instances.

ENERGY AND ENVIRONMENT

■ WB-16

Wednesday, 11:30 - 13:00, Room B305

Planning Energy Systems I

Chair: *Bo Hu*, Department of Management, Universität der Bundeswehr München

1 - Optimal control models of renewable energy production under fluctuating supply

Elke Moser, Institute of Mathematical Methods in Economics, Vienna University of Technology, *Dieter Grass*, *Gernot Tragler*, *Alexia Prskawetz*

Climate change and current environmental developments underline the urgency of climate mitigation policies. Since the energy sector is one of the main sources of green-house gas emission, the probably biggest challenge is to find a way to guarantee a low-carbon energy supply. Sustainable alternatives, such as energy gained from renewable sources, already exist, but here technology and policy efforts are not yet sufficient. The major problem is to find a balance between energy security, economic development, and environmental protection. Especially the first aspect exhibits the highest difficulty with renewable energy. It is well known that the supply of renewable energy sources, like wind and solar power, is not at all constant over time. It is subject to seasonal variations and often hardly predictable. Furthermore, storage possibilities in periods of surpluses are limited. To address this issue we consider an economy, in which fossil and/or renewable energy are perfect substitutes, to cover production-related energy demand, given all the advantages and disadvantages of both energy types. The main focus lies on the investigation how prices of fossil fuels can affect the attractiveness of renewable energy and whether a switch towards a more sustainable energy supply is possible. The models themselves are optimal control models with infinite horizon. Due to the inclusion of the fluctuating supply of renewable energy sources, the models are non-autonomous, which makes the problem numerically sophisticated. In a further extension we also investigate a multi-stage approach to determine the optimal switching time from a fossil to an independent renewable energy system given constantly increasing fossil fuel prices.

2 - Investment decisions in electricity markets from the perspective of control theory

Jessica Raasch, Chair for Management Science and Energy Economics, University Duisburg-Essen, *Christoph Weber*

Feeding in renewables into the electricity grid makes not only the residual load more volatile and uncertain but also the decision making for investments in the electricity market gets more complex and even more critical. Due to the fact that signals for investments can easily be misinterpreted the sustainability of the electricity market may be endangered. This problem of possibly noisy scarcity signals and corresponding inadequate investment decisions may be analyzed using concepts of control theory. We take as starting point the peak-load-pricing model which provides an analytically tractable description of long-term equilibria in the power market including prices and the optimal generation mix. We then transform the peak-load-pricing problem into a linear quadratic control problem and therefore to a typical model of control theory. This allows analyzing the stability, efficiency and also robustness of the market development in the presence of various disturbances. The aim thereby is to use concepts of sensitivity (efficiency) and robustness from control theory to analyze the impact of disturbances and misperceptions on electricity market equilibria.

3 - Germany's electricity energy portfolio and its transition: a system dynamics model

Armin Leopold, Department for Computer Science, Universität der Bundeswehr München, *Bo Hu*, *Klaus Arto*, *Stefan Pickl*

Explained the historical development of renewable energy in Germany over the last 20 years, the success story of "green energy' has to be shown to understand Germany's beginning energy transition. Being a core part of the actual electricity economy, renewable energy sources are still discussed and consequently bring new challenges for the interaction with the energy system itself. By modelling essential interactions within the actual electricity system with the help of System Dynamics, the active public should be able to understand the complex interactions. System Dynamics modelling supports the comprehension about the main interdependencies related to the successful market integration of new sustainable technologies, which are essential for Germany's energy transition in the next 20 years. Therefore System Dynamics tries turning on the energy transition process in Germany.

■ WB-17

Wednesday, 11:30 - 13:00, Room F020

Sustainable Networks

Chair: *Karsten Kieckhäfer*, Institute of Automotive Management and Industrial Production, Technische Universität Braunschweig

1 - Selection of Technologies and Capacities for the Recycling of Lithium-Ion Batteries from Electric Vehicles

Claas Hoyer, Institute of Automotive Management and Industrial Production, Technische Universität Braunschweig, *Karsten Kieckhäfer*, *Thomas Spengler*

We present a model supporting strategic investment decisions for the development of recycling networks with uncertain and dynamic product return. The mixed-integer linear optimisation model determines the number of recycling facilities of a certain recycling technology and capacity to be operated over time maximising the net present value of the resulting cash-flows. Decentralisation effects in the collection of products and capacity-dependent economies of scale are balanced by presetting product-specific variable collection costs, declining with an increasing number of collecting facilities. Recover-or-dispose decisions are made trading off additional expenses for required facilities, production factors, material transportation, and revenues for selling recyclables against disposal costs. The model allows for mapping different multi-stage co-production processes, product variants, materials, and material qualities. By explicitly incorporating the material flow, legal minimum recycling quotas can be provided. We analyse the applicability for a real-world planning problem regarding the recycling of lithium-ion batteries from electric vehicles. Therefore, we consider the newly developed LithoRec recycling process, encompassing 3 consecutive technology modules with each 2 capacity classes. Further, 6 variants of the lithium-ion battery technology, 4 intermediate fractions, and 6 different recyclables are regarded. The results show that, despite of high uncertainties which are met by scenarios and sensitivity analysis, valuable information about economically efficient decisions can be gained. One main finding is that the legally demanded recycling quota of 50 percent by weight can be reached highly economically especially if cobalt-based lithium-ion batteries prevail.

2 - Planning a network for biodiesel production of the 2ed generation under ecological and economical aspects

Laura Elisabeth Hombach, School of Business and Economics, Operations Management, RWTH Aachen, *Grit Walther*

The transportation sector is the second largest contributor to world CO2 emissions, and road transportation is with 75% the leading emitter within this sector (IEA 2011). Until 2020 10% of the energy used in the EU transportation sector must originate from renewable energy sources (DIRECTIVE 2009/28/EG (9)). In the short- to mid-term, this can only be fulfilled by utilization of biofuels. Since it is also required that biofuels have to emit at least 35% less CO2 than fossil fuels (DIRECTIVE 2009/28/EG Article 17 (2)), currently used biofuels of the 1st generation will not be sufficient. Thus, 2nd generation biofuels (synthetic biofuels) must be generated and corresponding production capacities have to be built up. Within this contribution, a model for planning of production networks for 2nd generation biofuels (Schatka, 2011) is extended taking economic and ecological criteria into account. Thereby, the objectives of different stakeholders are regarded. First, industrial investors (e.g. oil companies, automotive industry) consider the political requirements as additional restriction in planning of production capacities of (bio-)fuels. Secondly, political decision makers regard emissions as distinct objective besides profit. Thus, legal requirements are established based on the trade-off between profitability and emission reduction. The paper will provide an overview of model extensions with regard to these planning attitudes, and first modeling results will be presented.

3 - Determination Of The Most Suitable Location For Solar Energy Usage In Turkey

Şenim Özgüler, Department of Industrial Engineering, Yildiz Technical University, *Ali Fuat Guneri*

In these days, scientists have focused on renewable energy sources. One of these alternative sources is solar energy. Turkey's geographic location has several advantages for solar energy usage. Due to take place in the sunny belt, the solar energy potential is very high in Turkey. This study aims to determine the most suitable area for using solar energy in Turkey. For this reason, two Multi-Criteria Decision Making methods, AHP (Analytical Hierarchy Process) and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), are applied to select the most convenient area among different alternatives throughout Turkey.

■ WC-16

Wednesday, 14:00 - 15:30, Room B305

Planning Energy Systems II

Chair: *Valentin Bertsch*, Chair of Energy Economics, Karlsruhe Institute of Technology (KIT)

1 - Costs of CO2-Emission Abatement in Power Systems

Felix Müsgens, Chair of Energy Economics, BTU Cottbus

The paper analyzes the costs for CO2 abatement in power systems. We will start with a discussion of short term emission reduction costs and potentials, mainly achieved by shifting generation of existing power plants from hard coal to gas ('fuel switch'). Furthermore, we analyze the situation in the long run when investments in new capacity become necessary. For new power plants, investment costs are variable in addition to short term generation costs. This affects the costs for CO2 abatement. The paper presents a detailed large scale power plant investment and dispatch model (LP). Based on market fundamentals such as fuel prices, existing power plants, investment costs, and electricity demand, the model determines the cost minimal investment path and electricity production. We apply this model to quantify the costs for emission reductions in the short and long run in the German power system. Furthermore, we analyze how variations in input factors such as fuel prices (especially differences between hard coal and natural gas) affect short and long term emission reductions.

2 - Implementing Case-specific Decision Constraints For Linear Optimisation: An Application In Times To Heat And Power Supply In The German Residential Sector

Erik Merkel, KIT-IIP, *Russell McKenna*, *Wolf Fichtner*

The German Federal Government has set ambitious goals for the transformation of energy supply. A large potential for energy efficiency improvement lies in the provision of space heating and domestic hot water in the residential sector. For the assessment of different energy demand and supply options to achieve these objectives, an optimizing energy system model in the TIMES model environment is presented. In the developed model, the integrated analysis of the electricity and heat system allows the investigation of the economic potential of technologies at the interface of both systems over a planning horizon up to 2050, in particular decentralized combined heat and power (CHP) technologies and heat pumps in residential buildings. The coupling of the residential heat system and the electricity system into one model represents a significant methodological development over existing electricity or heat system models. The model is based on linear programming and belongs to the class of integrated power plant capacity and dispatch planning. One common problem with this class of models is the so-called bang-bang behaviour, in which for example small modifications to the constraints result in very different optima, whereby just one technology is exploited across the board. This clearly does not reflect the reality in which technology combinations out of CHP, solar thermal, photovoltaics and heat pumps etc. are often adopted. Hence this paper presents a methodology for implementing case-specific constraints between the decision variables of power plant investment within the standard equation set embedded in TIMES. Applied as capacity-constraints, these restrictions mean that certain demands (for heat and power) can only be met by technology combinations in specific proportions. The results of the developed methodology are contrasted with the model results based on an optimization without such constraints.

3 - Model-based analysis and evaluation of strategies to resolve grid congestions in energy supply systems

Valentin Bertsch, Chair of Energy Economics, Karlsruhe Institute of Technology (KIT), *Christoph Nolden*, *Anke Eßer-Frey*, *Wolf Fichtner*

The promotion of renewable energy sources (RES) and combined heat and power generation leads to an increasing decentralization of energy systems and brings about new challenges. Especially in Germany, the realisation of the ambitious targets concerning the expansion of RES necessitates an extensive structural rearrangement of the system. For instance, large amounts of electricity need to be transported from the North Sea to the large load centres. As a result, the grid load in the system will rise to an extent that is not manageable with the existing grid capacities any longer. In order to be able to carry out sound analyses of the long-term impact of such structural changes on the development of power systems and to derive and evaluate strategies to avoid grid congestions, techno-economic energy system models are needed that allow for the consideration of grid constraints. Therefore, a multi-period linear optimization model is presented, which comprises the system equations for power generation and transmission. Moreover, the model provides a regional capacity expansion planning approach. The model is applied in a scenario-based analysis in order to gain insight into potential grid congestions. Depending on the scenario assumptions, in particular concerning RES and grid expansion, the model shows possible congestions at different locations and different times. Alternative strategies to avoid the congestions are analysed and evaluated using a multi-criteria approach — especially taking into account their costs, effectiveness and feasibility. Finally, possible further developments of model and methodology are discussed.

■ WC-17

Wednesday, 14:00 - 15:30, Room F020

Sustainable Measures

Chair: *Magnus Fröhling*, Institute for Industrial Production (IIP), Karlsruhe Institute of Technology (KIT)

1 - Using Indicators to measure sustainable development based on the petroleum industry

Susanne Lind-Braucher, Institute for Economics, Montanuniversität Leoben, *Vassiliki Theodordiou*

All energy forecasts predict that oil and gas will continue to dominate energy supply for the next decades. To fulfill this demand the use of tertiary recovery and also the production of oil sands, heavy oil and shale gas will be indispensable. Facing the fact that all these production options have a great environmental impact, it would be rather a great challenge for the oil and gas industry to meet the rising demand by acting sustainably. Some companies in this industry have already achieved a leadership position by defining years ago sustainability as a strategic goal. Recent studies try to establish the relationship between ecology and economy and this served as a starting point for a detailed evaluation of the oil and gas industry. The main question to be answered is if there is an industry specific correlation between sustainable acting and economical performance. For this case we carried out an empirical analysis and compare the performance of the overall oil and gas industry performance to this of "sustainable" companies in the industry.'Sustainable' companies were identified based on their inclusion in the Down Jones Sustainability Index (DJSI) about six years (2005 — 2011). The comparison of the performances shows significant relationships between economic performance and sustainable strategy for the industry. The results validate that the general hypothesis that companies with a "green' focus have a steady growth, also applies to the petroleum industry.

2 - Multicriteria decision support for the selection of resource efficiency measures

Eva Burgard, Production and Logistics, Bergische Universität Wuppertal, *Grit Walther*

Scarcity of fossil fuels and of certain resources is considered to be one of the biggest megatrends in the future development. Since the industrial production in Germany strongly depends on the import of these resources, increasing energy and resource efficiency is of strategic importance for the policy makers and especially for companies. Various studies show that there is potential for the reduction of resource and energy consumption within industry. However, existing efficiency measures to exploit this potential are often not sufficiently implemented. Among other reasons, investment decisions are often taken based on short-term results and on monetary criteria only. Thus, aspects like increasing market prices for resources and risk of resource scarcity are not taken into account. Also, conventional investment appraisal methods are not able to show the advantages of efficiency measures, since these aspects are not regarded despite of their strategic relevance. The paper aims to point out the limitations of existing methods for the evaluation of efficiency measures and to develop an extended method. To accomplish this goal, we first carry out a survey of methods for the evaluation of efficiency measures, and show possible disadvantages and recent developments. Secondly, we discuss possibilities to include additional information about scarcity of resources, increasing market prices and other environmental information in an efficiency analysis approach. The approach is applied to a small case study. The results show that the new approach could give interesting insights into the unexplored areas of the evaluation of resource efficiency measures. The goal is not to give one optimal solution but to describe the decision situation and to analyze the inherent trade-offs.

3 - A linear material and energy flow model to assess resource efficiency measures in production and recycling networks

Magnus Fröhling, Institute for Industrial Production (IIP), Karlsruhe Institute of Technology (KIT), *Frank Schwaderer*, *Ana Fernandez*, *Frank Schultmann*

Depending on their characteristics many residues in metal industry can be recycled internally, i.e. within the same process or company, or be recycled externally, i.e. in specialized companies or processes. The recycling enables to regain valuable metals which can be sold to other actors in the metal industries. Thus production and recycling networks are formed. Changes in one process can thereby affect others in terms of raw material and energy demand, quantity and quality of main and by-products as well as emissions. Therefore the assessment of internal and external recycling measures should be made in the context of the linked processes. Further, the question arises, if superior configurations of the whole network can be achieved when residue flows are changed. This requires knowledge about the technological feasibility but also about the economic and ecological effects of such measures. The contribution presents an approach to carry out such assessments and applies it to a representative part of a production and recycling network of the German iron and steel and zinc industry. Using thermodynamic process models the considered process steps are simulated. Multiple linear regression analysis is applied to determine linear transformation functions for the process steps. These are used to build up a linear material and energy flow model formed by a linear set of equations. This model is used to calculate the material and energy flows in automated scenario and sensitivity analyses. The quantitative structure which is obtained from these calculations is assessed with regard to economic and ecological objective criteria. The approach is presented and applied in example scenarios to discuss its opportunities and limitations.

■ WE-16

Wednesday, 17:00 - 18:30, Room B305

Managing Energy Systems

Chair: *Gerhard-Wilhelm Weber*, Institute of Applied Mathematics, Middle East Technical University

1 - Estimation, simulation and tree construction for mid-term thermal power production planning

Raimund Kovacevic, Statistics and Decision Support Systems, University Vienna, *Florentina Paraschiv*, *Florentina Paraschiv*

Dealing with the stochasticity of prices is a key issue in contemporary energy markets and cannot be neglected by the producers of electrical power. We propose a stochastic programming model for mid-term planning which involves mixtures of fuels and the effect of CO2 prices and develop models for related stochastic spot prices. The first goal is to find a joint simulation model for European gas, oil and EUA (emission allowances) spot prices. Given the patterns from descriptive statistics, we apply a Geometrical Brownian Motion with Jump process to this variables. On the other hand, spot electricity prices behave considerably different from other commodities and need a separate modeling approach. We therefore employ a regime switching model taking into account the strong seasonality pattern, as well as the spiking behavior observed in electricity prices. After constructing probability trees from the simulated scenarios we use them to solve one year planning problems for a fictitious configuration of thermal units, optimized against the market.

2 - Integrating small scale distributed energy generation, storage and demand side management in the unit commitment problem

Johann Hurink, Department of Applied Mathematics, University of Twente, *Maurice Bosman*, *Vincent Bakker*, *Albert Molderink*, *Gerard Smit*

In this talk we consider a general energy planning problem as an extension of the Unit Commitment Problem (UCP). Where the UCP focuses on the commitment and the economic dispatch of large electricity generating entities (units), we add small scale distributed generation, distributed storage and demand side management possibilities to this problem. Hereby we shift the focus of the optimization problem towards the decentralization occuring within Smart Grids. The resulting general energy planning problem differs from the UCP in size and in objective. We treat significantly more appliances and use a combination of objectives to include different types of generators and appliances. The general energy planning problem is solved using a hierarchical structure. In the top level next to the large generators of the UCP also large groups of small scale distributed generators are incorporated by considering them as one entity. A more detailed planning for these groups is done in the lower levels of the hierarchical structure. In these levels also the distributed storage and the demand side management options are taken into account. The general framework consists of creating patterns for single entities/appliances, combining patterns for such appliances on higher levels into so-called aggregated patterns, and using these aggregated patterns to solve a global planning problem on the top level. This process is organized in an iterative way. Two different case studies show the applicability of the method.

3 - A Renewable and Sustainable Electricity Planning Model under Uncertainties: A Case Study for Marmara Region of Turkey

Miray Hanım Yıldırım, Scientific Computing, Institute of Applied Mathematics, *Özlem Türker Bayrak*, *Gerhard-Wilhelm Weber*

This paper presents a novel renewable and sustainable electricity planning model for Marmara region of Turkey, which involves uncertainties in renewable energy resources. Sustainability of the model enables to track the changes in supply-demand balance of electricity in time. In addition, the model dynamically maximizes the utilization of renewable energy resources. Marmara is the most densely populated and the most industrialized region of Turkey. As a consequence, the electricity demand is continuously increasing in Marmara while the resources are limited. Hence, modeling a renewable and sustainable electricity plan is very critical. Besides, sustainability of the system does not imply that the renewable energy resources are utilized effectively. Therefore, both renewability and sustainability are addressed in the model. The model restrains fossil fuel consumption by penalizing carbon dioxide emission, hence maximizes utilization of renewable resources. However, the potential of these resources are uncertain. To handle these uncertainties in input parameters, a robust optimization method is used to guarantee a feasible solution dynamically, which ensures the sustainability of the system.

■ WE-17

Wednesday, 17:00 - 18:30, Room F020

Water and Hydrothermal Systems

Chair: *Corinna Dohle*, DS&OR Lab, University Paderborn

1 - A non-convex MICQP model for the optimal usage of water tanks in water supply systems

Corinna Dohle, DS&OR Lab, University Paderborn, *Leena Suhl*

Due to a growing cost pressure for German municipal utilities, optimization of German water supply systems has gained more and more attention in recent years. In addition, the decreasing water consumption in Germany yields a potential for improvements in water supply systems. When the water supply systems were designed, the planners assumed an increasing demand of water in the future. But due to water saving measures the water consumption decreased and therefore a lot of components in water supply systems do not have the right dimension to work efficiently. In summary, the municipal utilities have to decrease their cost and to increase the efficiency of the components of water supply systems. In this paper we focus on the optimization of water tanks in a water supply system. We present a mathematical model which optimizes the dimension of existing tanks and decides the optimal locations for new tanks. This task is subject to different constraints such as satisfying the demand of all clients at each time step, operating within the feasible range of the tanks, providing the necessary amount of water for firefighting and the nonlinear head loss equations to fulfill the hydraulic properties of a water supply system. To model those hydraulic properties we used the Darcy-Weisbach head loss equation which is a quadratic and non-convex function. Due to this equation and the presence of 0-1 variables for the tanks, our model becomes a non-convex MIQCP (Mixed Integer Quadratically Constrained Program). Different approaches to solve the proposed MIQCP are discussed, e.g. the Generalized Benders Decomposition.

2 - Network reduction for water distribution systems as a part of an optimization process

Florian Stapel, Business Information Systems, University of Paderborn

Optimization in water distribution systems has gained more and more attention in the last two decades. Currently, a broad variety of mathematical programming models concerning different aspects as planning tasks or problems of optimal operation are available. Due to aspects such as nonlinear network hydraulics or integer decisions, the mathematical problems can become hard to solve. Additionally, the number of variables and constraints for a specific instance may have a big influence on the solution time or the solvability in general. Therefore, reducing the size of the network model is an important task. Network reduction is applied as a preprocessing step before the generation and solution of the mathematical programming instance. Since all operations are performed on a network model, further difficulties can occur. When considering an optimization model whose solution may introduce changes to the network topology or parameters of aggregated network elements, a matching between the solution vector of the reduction based mathematical program and the non-simplified network model is not trivial. In this talk we will give an overview of existing techniques to simplify water distribution systems, thereby also discussing the problems one is confronted with when separating the network reduction from the mathematical programming model and its solution.

3 - A MILP Based Approach for Hydrothermal Scheduling

Dewan Fayzur Rahman, INESC TEC, *Ana Viana*, *Joao Pedro Pedroso*

Hydrothermal Scheduling aims at minimizing the overall operation cost of thermal units over a given planning horizon while satisfying practical thermal and hydro constraints. Main decision variables are deciding: 1) which thermal generators must be committed in each period of the planning horizon, as well as their production level; and 2) the discharge rates of each hydro generator. The problem is proven to be NP-hard and no exact methods have been able to efficiently solve it, for problem sizes of practical relevance. Therefore, heuristic and metaheuristic techniques have been used to solve them. In this work we explore two algorithms that hybridize MIP solvers with metaheuristics concepts: the so called "Local Branching' (LB) and a hybridization of "Particle Swarm Optimization' (PSO) with a general purpose MIP solver. In both cases the methods are supported by an iterative piecewise linear approximation that for the thermal Unit Commitment has proven to converge to optimality, even for large problems. In this approach the quadratic cost of thermal generators is approximated by a piecewise linear function that is adjusted iteratively as the main optimization problem is solved. The following thermal constraints are included in the model: ramps, minimum up and down times and production limits. For the hydro model the constraints considered are: water continuity constraints (water flow in an earlier time interval affects the discharge capability at a later period of time), hydro units discharge limits, hourly reservoir inflows, reservoir storage balance, and spillage limits. Thorough computational tests show the effectiveness of the approaches.

■ TA-16

Thursday, 9:00 - 10:00, Room B305

Gas Networks I

Chair: *Marc Steinbach*, Inst. for Applied Mathematics, Leibniz University Hannover

1 - Mixed-Integer Nonlinear Optimization of Gas Compressor Stations

Martin Schmidt, Institute of Applied Mathematics, Leibniz Universität Hannover, *Marc Steinbach*

We consider the problem of fuel gas or cost minimization for single gas compressor stations with fixed boundary conditions. Highly nonlinear and nonconvex gas physics and engineering models together with discrete switching of compressor units and drives lead to a mixed-integer nonlinear optimization problem. Because of its practical importance, this problem is frequently addressed in the engineering, optimization and simulation literature. In our talk, we revisit the problem and present mixed-integer nonlinear models for feasibility testing and cost minimization that can be used in industrial environments for mid and long term planning. Numerical experiments for real world compressor stations are given to demonstrate the applicability of our approach.

2 - Capacity determination of gas networks

Bernhard Willert, Institute of Applied Mathematics, Leibniz Universität Hannover, *Martin Schmidt*, *Marc Steinbach*

Recent changes in regulations of the European gas market require the publication of available capacities of gas network flows by network operators. Despite all the physical and technical constraints of gas networks, first and foremost all subsets of booked flows need to be feasible. In its full complexity this task leads to a mixed-integer nonlinear optimization problem with robust characteristics. With the help of small network examples the complexity of the problem is explained and results are presented.

■ TC-16

Thursday, 11:30 - 13:00, Room B305

Energy Storage Systems

Chair: *Stefan Minner*, TUM School of Management, Technische Universität München

1 - Optimizing storage placement in electricity distribution networks

J.m. van den Akker, Information and Computing Sciences, Utrecht University, *S.j. Leemhuis*, *G.a. Bloemhof*

Decentralized power generation may lead to operational problems in electricity distribution networks, such as current overloads and voltages deviations. Storage systems can have a beneficial effect to alleviate these problems. However, these systems are relatively expensive and have not been applied much in electricity grids in Europe. When determining whether storage systems can have a positive in influence on network operation, the cost of long term investments have to be balanced to the short term operational benefits. For this analysis, it is important to determine the optimal storage placement and control in electricity networks. This optimization includes number, locations and sizes of the storage units. To solve this problem, we developed a model, which identifies where storage systems could be placed to maximize benefit, while also providing the optimal storage control strategy. It makes use of a simulated annealing approach to find good storage configurations, with a linear programming model to determine the load and optimal storage control, maintaining all the loadflow constraints. Our model seems to be an interesting approach to solving the storage location problems, and a promising approach to solve other investment problems.

2 - Managing Energy Storages — Lessons from Inventory Theory

Stefan Minner, TUM School of Management, Technische Universität München

The redirection of Energy Policy towards sustainability significantly increases the share of renewable energies but the complexity of matching demand with supply increases due to multiple sources and increasing uncertainty of supply. Increasing the efficiency of energy systems and to account for high fluctuations in energy supply and demand not only requires advances in generation and storage technologies but also in the management of the associated operations processes. Energy storages are a core ingredient of a sustainable energy grid to decouple dynamic and uncertain, highly fluctuating supply of and demand for energy from different sources and at regionally dispersed locations. Where the majority of research is devoted to invent and improve storage technologies, efficiency increases might not only be achieved by enhanced technological capabilities but also by a more effective management of supply and demand. Inventory theory offers a broad spectrum of models, approaches, and methods to manage reservoirs and storages where only few contributions were devoted to energy due to its limited storage ability. The advice and decision support that existing knowledge can provide, and necessities of tailoring models to energy system specialties, will be reviewed and discussed in this presentation. A framework for advanced energy supply chain planning and management will be presented.

3 - Optimal Underground Pumped Hydroelectric Storage Design

Amir José Daou Pulido, Chair of Energy Systems and Energy Economics, Ruhr - Universität Bochum

Optimal design of utility scale energy storage systems has been strongly researched in the last decades. However, there are few studies addressing Underground Pumped Hydroelectric Storage (UPHS). In Germany, UPHS has become an interesting technology for both energy system flexibility and mining sector. We propose an optimization model for UPHS design, i.e., reservoirs, waterways and turbo machinery configuration. The model aims to find the UPHS design that maximizes long-term profit, given a certain power market development scenario.

■ TC-17

Thursday, 11:30 - 13:00, Room F020

Energy Management Systems

Chair: *Milad Ziaeian*, business adminstration, QIAU

1 - Investigating the relationships between Energy management system (EMS) based on ISO 50001 implementation and organization survival

Milad Ziaeian, business adminstration, QIAU, *Reza Kiani Mavi*, *Karim Bahramipour*

ISO has identified energy management as a priority area meriting the development and promotion of International Standards. Effective energy management is a priority focus because of the significant potential to save energy and reduce greenhouse gas (GHG) emissions worldwide. This paper wants to clarify the importance and reflex of energy management and its cost and their parameters on system survival. Regarding Painuly (2009) improving energy efficiency is considered as one of the most desirable and effective short-term measures to address the issue of energy security, and also reduces the emission of greenhouse gases. However in the final cost of factory products, energy cost has its slice. Analysis of questionnaires with SPSS 18 shows that implementing energy management base on ISO 50001 contributes positively to the organization survival and final cost of products.

2 - Heuristics for Extending the Battery's Life in Electric Vehicles

Ron Adany, Computer Science, Bar-Ilan University, *Doron Aurbach*, *Sarit Kraus*

The battery is a key component in any Electric Vehicle (EV) and its method of operation may have a tremendous effect on its life. In this paper our goal is to improve the battery life property, which is greatly affected by the method of use. We decided to focus on the effects of the discharge current. Each battery is a pack of cells designed to be discharged and charged with specific optimal currents, whereby other currents, i.e. higher or lower than the optimal currents, may have negative effects on the life of the battery. We refer to these negative effects as penalties that are aggregate over time and propose a discharge method to minimize them. The common discharge method is very simple but far from optimal. In this method the energy demand is supplied using all cells in the battery simultaneously, so the load is equally divided among them. Since discharge power demands are not constant, there is room for improvement. The method we propose is an advanced switching algorithm, which for each energy demand selects the battery's cells and controls the discharge current from each, based on understanding the electrochemical properties of the individual cells. We evaluated our proposed switching algorithm using simulations on several battery pack configurations, i.e. number of cells, and power demands. The power demands we employed are based on standard driving cycles used in the United States, Europe and Japan for diversified driving behavior including urban, highway, aggressive and low speed city driving. The performances of the proposed algorithm were found to be significantly better than the performances of the common discharge method. As the number of cells increased the aggregate penalty was exponentially reduced and almost totally avoided.

3 - Establishment of the energy management system in Tehran municipality (case study district 7)

Arezoo Farazdaghi, environment, municipality of Tehran and zaminkav reserch center

Using patterns, models and standards of the energy management for systematic directing of the organizations' activities in the area of energy consumptions is the most appropriate, logical and economical technique. In municipality of district 7 is the first district in which the abovementioned management system has been established and administered. Materials and methods:The basis of the work includes the requirements of Iso 50001: 2011 standard, topic 13 and 19 of national regulations of the building. Implementation method: 1-Documentation Including the compilation of all executive methods, instructions, charters and policies of the organization 2-Implementation a)Identification of the energy aspects b)Initial measurement (recording the consumption bills) c)Energy audit Conclusion: •Identification, prioritization, and revision of the evident aspects of the energy •Updating of the equipments for optimization of the energy consumption and promotion of the efficiency 1-Making the powerhouses' system intelligent 2-Installing the solar water heater •Promotion of the awareness and knowledge of personnel at all organizational levels, the organization's objectives for establishment of the energy management system 1-Reducing the costs 2-Reducing the energy 3-Reducing pollution 4-Estimation of the energy saving 5-Identification existing situation 6-Identification of the areas in need measurements

■ TD-16

Thursday, 14:00 - 15:30, Room B305

Demand Side Management

Chair: *Roman Kanala*, University of Geneva

1 - Mixing Behavioral and Technological Data in the Mathematical Programming Framework: the Case of Energy and Environmental Planning

Roman Kanala, University of Geneva, *Emmanuel Fragniere*

Optimisation models for energy environmental planning based on the concept of economic equilibria share a common flaw that stems from their neoclassic roots: hypothesis of a perfect information and hypothesis of perfect economic rationality. While these are well satisfied on the production side, the huge number of decision makers on the demand side, consumers making frequent penny-worth investment decisions with their imperfect information and many irrational preferences are causing the extension of the model beyond its domain of validity every time when modeling demand side management (DSM) in detail. Our method to circumvent this issue consists in soft-linking data from sociological surveys that determine technical coefficients for MARKAL model, the energy and planning model of the IEA, creating a hybrid approach of coupling a deductive engineering model with typical inductive methods of social sciences. Behavioral changes are described as virtual technologies (moderate use and technology switch) with usual technology attributes. In this setting, virtual technologies of behavioral change are triggered by information and marketing campaigns. We illustrate this new method with a case of lighting bulbs, based on a survey done in 2009 just before the administrative ban of incandescence bulbs in Switzerland. Ultimately energy and environment planning models are employed to determine long term sustainable development policies for a region or a country. So the goal of our approach is to build long term policies that are not solely based on technology progresses but also taking into account social change.

2 - Optimal Operation Planning of Home Equipment Considering Power Supply and Demand

Takashi Yamaichi, Department of Information and System Engineering, Faculty of Science and Engineering, Chuo University, *Tomomi Matsui*

March, 11, 2011, East Japan Earthquake brought severe damage to Fukushima Daiichi nuclear power station. After that, there is insufficient power supply at a peak of power demand in Japan. In order to avoid rolling blackouts, we need to shift a demand for power as power demand does not exceed the amount that can be supplied. Japanese electric power industries are underway to secure power supply capacities. We also need to adjust the demand side, such as homes and businesses. A home energy management system will be introduced in a near future which has an ability to control operations related to the power supply and demand. We discuss a problem of optimal operation planning of home equipment including electric vehicle, heat pump and photovoltaic system available at home, under power supply and demand. We formulated the problem as a mixed integer linear programming problem and solved by commercial software.

3 - Optimizing Electrical Vehicle charging cycle to increase efficiency of electrical market participants

Yann Hermans, PRiSM Laboratory - University of Versailles St-Quentin-en-Yvelines, *Sebastien Lannez*, *Bertrand Le Cun*, *Jean-Christophe Passelergue*

Most European electricity markets know the principle of Balanced Responsible Parties (BRP) which are entities in charge of ensuring the energy balance over each settlement period on their balance area. We present one of the many challenging problems that must be solved to increase penetration of Electrical Vehicle (EV) in Smart Grids : the valorization of the storage capacity owned by an Electrical Vehicle Rental Service (EVRS). Our purpose is to present a workable business model in the context of European BRPs, and to describe an industrial optimization tool which conjointly minimizes EV charging cost and increases the revenue of a BRP. Electrical Vehicles are consuming power when they are used to transport people. During transport, the flexibility of the battery is not available for grid services. But when idle, the optimizer can define if the vehicles battery has to be charged for future transport or if it can be used to store energy for different potential future usages (either injection in the grid or transport). The decisions are based on the forecast of vehicles reservation (speculation about the transport service usage) and on the price the BRP is exchanging electricity. We describe two complementary modules. The first one is used on the EVRS side to optimally schedule EV charging cycles and the second one on the BRP side to optimally schedule and dispatch their generation portfolio. An industrial grade proof-of-concept has been built to simulate the behavior of combining the proposed business model and the optimization algorithm. We conclude by an analysis of the economic efficiency of the business model combined with the optimization algorithm.

■ TD-17

Thursday, 14:00 - 15:30, Room F020

Electricity Markets

Chair: *Reinhard Madlener*, Faculty of Business and Economics / E.ON Energy Research Center, RWTH Aachen University

1 - Dynamic Portfolio Optimization for Power Generation Assets

Barbara Glensk, School of Business and Economics, E.ON Energy Research Center, RWTH Aachen University, *Reinhard Madlener*

Proposed by Markowitz, the well-known classical mean-variance approach for portfolio selection considers only single-period investments and so far received very little attention in the context of long-term investment planning. Moreover, this static methodology is inadequate for studying multi-stage investment problems of an investor. Considering dynamic aspects, already Markowitz (1959) mentioned the attractiveness of multi-period portfolio selection problems in the context of portfolio readjustments during the planning horizon. His considerations were related with the use of a utility function based on the consumption of wealth over time, instead of a characterization of only final wealth by its mean and variance. The direct application of the mean-variance model to multi-stage portfolio problems, however, caused many difficulties connected with this model. A number of studies has shown different directions of solving these difficulties and provided suggestions on how the dynamic aspects of portfolio optimization should be considered. One of the suggestions is a reallocation methodology, based on scenario analysis and a tree approach (Mulvey et al., 1997). Specifically, this framework consists of three elements: (1) scenario generation procedure, (2) simulation of policy rule, and (3) optimization module. Moreover, scenario analysis offers an effective and easily understood tool for addressing the stochastic elements in a multi-stage model. The aim and original contribution of this paper is the application of the mentioned methodology to power generation assets, in order to capture the constantly changing values of the economic as well as technical parameters considered when evaluating investment in power plants.

2 - Profit optimization of the cross-border trade between the Nordic and Russian electricity markets

Olga Gore, Electricity market and Power System, Lapeenranta University of Technology, *Satu Viljainen*, *Ari Jantunen*, *Kalevi Kyläheiko*

Europe aims for internal market in electricity. The target is to ensure the efficient use of interconnections, increase in social welfare and electricity price convergence. However, different market designs across Europe may create a threat to the efficiency of market integration. This paper presents results of a case study of the current operational principles of cross-border trade between Russian energy+capacity market and Nord Pool energy-only market. The principles of the physical electricity trading in the Nordic and Russian markets are different. In the Nordic market, electricity is traded only in the day-ahead spot-market. In Russia, the electricity market comprises two elements: the day-ahead spot-market and the capacity market. Even though the electricity price in Nord Pool has been higher that the electricity price in Russian market, electricity flow at the cross-border interconnection has been reduced as a result of the profit maximization task of the cross border trader. In this paper, the optimal strategy of the cross-border trader operating in two markets with different designs will be shown by calculating the optimal electricity flows at different price levels. The results of the study show that integration of energy only and energy+capacity markets may lead to the non optimal use of transmission lines and the emergence of 'dead bands' or price intervals when it is not rational to transmit electricity between the two markets.

3 - Risk Assessment of Electrical Energy Pricing for Turkish Market

Asena Özdemir, Actuarial Sciences, METU Institute of Applied Mathematics, *Sevtap Kestel*, *Kasirga Yildirak*

Sustainable energy production and management has become a crucial part of the every aspect of life in modern societies. Since it is an important mode of energy, electricity market merits have widely been studied all over the world. This article provides an overview of the current and projected energy scene of Turkey by modeling demand curve and supply curve for electricity energy. Moreover; major risk factors are also integrated to the model to construct the true equilibrium model of Turkey by using appropriate econometric model. For pricing of electricity energy, better way to model the spot price is by modeling the underlying aggregate demand and aggregate supply curves separately. Therefore; true pricing model for Turkish energy system in electrical power is studied by using the demand and supply equations. Additionally, the study examines the demand for electrical energy in Turkey, and aims at fitting a model covered significant factors of the demand for electricity and making a demand projection for the period 2012-2020. An econometric model would be estimated for overall Turkey and consumer groups such as industry and households using the time series data for the period of 1983-2011. Moreover; a demand projection for the period 2012-2020 would be carried out by fitting error correction models. Results of this study is expected to provide a basis for further studies in electrical energy sector in Turkey and to introduce an examined model and methodology with the usage of demand and supply analysis in order to find true pricing model with regarding the risk factors which affect production, demand for electricity energy or spot price of electricity energy.

■ FA-16

Friday, 9:00 - 10:00, Room B305

Gas Networks II

Chair: *Marc Steinbach*, Inst. for Applied Mathematics, Leibniz University Hannover

1 - Extending Gas Transmission Networks

Robert Schwarz, Optimization, Zuse Institute Berlin, *Armin Fügenschuh*, *Benjamin Hiller*, *Jesco Humpola*, *Thorsten Koch*, *Jonas Schweiger*

Gas Transmission Networks consist of pipelines and active elements such as valves and compressors. The active elements can be configured to control the flow of gas through the network and regulate the pressure loss. The operator's job is to find a feasible configuration that transports the nominated amounts of flow from the sources to the sinks. Defined as an optimization problem, the operational constraints and physics of gas yield a non-convex mixed integer non-linear program. When a nomination scenario is found to be infeasible, new elements must be built into the network to increase its capacity and flexibility. In principle, every type of element can be built into the network at any position, in a variety of dimensions, resulting in an infinite number of choices. To handle this difficulty, we decompose the problem in three steps as follows: First, various slack models are solved to locate possible bottlenecks of the network. From the solutions of the slack models, a set of extension candidates is generated. Finally, a cost-optimal subset of extension is selected among those that enable the previously infeasible nomination scenario.

2 - Solving sparse KKT systems in operative planning gas networks

Djamal Oucherif, Institut für Angewandte Mathematik, Leibniz Universität Hannover, *Marc Steinbach*

The operative planning of large gas networks containing pipes, valves and compressors is very complex. The operative cost should be as low as possible while a multitude of physical, technical and contractual constraints must be satisfied. Mathematical models and algorithms for solving such optimization problems lead to very large and highly structured KKT systems. We develop a specialized, structure exploiting algorithm to solve the arising KKT systems as fast as possible with sufficient accuracy. The sparsity structure of the KKT system stems from different types of constraints, namely local constraints, which must be satisfied for a single timestep, the dynamics, coupling successive timesteps, and global constraints, coupling variables from possibly all timesteps. The algorithm successively removes timesteps from the KKT system by performing projections with near-minimal fill-in. Finally, a small dense system is solved. The exploitation of structure is independent of the gas network under consideration. However, the algorithm can possibly be improved by analyzing the specific gas network.

FINANCIAL MODELING, BANKING AND INSURANCE

■ WB-12

Wednesday, 11:30 - 13:00, Room F023

Risk Analysis

Chair: *Ashok Banerjee*, Finance & Control, IIM Calcutta

1 - Vector Risk Functions

Raquel Balbás, Actuarial and Financial Economics, University Complutense of Madrid, *Alejandro Balbás*

The paper introduces a new notion of vector risk function, crucial concept in Actuarial and Financial Mathematics. Both deviations and expectation bounded or coherent risk measures are defined. The relationships with both scalar and vector risk functions of previous literature are discussed, and it is pointed out that this new approach seems to appropriately integrate several preceding points of view. The framework of the study is the general setting of Banach lattices and Bochner integrable vector?valued random variables. Sub?gradient linked representation theorems are provided. Dynamic risk measures may be a particular case of our vector risk functions.

2 - Measuring Risk in Risk Factor Models

Steffi Höse, TU Dresden, *Stefan Huschens*

The main results of this paper are monotonicity statements about the risk measures value-at-risk (VaR) and tail value-at-risk (TVaR) with respect to the parameters of single and multi risk factor models, which are standard models for the quantification of credit and insurance risk. In the context of single risk factor models, non-Gaussian distributed latent risk factors are allowed. It is shown that the TVaR increases with increasing claim amounts, probabilities of claims and correlations, whereas the VaR is in general not monotone in the correlation parameters.

3 - Impact of information arrival on volatility of intraday stock returns

Ashok Banerjee, Finance & Control, IIM Calcutta

In this empirical study we have considered the impact of information flow on the volatility of a particular stock using high frequency return and news data on the Eurostoxx 50 market. In addition to using volume as a proxy for information flow, we have included company specific announcements, to the conditional variance of the Generalized Autoregressive Conditional Heteroscedastic model (GARCH). For this purpose we have constructed five measures of the impact of public information flow in the market transforming commonly available news scores through different techniques such as linear and exponential decreasing weight, impact function etc. We have analyzed the behaviour of volatility, estimated by squared returns for the next 4 hours after arrival of a non overlapping news, having a significant impact on the firm's stock return. A significant impact of the information flow accessed by the news score coefficient is observed for majority of in our analysis. Furthermore, the inclusion of the news scores variable improves the overall model in the sense that it increases the likelihood value of the model. However we do not observe any significant change in the volatility persistence due to inclusion of our news variable.

■ WC-12

Wednesday, 14:00 - 15:30, Room F023

Pricing and Design of Financial Instruments

Chair: *Rouven Wiegard*, Institut für Wirtschaftsinformatik, Leibniz Universität Hannover

1 - An Efficient Method for Option Pricing with Finite Elements: An Endogenous Element Length Approach

Tomoya Horiuchi, Business Design and Management, Graduate School of Waseda University, *Kei Takahashi*, *Takahiro Ohno*

This paper proposes an efficient method of finite element method (FEM) in option pricing without reducing the accuracy. In option pricing, numerical analytical approaches of partial differential equation (PDE) such as FEM or finite difference method (FDM) are mainly used. However, these methods have a drawback that the actual computation time becomes longer exponentially as the dimension of the PDE increases. Due to recent developments of multi-dimensional options, it is necessary for these methods to reduce the computation time. In this study, we provide the endogenous method that determines element lengths from the curvature of the PDE in order to improve the computational performance. Although there are many studies on option pricing using FEM, they use a priori determined element lengths. Therefore, attempting in various combinations of element lengths is needed to gain more precise solutions. Our method consists of two algorithms, element length expanding and redivision algorithms. By using these two algorithms, the model endogenously makes the element length larger if the curvature of the local analytical domain is low, and smaller if that is high at each time step. In this study, we apply this method to one-dimensional options in order to investigate how much the experiment time is reduced. We employ an up-and-out call option which has high curvature around the strike price and the barrier so that the efficiency of our method can be measured. In the numerical experiments, the accuracy of our method is compared to the Feynman-Kac solution in European options, and to the FDM solution in American options. As a result, we found that this method is able to reduce the experiment time while the accuracy remains at the comparable level.

2 - Near Term Investment Decision Support for Currency Options

Rouven Wiegard, Institut für Wirtschaftsinformatik, Leibniz Universität Hannover, *Cornelius Köpp*, *Hans-Jörg von Mettenheim*, *Michael H. Breitner*

Currency options on a future confer the right but not the obligation to trade the underlying currency future at a pre-agreed price (the strike). Most currency options trade over-the-counter (OTC). That means that they do not follow standard rules for option contracts. They can, in principle, have arbitrary maturities, strike prices, and volume. Valuing OTC options is complex and various models have been developed for that task. Here, we present a Decision Support System (DSS) that helps in gauging the probable price of a curreny option within the next thirty minutes. The forecast horizon is continuous and also an input to the model. We train an artificial neural network on past price data, using tick prices of option and underlying future of the past two hours. Fuzzy coding of time-points increases the robustness of our model. Error on the out-of-sample data set is small. Interestingly, we do not need additional data to obtain satisfactory results. The tick data time series of option and future prices contains enough information to lead to a good forecast. Especially, we do not use volatility or interest rate data. The neural network is, in most cases, able to correctly forecast the main troughs and peaks of the following thiry minutes. An ensemble of neural networks further smoothes the result. Our DSS is useful for both sellers and buyers of options. Sellers get a tool that is calibrated on the latest market data. Buyers can judge, whether they should hedge their risks now or rather wait a short amount of time.

3 - Planning your Life Ahead

Nikolaos Frangos, Statistics, Athens University of Economics, *Irini Dimitriyadis*

Longevity is one of the most important issues in planning for the future concerning both the customer (insured) as well as the provider (insurer). The risk to both parties is becoming insolvent;the insured may not have enough money to live well at late ages, while the insurer may not be able to meet his liabilities. The aim of the study is to discuss important aspects of modelling longevity as well as ways of utilizing the information so that "wellbeing" is guaranteed. This involves the accumulation of pension funds, the design and use of annuities and alternative spending instruments at retirement, as well as health caring for the elderly. We are using besides actuarial techniques, financial modelling, scenario analyses and optimisation techniques.

■ WE-12

Wednesday, 17:00 - 18:30, Room F023

Finance and Banking

Chair: *Daniel Roesch*, Institute of Banking and Finance, Leibniz University Hannover

1 - Optimal Liquidity Execution using Multi-Stage Stochastic Programming

Helgard Raubenheimer, Centre for BMI, North-West University, *Fanie (SE) Terblanche*, *Machiel Kruger*

The new Basel III framework sets out higher and better-quality capital, better risk coverage, the introduction of a leverage ratio as a backstop to the risk-based requirement, measures to promote the buildup of capital that can be drawn down in periods of stress, and the introduction of two global liquidity standards. These liquidity standards focuses on testing the short- and long- term solvency of banks, namely the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR). The fundamental characteristics of high quality liquid assets are: low credit and market risk; ease and certainty of valuation; low correlation with risky assets; and listed in a developed and recognized exchange. Apart from managing a dedicated portfolio of these high quality liquid assets and attaining short-term (LCR) and long-term (NSFR) liquidity ratios of above 100%, banks must also consider strategizing its response to liquidity crisis in advance, including a plan for liquidity execution. We propose a stochastic programming model incorporating uncertainty for resource allocation to optimize the liquidity execution across stages. We model the uncertainty in terms of scenario trees and include the following sources of randomness: cost, "market depth" and liquidity stress. We will discuss our formulation and implementation of a multi-stage stochastic programming model incorporating uncertainty that minimizes the cost of the liquidity execution.

2 - Ratings based capital adequacy for securitizations

Daniel Roesch, Institute of Banking and Finance, Leibniz University Hannover, *Kristina Alexandra Lützenkirchen*, *Harald Scheule*

This paper develops a framework to measure the exposure to systematic risk of asset securitizations. The paper measures empirically whether current ratings-based rules for regulatory capital of securitization reflect this exposure. The analysis is based on US data for asset securitizations for the time period between 2000 and 2008. The paper finds that the shortfall of regulatory capital during the Global Financial Crisis is strongly related to ratings. The paper shows empirically that insufficient capital is allocated to tranches with the highest rating. The problem is exacerbated by the fact that these tranches account for the greatest part of the total issuance volumes. Furthermore, this paper is the first to calibrate risk weights which provide sufficient capital charges to cover the exposure during economic downturns. These policy-relevant findings suggest a re-calibration of RBA risk weights and may contribute to the current efforts to re-establish sustainable securitization markets.

3 - The Valuation of Systematic Risk in Credit Default Swap Spreads

Sebastian Löhr, Institut für Banken und Finanzierung, Leibniz Universität Hannover, *Daniel Roesch*, *Arndt Claußen*, *Harald Scheule*

Using quoted market spreads on credit default swaps (CDS), we investigate the determinants of CDS spread changes. Variables that should in theory determine CDS spreads have rather limited explanatory power since systematic risk factors remain mostly unconsidered. Our paper addresses explicitly such common risk factors driving credit spreads cross-sectionally. In a two-pass regression procedure we consider several macroeconomic and financial variables as candidate proxies to explain common systematic components. Our results demonstrate that both daily and weekly credit spread changes are principally driven by macroeconomic components that are independent of idiosyncratic credit-risk factors. Eventually, we mainly identify two systematic risk factors simultaneously affecting the pricing of CDS.

■ TC-12

Thursday, 11:30 - 13:00, Room F023

Portfolio Management

Chair: *Maximilian Wimmer*, Department of Finance, University of Regensburg

1 - About the existence of good deals in capital markets: Theoretical and empirical approaches

Beatriz Balbas, Finance and Economic Analysis, University of Castilla-La Mancha

Classical Portfolio Choice Theory may be extended so as to involve Generalized Sharpe Ratios, i.e., risk/return ratios such that the role of the standard deviation is played by a Coherent Measure of Risk. Surprisingly, if one deals with a Complete Pricing Model (Black and Scholes, some Stochastic Volatility Models, etc.), then for every Coherent and Expectation Bounded Risk Measure (DPT, CVaR, Wang, etc.) the Sharpe ratio is unbounded and cannot be optimized. In other words, the Sharpe ratio may become as large as desired, and it clearly outperforms the Market Portfolio Sharpe ratio. This paper deals with this paradox, some possible theoretical solutions to this caveat, and the empirical performance of those sequences of portfolios whose Sharpe ratio tends to infinite.

2 - Multi-Asset Portfolio Optimization and Out-of-Sample Performance: An Evaluation of Black-Litterman, Mean Variance and Naïve Diversification Approaches

Dominik Wolff, Justus-Liebig-Universität, Gießen, *Wolfgang Bessler*

The Black-Litterman (BL) model aims to enhance asset allocation decisions by overcoming the weaknesses often experienced with standard mean-variance (MV) portfolio optimization. In this study we implement the BL model in a multi-asset portfolio context. Using an investment universe of global stock indices, bonds, and commodities, we empirically test the out-of-sample portfolio performance of BL optimized portfolios and compare the results to mean-variance (MV), minimum-variance, and naïve diversified portfolios (1/N-rule) for the period from January 1993 to December 2011. We find that BL optimized portfolios perform better than MV and naïve diversified portfolios in terms of out-of-sample Sharpe ratios even after controlling for different levels of risk aversion, realistic investment constraints, and transaction costs. Interestingly, the BL approach is well suited to alleviate most of the shortcomings of MV optimization. The resulting portfolios are less risky, provide a higher level of diversification across asset classes, and exhibit less extreme asset allocations. Sensitivity analyses indicate that the outperformance of the BL model is due to the consideration of additional information on the reliability of return estimates and a lower portfolio turnover.

3 - Computing the Nondominated Surface in Tri-criterion Portfolio Selection

Maximilian Wimmer, Department of Finance, University of Regensburg

Computing the nondominated set of a multiple objective linear program has long been a topic in multiple criteria decision making. In this paper, motivated by the desire to extend Markowitz portfolio selection to an additional linear criterion (dividends, liquidity, sustainability, etc.), we demonstrate an exact method for computing the nondominated set of a tri-criterion program that is all linear except for the fact that one of its objectives is to minimize a convex quadratic function. With the nondominated set of the resulting quad-lin-lin program being a surface composed of curved platelets, a multi-parametric algorithm is devised for computing the platelets so that they can be graphed precisely. In this way, graphs of the tri-criterion nondominated surface can be displayed so that, as in traditional portfolio selection, a most preferred portfolio can be selected while in full view of all other contenders for optimality. Finally, by giving an example for socially responsible investors, we demonstrate that our algorithm outperforms standard portfolio strategies for multi-criterial decision makers.

GAME THEORY AND EXPERIMENTAL ECONOMICS

■ WE-10

Wednesday, 17:00 - 18:30, Room F025

Experimental Games

Chair: *Ulrike Leopold-Wildburger*, Statistics and Operations Research, Karl-Franzens-University

1 - To Choose or Not to Choose: Contracts, Reference Points, Reciprocity, and Signaling

Mathias Erlei, Institut für Wirtschaftswissenschaft, Abteilung für Volkswirtschaftslehre, TU Clausthal, *Christian Reinhold*

Hart and Moore (2008) argue that varying degrees of flexibility in contracts induce differing reference points and aspiration levels for parties' shares of a transaction's total surplus. As a consequence, a trade?off between adaptational flexibility and the prevention of distributional conflicts emerges. In a recent paper, Fehr et al. (2011) analyze a buyer-seller- relationship with incomplete contracts and ex ante uncertainty regarding the sellers' cost level to test these effects. We re-run their experiment and introduce another treatment with exogenously determined contract types. Like FHZ we find reference point effects in both treatments. However, uncooperative shading behavior in our treatments differs substantially from that described in FHZ. Furthermore, it makes a significant difference whether contract types are determined by buyers or determined exogenously. We explain this by introducing two further effects, a reciprocity effect and a signaling effect.

2 - Bounded Rationality in Principal-Agent Relationships

Heike Schenk-Mathes, Institut für Wirtschaftswissenschaft, Technische Universität Clausthal, *Mathias Erlei*

The moral hazard problem in principal-agent relationships has received much attention in applied microeconomics, in topics such as labor economics, insurance economics, organizational design, and managerial accounting. Therefore, empirical studies are necessary to confirm the theoretical results. Unfortunately, field data (such as payment schemes for managers) are rarely available, and real-world contract design is much more complex than theoretical principal-agent models. Furthermore, it is impossible to control for all variables. Laboratory experiments are a more appropriate means of testing theoretical predictions. Previous experiments show that individuals often deviate from the predictions of standard principal-agent theory and that actual behavior in experiments is sometimes better explained by fairness norms and reciprocity than by standard theory. Our objective is to determine whether bounded rationality provides an even better explanation of the experimental data. We conducted six treatments of a standard moral hazard experiment with hidden action. All treatments had identical Nash equilibria. However, the behavior in all treatments and periods was inconsistent with established agency theory (Nash equilibrium). In the early periods of the experiment, behavior differed significantly between treatments. This difference largely vanished in the final periods. We used logit equilibrium (LE) as a device to grasp boundedly rational behavior and found the following: (1) LE predictions are much closer to subjects' behavior in the laboratory; (2) LE probabilities of choosing between strategies and experimental behavior show remarkably similar patterns; and (3) profit-maximizing contract offers according to the LE are close to those derived from regressions.

3 - The opportunity for bribes and the willingness to whistle blow — an experimental study on negotioations.

Ulrike Leopold-Wildburger, Statistics and Operations Research, Karl-Franzens-University

The following experimental study of a contract award with the possibility of corruption is based on different aspects and ideas of the described experiments in the papers of Abbink et al. (2000), Abbink (2002), Abbink et al. (2002), Buchner et al. (2008), Apesteguia et al. (2007) and Berentsen et al. (2008). The developed contract award respectively the final acceptance of a bid allows the study of the willingness of bribery and corruption, using different detection probabilities and the analysis of leniency as a preventive measure to combat corruption for the first time. The data analysis of the contract study part clearly shows that the majority of subjects declines dishonest or corrupt behavior. However, there are quite a numer of participants using the possibility of corruption. We run different treatments: (a) variation of the probability of dedection. (b) variation of partners: partner design and stranger design.(c) additional the possibility for whistle blowing. The study of different detection probabilities shows that with increasing detection probability the number of dishonest offers respectively the number of corrupt agents decreases. The data analysis of examining the willingness to whistle blow the corrupt partner shows that the vast majority of detected negotiators makes use of the leniency. Furthermore the data obtained indicates that the leniency leads to more honesty the bribe offers are higher. Thus it can be concluded that the willingness to accept the leniency is very high. A connection between testimony and whistle blowing of the corrupt partner and criminal reduction is evident. In summary the leniency can be confirmed based on the analyzed data as an appropriate means to combat corruption. However, it was also noted that the leniency program due to the subsequent possibility of a penalty reduction leads to higher amounts in bribes at contract awards.

■ TC-10

Thursday, 11:30 - 13:00, Room F025

Applied Game Theory

Chair: *Francesc Carreras*, Applied Mathematics II, Technical University of Catalonia

1 - Does SFE correspond to expected behavior in the uniform price auction?

Alexander Vasin, Operations Research, Lomonosov Moscow State University, *Marina Dolmatova*

An important feature of electricity markets is demand uncertainty. Reasons for it are random changes of environment and variations of the demand within a day for which bids are submitted. Klemperer, Meyer (1989) propose a promising auction model for this case. The authors assume a bid of a producer to be a monotone smooth function and a demand function to depend on a random parameter. For each peremeter value the cut-off price is determined as equalizing aggregate supply function and current demand function. A bid profile is a supply function equilibrium (SFE) if it induces Nash equilibrium for each parameter value. SFE price is always less than Cournot oligopoly price. For some cases, the price reduction is considerable (Newbery, 1998), so the supply function auction model predicts market power reduction. However, computation of SFE bids is rather sophisticated mathematical problem. In general, its solution requires full information on the demand function and cost functions of all competitors. Why should one expect that actual behavior at the auction corresponds to this concept? The answer to a similar question for Nash equilibria of normal form games is given in the framework of adaptive and learning mechanisms' investigation. We consider best reply dynamics for the repeated auction game for two variants of a symmetric oligopoly with a linear demand function: 1) with linear marginal cost, 2) with constant marginal cost and capacity constraint. We show that in the first case it converges to the SFE with a geometric rate. However, in the second case the best reply may not exist at some step, and the dynamics does not converge to SFE in general.

2 - Two-stage Market with a Random Factor

Ekaterina Daylova, Lomonosov Moscow State University, *Alexander Vasin*

Large electricity producers have the ability to affect the market price and they take this ability into account choosing their strategies. This causes a deviation from the competitive equilibrium and leads to higher market prices, a decrease of total output, a reduction of social welfare and its redistribution to the benefit of producers and to the detriment of consumers. We consider the issue of increasing the efficiency of the electricity market with the purpose of minimizing the ability of deviation from the optimal market state. Standard measures of antitrust regulation (such as splitting the generating sector into smaller companies) are not always justified; therefore, we investigate the introduction of forward market as an alternative way to reduce market power. We construct and examine a two-stage model of the market, taking into account the presence of arbitrageurs. A symmetric oligopoly with a fixed marginal cost is considered as a market structure. Each consumer is described with a reserve price and a parameter of risk attitude. The main contribution is a consideration of a random factor that affects the outcome in the spot market. We determine agents' strategies that correspond to the subgame perfect equilibrium depending on the parameters of the model. We compare the subgame perfect equilibrium with the Nash equilibrium of a one-stage model. The results show that market power decreases with the growth of the probability of the outcome with a low spot price and the fraction of risk preferring consumers. Thus we reveal a dependence of producers' market power on the parameters of the model.

3 - A new allocation method for simple bargaining problems: the Shapley rule

Francesc Carreras, Applied Mathematics II, Technical University of Catalonia, *Guillermo Owen*

A cooperative game in a given finite set of players is defined by its characteristic function, which describes the utility that each coalition of players can obtain, if all its members cooperate, independently of the remaining players' behaviour. The Shapley value is a sharing rule for cooperative games, characterized by nice axioms. It implicitly assumes that all players will cooperate, and allocates the utility of the grand coalition efficiently. It takes into account the strategic strength of all players, since the payoff received by each player is a weighted sum of all his marginal contributions in the game. This gives to the value a great sensitivity in front of data changes. The proportional rule applies to simple bargaining problems, where only the total utility and the individual utilities are given. It allocates the total utility "proportionally' to the individual ones. Of course, the sum of individual utilities must not vanish. We will contrast the proportional rule and the Shapley value as allocation methods for simple bargaining problems, the natural framework of the proportional rule. First, each such problem is identified as a quasi-additive cooperative game, and this makes possible to translate the Shapley value to simple bargaining problems, thus getting what we call the Shapley rule. This new rule is given different axiomatic characterizations. It is also shown that the Shapley rule is completely free of a series of strong failures of the proportional rule, of both theoretical and practical nature (for example, in related cost-saving problems and added costs problems). Then, the Shapley rule should replace the proportional rule in all simple bargaining problems.

■ TD-10

Thursday, 14:00 - 15:30, Room F025

Dynamic Processes in Economic Games

Chair: *Kensaku Kikuta*, School of Business Administration, University of Hyogo

1 - Learning in Highly Polarized Conflicts

Sigifredo Laengle, Department of Management Control, University of Chile, *Gino Loyola*

Negotiations are often conducted in highly polarized environments, which are also uncertain and dynamic. However, the intense rivalry involved in these conflicts does not always prevent an agreement from being reached. A recently proposed static model sets out the conditions under which either an agreement is achieved or negotiations break down in this environment (Laengle and Loyola, Optim Lett, 2011, in print). Nevertheless, important aspects related to partial mutual knowledge of players in a dynamic context are not yet been studied. To fill this gap, we develop an extension of the static game to modelling highly polarized conflicts in an uncertain, asymmetric and dynamic environment. In this extension both parties bargain multiple negotiation rounds under uncertain threats that are materialised only if an agreement is not reached. If a negotiation breakdown occurs, each party learns about these threats from the outcome observed in the previous round. This paper presents the most important results, and a short discussion about possible applications. In particular, we provide the conditions that characterise different paths for negotiations held under polarized environments, which matches the observed evolution of many of these conflicts in the real world.

2 - Communication Leading to Coalition Nash Equilibrium

Takashi Matsuhisa, Department of Natural Science, Ibaraki National College of Technology

The purpose of this paper is to introduce the concept of coalition Nash equilibrium of a strategic game, and to show that a communication among the players in a coalition leads to the equilibrium through messages. A coalition Nash equilibrium for a strategic game consists of (1) a subset S of players, (2) independent mixed strategies for each member of S, (3) the conjecture of the actions for the other players not in S with the condition that each member of S maximises his/her expected payoff according to the product of all mixed strategies for S and the other players' conjecture. This paper stands on the Bayesian point of view as follows: The players start with the same prior distribution on a state-space. In addition they have private information which is given by a partition of the state space. Each player in a coalition S predicts the other players' actions as the posterior of the others' actions given his/her information. He/she communicates privately their beliefs about the other players' actions through messages among all members in S according to the communication network in S, which message is information about his/her individual conjecture about the others' actions. The recipients update their belief by the messages. Precisely, at every stage each player communicates privately not only his/her belief about the others' actions but also his/her rationality as messages according to a protocol and then the recipient updates their private information and revises her/his prediction. In this circumstance, we can show that the predictions of the players in a coalition S regarding the future beliefs converge in the long run, which lead to a coalition Nash equilibrium for the strategic game.

3 - A merger of search games on a finite graph

Kensaku Kikuta, School of Business Administration, University of Hyogo

Suppose there are optimization problems which have the same structure and parameters of which are different partly. Decision-makers for these problems may agree to consider a problem jointly which is obtained by merging those problems. If optimization problems are to minimize costs, decision-makers may get some saving of the cost by comparing the optimal cost for the merger with the sum of optimal costs for original problems. If optimization problems are to maximize profits, decision-makers may get some surplus. In these case, the merger is meaningful. Then the decision-makers consider a redistribution of the saving or the surplus among them. To determine a redistribution, they may apply cooperative game theory. In this report, optimization problems are search games on a finite and connected graph with traveling and examination costs. That is, a finite number of search games are played on the same graph. We try to construct a merger of those games. Each of search games is as follows. A player, called the hider, hides an immobile object at a node in a finite and connected graph. Another player, called the searcher, searches the object, traveling along edges. When the searcher examines a node, there is the examination cost. When the searcher is moving along edges, there are traveling costs. Before starting a search, the searcher needs to determine an order of nodes, in which he searches, so that total expected costs for search become smaller. We see that the resulting cooperative game have a nonempty core.

HEALTH CARE MANAGEMENT

■ TA-08

Thursday, 9:00 - 10:00, Room F018

Risk Management

Chair: *Axel Focke*, Faculty of Health Management, Hochschule Neu-Ulm, University of Applied Sciences

1 - A new iterative method for the ambulance location problem using the vector assignment p-median problem and the Markov chain model

Takehiro Furuta, Nara University of Education, *Keisuke Inakawa*, *Atsuo Suzuki*

We provide a new iterative method to obtain the optimum locations of ambulances. The most important characteristics of ambulance systems is that the ambulance could not be necessarily dispatched from the closest station to the patient who make the emergency call if the ambulances in the closest station are all in use. We utilize the vector assignment p-median problem (VAPMP, Weaver and Church 1985) to implement the characteristic in our model. In the model, each demand has a vector of assignments in which the k-th element of the vector is the amount of assignments to the k-th closest facility. We need to estimate the relative frequency of the assignment of demands to the k-th closest facility. However, it is not straightforward, because the relative frequency depends on the location of ambulances. When we solve the model using an estimated relative frequency, the number of assigned demands of each location of ambulances could be changed, and as the result, the relative frequency could also be changed. So we need to resort to an iterative method. Our method iterates the following two steps: the first step is to solve the VAPMP under a given relative frequency and the second step is to simulate the ambulance system using the Markov chain model to reestimate the relative frequency. The effectiveness of the method is demonstrated by numerical experiments in which the actual ambulance call data of Seto city in Japan is used.

2 - The Evaluation of Risk in Pharmaceutical Research

Anne-Marie Maleena, oxford, *John Gittins*

Our aims with this research are to describe current methods of risk evaluation in pharmaceutical research, compare them with two proposed new methods, and to implement suitable methods in our new software which has been created to evaluate risk in drug research. We first provide a review of recent articles written on risk evaluation in pharmaceutical research. We then propose two new risk measures, state and prove a relevant lemma, and then show how they can be utilized, demonstrating with examples. Using numerical simulations as well as analytical assays, we found that our two new risk measures provide information over and above what is given by current risk measures. In our opinion, none of the current risk measures service pharmaceutical research planning objectives sufficiently. Our two new risk measures ameliorate this problem by providing additional insights into the financial risk of a drug project in a transparent, accurate, consistent, and specific way. Our future work will explore these measures in even greater depth.

■ TD-08

Thursday, 14:00 - 15:30, Room F018

Location/Allocation of Health Care Facilities

Chair: *Walter Gutjahr*, Department of Statistics and Decision Support Systems, University of Vienna

1 - A Multi-Period Location Planning Approach for Medical Facilities

Sven Müller, Institute for Transport Economics, Universität Hamburg, *Knut Haase*

Due to the act "Landarzt-Gesetz" that has come into effect in Germany since january 2012, there is an immediate need for approaches that support decision making in terms of locating physicians — particularly in rural areas. This act envisions the location planning for general practitioners and medical specialists by authorized certification committees. Hence, in the near future physicians are not free to choose the location of their medical practice. Therefore, we propose a multi-period facility location model. The objective of our mixed integer program is to minimize (i) the periodised fixed locational cost (including subsidies in order to enhance the willingness of the physicians to locate in rural areas), (ii) the transport cost of patients, and (iii) the opportunity cost of patients due to potential latency of appointments. In each period the locations of general practitioners and medical specialists are planned such that the capacities of the facilities are met and that each demand point (containing the population) is assigned to at least one general practitioner and medical specialist. If the total demand at a facility exceeds a certain level, waiting times for appointments occur. Because of our objective function, there is a tradeoff between transport cost and opportunity cost due to latency of appointments in terms of the assignment of demand points to facilities: It might be cost efficient to assign a certain demand point to a facility that is located more distant but the waiting time for an appointment is lower at this facility. This tradeoff is verified by several empirical studies on physician choice of patients. We present the results of a case study of the state Saxony, Germany. An application to Germany as a whole is intended for the near future.

2 - Capacitated Blood Bank Location Model with Emergency Referral and Limited Traveled Distance

Phongchai Jittamai, School of Industrial Engineering, Suranaree University of Technology

Regionalization of local blood banks (LBBs) has been found to be beneficial in the blood management system. LBB is vital for blood supply to hospitals and clinics in the responsible area to fulfill demands in both normal and emergency cases. Determining locations of LBBs is a strategic decision-making in the blood supply chain. Poor location decision may lead to an excessive cost and an increase in mortality rate. This study also focuses on an analysis for blood supply management based on emergency or disaster basis. In this study, we develop a mathematical model to solve the location problem in regionalization of blood bank services. The model is extended from the p-median problem. Two additional conditions, emergency referral and capacity of each LBB, representing the real-world problem are constrained in the model. The objective of the problem is to minimize three major costs, fixed costs of LBBs, periodic delivery costs, and emergency referral deliver costs. The model is formulated based on the assumptions that (i) the travelled distance for both periodic delivery and emergency referral may not exceed the maximum distance specified in the problem, and (ii) each hospital is allowed to acquire blood from only one LBB. The model is verified and solved using the data from Regional Blood Center V of the Thai Red Cross Society. Data are composed of weekly blood demands, the number of emergency referral, fixed cost, delivery cost per unit distance and shortest path from 93 hospitals in the area. Computational results are reported. The number of LBBs is determined and locations of LBB are solved in such a way that the total cost is minimized. 22 hospitals are selected as LBBs and the maximum distance from the hospital to the LBB is 45 kilometer.

3 - Locating volunteer fire departments in an urban region

Dirk Degel, Faculty of Management and Economics, Ruhr University Bochum, *Brigitte Werners*

Timeliness is one of the most important objectives to reflect the quality of emergency services such as firefighting systems. Timeliness means that in most instances the place of an emergency can be reached within a predefined time limit after reception of the emergency call. A sufficient number of firefighting facilities must be established and located to provide high quality services over a wide area with spatially distributed demands. In order to optimize the locations for these facilities different criteria are taken into account. Minimizing the average travel time and minimizing the maximum travel time are goals, which are in conflict with minimizing costs. Due to historical developments and growing cities the present location of the volunteer fire departments can be suboptimal with respect to costs and availability. Here, a mixed-integer linear program is presented to investigate the consequences of partial relocating or closing several volunteer fire departments. Multi-criteria optimization methods are applied and different solutions for an urban area with several volunteer firefighting departments are investigated. The tradeoff between maximizing the quality of emergency services and cost reduction is illustrated using a real world case study with 18 existing volunteer fire departments.

■ FA-08

Friday, 9:00 - 10:00, Room F018

Multiobjective Decision Making in Health Care Management

Chair: *Katja Schimmelpfeng*, Lehrstuhl für Beschaffung und Produktion, Universität Hohenheim

1 - A Three-Objective Optimization Approach to Cost Effectiveness Analysis Under Uncertainty

Walter Gutjahr, Department of Statistics and Decision Support Systems, University of Vienna

The paper provides an approach to the selection of a set of healthcare programmes based on cost and effect information estimates (the later being expressed, e.g., in quality-adjusted life years, QALYs), where it is assumed that both the cost and the effect are subject to uncertainty that can be represented by a stochastic model. The decision maker is assumed as risk-averse, but it is argued in the paper why in many cases, risk aversion in public health will only refer to total cost but not to total effect. Under this assumption, a recent theoretical stochastic-dominance result is used to show that in the obtained multi-objective stochastic optimization model, the random variables for cost and for effect can be suitably decoupled even in the presence of stochastic dependence. Extending a mean-risk model (as usual in financial portfolio optimization) for the cost objective by the addition of the effect objective, we arrive at a three-objective mean-mean-risk model for which the Pareto frontier can be determined as a tool to give practical decision support. We apply the approach to a more special type of health programme portfolio selection problems investigated before by Al, Feenstra and van Hout (2005) and other authors, and illustrate by a concrete example how the proposed technique works. As a risk measure, absolute semideviation (and a measure derived from it) and budget overrun probability are used alternatively. It turns out that the semideviation-based choice can lead to a degeneration of the Pareto frontier to a curve for which only expected cost and expected QALYs count, whereas this does typically not happen for the second, more conservative measure depending on a budget limit. The method can be applied both to discrete and to continuous stochastic models.

2 - Decision Support for Rehabilitation Hospital Scheduling — Ideas for Heuristic Algorithms

Steffen Kasper, Institute of Production Management, Leibniz Universität Hannover, *Katja Schimmelpfeng*, *Stefan Helber*

Patients are treated in a rehabilitation hospital after a main surgery (e.g., hip replacement) to recover. To this end, it is necessary to schedule resources like personnel, rooms and devices. The processes in a rehabilitation hospital are typically not limited by any central bottleneck resource (such as the operating room in an acute hospital). Therefore, the schedule of treatments requiring various resources combined with a discrete time line as well as a range of patient-related restrictions leads to a planning problem of high complexity. Solving larger problem instances is not possible via a monolithic approach. As an alternative, different patient-wise decompositions are explored. We present a three-part algorithm which can be seen as a combination of a greedy- and a local search heuristic with incentive structures. Finally, results with respect to runtime as well as solution quality are presented.

INFORMATION SYSTEMS, NEURAL NETS AND FUZZY SYSTEMS

■ TA-18

Thursday, 9:00 - 10:00, Room E242

Neural Networks and Fuzzy Systems

Chair: *Joachim Vierling*, Universität Heidelberg

1 - A Hybrid Method for Task Flow Control in a GRID-System

Vlad Kucher, Educational-scientific complex - Institute for applied system analysis, National Technical University of the Ukraine (KPI)

Model of a scheduling process for task performance in a GRID-system with multilevel hierarchical structure is introduced. The model allows the estimation of system state variation dynamics with respect to the task flow variation as well as to the cluster and networks configuration. The model enables also efficiency evaluation for the algorithm introduced etc. The fuzzy-set approach to estimate the level of factors characterizing the resources and the tasks in a flow and also the application of a principle of square stowage of tasks in a queue into the band of a given width, furthermore, the choice of an aggregate system as a mathematical model of the scheduling process, have allowed the development of a task performance scheduling algorithm, which minimizes time of task performance and balances workload of resource suppliers. Principle of matrix assessment of the level of factors characterizing the properties of tasks in a flow enables us to reveal the most important factors for control strategy choice. For each task category, which is specified with respect to the information on task priority, resource requested (whether the task is performed within one cluster or on the resources of several clusters), task performance duration estimation, necessity to process and analyse the large data amounts; the control strategy involves certain rules of resource provision and consumption, what enables us to increase the efficiency of the scheduling and of the resource distribution on a task performance level. Task category specification and selection of the heuristics of a way to allocate resources are implemented with the help of neural network model, which is realized as a two-layer network of information feedforward with one hidden layer, trained by error backpropagation.

2 - Fuzzy data analysis for mixed type data

Joachim Vierling, Universität Heidelberg

In economics there are often issues, which can be described only vaguely. Issues of this kind can be modelled appropriatly with fuzzy rule based systems. There are many methods to derive fuzzy rule based systems from cardinal scaled data. However, a number of problems in the economic context is based on data of different levels of measurement. Corresponding fuzzy methods are explored only rudimentary in the past. This Presentation will introduce a new approach for generating fuzzy rule based systems also from nominal, ordinal and particularly mixed type data. The applicability to economic problems will be shown by means of selected examples.

■ TC-18

Thursday, 11:30 - 13:00, Room E242

Information Systems and Neural Networks

Chair: *Hans Georg Zimmermann*, Corporate Technology CT T, Siemens AG

1 - Information Systems for Farms' Financial Management Decisions

Liliana Mihaela Moga, Dunarea de Jos University of Galati and The Bucharest Academy of Economic Studies

The paper identifies the limits of the traditional design methods used to develop information systems customized for the financial management needs of a certain economic activity, as the case of agriculture is. The research aims to solve the gap of traditional design methods by working on the main causes which generate this situation — system analysis and design methods by introducing Value Analysis as a design method for the farms' management information systems. The research use a systemic analysis based on a linear least squares method in order to get the optimal ratio between the utility and the cost for each function provided by the information system. The method is based on a linear regression model. If the Value Analysis is currently used mainly for the design of the goods, the researches made in the last years allowed to elaborate new methodologies in order to extend the application area of the method to the information systems used in the decision making process of the companies. By using the Value Analysis in Software Engineering, the recent research accomplished in this field with those carried out in software architecture will be unified, so as to bring increased benefits to the farms financial management and implicitly, to their economic efficiency.

2 - Multi-Agent Market Modeling based on Neural Networks

Ralph Grothmann, Corporate Technology CT IC 4, Siemens AG, *Hans Georg Zimmermann*, *Christoph Tietz*

The talk is about modeling financial markets from the bottom up with a large number of interacting agents. The market price dynamics results form a superposition of the decision making processes of the agents. In order to model the agents decision making, we introduce two concepts: The first concept is based on feedforward neural networks. We point out, that a single neuron can be seen as an elementary decision making model of a single agent. With regards to this interpretation of a neuron, a neural network consisting of large number of neurons represents the interaction of many decisions and thus, can be see as a market process. In the second concept, the decision making processes of the agents are based on the idea of an elementary cognitive system with three basic features (perception, internal processing and action). A cognitive system is structurally represented by a time-delay recurrent error correction neural network. The introduced features should be seen as necessary conditions of a cognitive system. Merging the economic theory of multi-agent market modeling with neural networks, our models concern semantic specifications instead of being limited to ad-hoc functional relationships. As an advantage, our multi-agent models allow the fitting of real-world financial data.

3 - Neural Networks in the Energy Sector: Principles, Techniques and Applications

Hans Georg Zimmermann, Corporate Technology CT T, Siemens AG, *Ralph Grothmann*, *Christoph Tietz*

Today's energy management involve a variety of forecast problems: We not only have to predict the energy demand (load) but also the expected energy supply originating especially from renewable energy sources. In addition structured procurement processes require price forecasts for spot and future markets. In the talk we present neural network architectures for the outlined problem settings and report results from customer projects. 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 (energy) domain knowledge. The developments from recent years have provided a deeper understanding of appropriate neural network architectures and corresponding learning algorithms, which resulted in an easier way to handle the characterized tasks.

■ TD-18

Thursday, 14:00 - 15:30, Room E242

Neural Networks

Chair: *Hans-Jörg von Mettenheim*, Leibniz Universität Hannover, Institut für Wirtschaftsinformatik

1 - Artificial Neural Inverse Problem for Identification of Non-Conductive Section of MagLev Train Track

Dudi Darmawan, Engineering Physics, Bandung Institute of Technology, *Deddy Kurniadi*, *Suyatman Suyatman*

The main of human mobilitation equipment is transportation. One of the massive land transportation is a train. Maglev train has been a promising choise in train velocity parameters. But the high train velocity appear a stabilization problem. The principal stabilization parameter is levitation height. This parameter is determined by magnetic force generated by induction current occured in a conductor track. But the induction current is influenced by a track condition. Defect on track can decrease the magnitude of induction current. Thus, testing and evaluation of track condition are a very important issue. For instance, defect identification is one of procedure for evaluating the reliability of a track system. Detection of a defect is the first step that should be performed in testing and evaluation procedures. This procedure is an integral part of quality control and maintenance policy and management. Until recently, some defect identification techniques are already developed in many researches. Most of them concentrate to identify a physically regular shape defect. Moreover, many identification techniques are performed by observing the object visually or by capturing the image of object by a camera. These techniques, generally, identify the defects based on the geometrical shape. But in some cases, the change of electrical conductivity of track can occure without physically defect. Thus, a method for the identification of a physical parameter of defect is need to developt. In this paper, a method for identification of non-conductive section of maglev train track is proposed. Non-conductive section is identified as a physical parameter and the identification is performed in a magnetic field. The magnetic field is generated by flowing the electrical current on the metal track. The current pattern occured in the metal is influenced by the composition of defect. Thus, the defect can be identified by observing and recognizing the magnetic field distribution. This distribution is uniquely produced by current distribution. Thus magnetic field is used as an observation variable. In the previous works, artificial neural networks (ANNs) has shown its ability to recognize a pattern of magnetic field distribution based on current distribution. Furthermore, ANNs has well performed to solve some of inverse problem. Therefore, we will try to use ANNs for recognizing a magnetic field distribution based on composition of non-conductive section directly. In this study, we will use a square segmentation to approach irregular shapes of non-conductive section. This object area is divided into several elements. The magnitude of magnetic field is calculated using Biot-Savart Law which is based on simulation of approaching the several straight lines of current. The magnetic field that relevant to the non-conductive section, will be calculated in order to obtain a pair of data pattern. Furthermore, using this relationship pattern, ANNs is expected to solve the inverse problem of non-conductive section identification based on recognizing of magnetic field distribution.

2 - Spot and freight rate futures in the tanker shipping market: short-term forecasting with linear and non-linear methods

Christian von Spreckelsen, Institut für Wirtschaftsinformatik, Leibniz Universität Hannover, *Hans-Jörg von Mettenheim*, *Michael H. Breitner*

We investigate the performance of linear and non-linear forecasting models, to generate short-term forecasts of spot rates and corresponding freight futures respectively Forward Freight Agreements (FFA) in the dirty tanker shipping market. We attempt to uncover the benefits of using several time series models and the potential of neural networks. This is achieved by analyzing daily spot and freight futures data from April, 5th 2001 to April, 1st 2011 of two dirty tanker routes. Maritime forecasting studies with neural networks are rare and only include spot rates. We focus on short-term forecasting and compare neural networks with a wide range of time series models. We expand our investigation by including freight futures. First, we benchmark the performance of several forecasting models when forecasting spot and forward rates. The main objective is to reduce error and allow the model to maintain a stable error variance during high volatility periods. Second, we take a look at the economic evaluation of forecast freight rates, which is a better indicator for trading purposes than forecasting performance measures. Our evidence shows that non-linear methods like neural networks are suitable for short-term forecasting of freight rates, as their results are at least as good as statistical models, and often significantly better. We confirm that forward rates do help to forecast spot rates, but not vice versa.

3 - Forecasting Daily Highs and Lows of Liquid Assets with Neural Networks

Hans-Jörg von Mettenheim, Leibniz Universität Hannover, Institut für Wirtschaftsinformatik, *Michael H. Breitner*

We use Historically Consistent Neural Networks (HCNN) to forecast intraday highs and lows of liquid and volatile stocks. To build our forecast model we only use easily available open-high-low-close (OHLC) data. This is a novel application of HCNN to intraday data. It is important to note that model performance evaluation does not need tick data, which is more difficult to obtain and to handle. However, there is only few academic literature on forecasting intraday high-lows with neural networks. The present study aims at closing this gap. We measure the economic performance of strategies using forecast high-low data. All strategies are intraday. They exit all positions at the close. This reduces the risk of being caught in abrupt price moves without the ability to exit the position. We test the strategy on a sample of S&P500 stocks. It turns out that profit and reward to risk ratios are attractive and confirm the good results of previous studies on an emerging market.

MANAGERIAL ACCOUNTING

■ WB-20

Wednesday, 11:30 - 13:00, Room B302

Managerial Accounting I

Chair: *Matthias Amen*, Chair for Quantitative Accounting & Financial Reporting, University of Bielefeld

1 - The process of perpetual physical stocktaking as a scheduling problem

Matthias Amen, Chair for Quantitative Accounting & Financial Reporting, University of Bielefeld

The process of physical stocktaking exists explicitly or implicitly (IFRS, ISA 501) in all accounting systems. The German Commercial Code (Handelsgesetzbuch, HGB) requires an annual process of physical stocktaking for each kind of asset that is aggregated to a monetary entry of the balance sheet. For inventory items, like raw material, unfinished and finished products the process of stocktaking has to be performed on each stage of the internal value chain: inputs, throughputs at different stages, outputs. Traditional stocktaking requires a stop of operations of the production plant for a certain period around the balance sheet date. To ensure continuous production, perpetual physical stocktaking is also allowed. The problem of the inventory manager is to decide, when which item has to be counted under a certain objective function. Under HGB, each item has to counted at least once a year. Assuming that the demand of the product is not constant over the year (e.g. there could be cyclical demand), each item should be counted at it's expected date of minimum inventory level. In general this is not possible for similar items because of the limited capacity of the operative stocktaking team. Among others, the objective could be minimizing the slack time of the stocktaking team, i.e. to minimize the capacity and to smooth the effort needed for stocktaking. We present an optimization approach to determine the schedule of stocktaking in a perpetual physical stocktaking system during the accounting period.

2 - Bargaining over Incentives and the Distribution of Earnings in Family Firms

Kai Sandner, Ludwig-Maximilians-Universität München, Department für Betriebswirtschaft, Institut für Produktionswirtschaft und Controlling, *Richard Peter*

In our paper, we analyze the relation of negotiation between partners in family firms over the distribution of earnings on the one hand and negotiation over the provision of incentives for an agent on the other hand in a situation of Moral Hazard. Two family members or families have conflicting interests concerning the weighting of economic goals and family oriented goals. Task fulfillment is delegated to an agent, who has limited capacity and must be incentivized in oder to pursue each of the two goals. Therefore, agreements between family members or families have to be achieved. Results hinge on bargaining power and in particular the timing of the bargaining process. In particular, we analyze whether it is beneficial to negotiate incentives and the distribution of earnings simultaneously or sequentially.

3 - Cost accounting, real options and short-term decision making

Christian Lohmann, Schumpeter School of Business and Economics, Bergische Universität Wuppertal

Models of short-term decision making in traditional cost and production theory are typically based on the simplifying assumption that revenues and costs are deterministic model inputs. This assumption may be reasonable in the very short-term. However, this is no longer the case if current short-term decisions strategically interact with short-term decisions in future periods. For example, a current decision on the operating mode of a production process may influence future choices of the operating mode whenever switching between operating modes is costly. In this case it may be worthwhile to forego some certain short-term profits if this loss is over-compensated by an increase in next period's expected profits. If such interactions are neglected in short-term decision making, the long term results may be suboptimal even though all short-terms decision are optimized with regard to current revenues and costs. In this paper we apply real options methodology to short-term decision making. We show that managerial flexibility to switch between operating modes creates additional opportunity costs and benefits for short-term decisions. We demonstrate how real options methodology helps identifying the optimal short-term operations with respect to the interactions of current and future decisions under uncertainty. Our findings are illustrated with a simulation analysis pro-viding for a rich set of different environments characterized by different levels of uncertainty and different switching costs between operating modes. Furthermore, we analyze the condi-tions under which real-option values increase and decrease, as well as alter or intensify the short-term decision.

■ WE-20

Wednesday, 17:00 - 18:30, Room B302

Managerial Accounting II

Chair: *Anne Chwolka*, OvGU

1 - Modeling Aggregation and Measurement Errors in ABC Systems — A Simulation-Based Analysis

Arndt Rüdlin, BWL Seminar I, Albert-Ludwigs-Universität Freiburg, *Jan-Gerrit Heidgen*, *Stephan Lengsfeld*

The seminal papers by Labro/Vanhoucke [Accounting Review (2007); Management Science (2008)] made strong contributions to the analysis of errors in Activity Based Costing (ABC) systems. We pick up their simulation-based approach of modeling ABC systems and the implementation of aggregation and measurement errors. We extend the analysis and discuss the importance of the implementation sequence of these errors. The background is: Does a company first determine the organizational structure (i.e. arrangement of cost pools) or does it change the organizational structure after implementing measurement processes (e.g. after deciding on employees' skills)? Furthermore, we analyze different types of aggregation errors and discuss the interplay of aggregation and measurement errors at the same stage of the cost system. Here, the existing literature identifies some alleged compensatory interaction effects. On the one hand, our analysis confirms the main results of Labro/Vanhoucke. On the other hand, we show that some of the results change dramatically if one changes the implementation sequence for aggregation and measurement errors. Here, a primarily implemented measurement error leads to compensation effects if it occurs at the same allocation stage as the aggregation error: For very inaccurate measurement processes increasing aggregation may increase overall accuracy. Analyzing different types of aggregation errors reveals some types, where the aggregation error dominates the measurement error. In addition, we explain how alleged compensatory effects may be caused by rounding and propose a solution to avoid those in simulation-based studies of ABC systems.

2 - A New Accounting Approach for Public Universities

Hans-Ulrich Küpper, Institut für Produktionswirtschaft und Controlling, Ludwig-Maximilians-Universität München

In Germany we can observe a tremendous change in the field of higher education concerning its most important areas: study and research as well as the management of universities. The "Bachelor and Master system' was introduced in most disciplines and the 'excellence initiative' enhanced competition and research. As the states reduced their influence and increased autonomy the universities need efficient management tools based on effective accounting systems. In this paper therefore we will analyse whether industrial accounting can be used appropriately by public universities. We will show that the traditional systems of financial and management accounting cannot be transferred to public universities without changes. The concept of a new and special accounting for public universities has to be developed. After analyzing the current changes in the German system of higher education and the resulting challenges to universities in chapter 2 we develop the theoretical background of accounting in public universities in chapter 3. The structure and the relevant components of a new approach of management and financial accounting will be developed in chapter 4. In chapter 5 we will integrate the new accounting system for public universities in their management mechanisms, e.g. as components of a university balanced scorecard. On this way it can be combined with strategic planning of a university on the one hand and the reinforcement of the decisions on the other hand. In the last chapter we will analyze the status quo of the implementation process of several elements of the new accounting system to German public universities.

3 - Component-Level Target Costing — Revisiting the Functional Method of Tanaka

Anne Chwolka, OvGU

Target costing is a method of cost management for planning and developing profitable products. The aim is to reduce manufacturing costs to targeted levels. According to the "Functional Method', as introduced by TANAKA 1989, the target costs are allocated according to the importance of the product's functions. The target costs for the components and parts of a product are derived (indirectly) from the customers' willingness to pay. In the present paper, we question whether the assumption of the functional method concerning the optimal cost structure of the product, i.e. a value ratio of one, is justified. It is shown, that from a production-theoretical perspective, this basic assumption is, in general, not tenable. Nevertheless, it is shown that the functional method has several advantages as a method for incentivizing engineers. Therefore, we propose a "Modified Functional Method", which starts with an existing prototype model and where improvements of the functionality should only be carried out, if the additional associated benefit is at least as big as the incremental cost. These two methods are then compared with respect to their incentive effects, practical problems and the capability to develop novel products.

PRODUCTION AND OPERATIONS MANAGEMENT

■ WB-09

Wednesday, 11:30 - 13:00, Room F102

Designing (Energy Efficient) Production Systems

Chair: *Philipp Hungerländer*, University of Klagenfurt

1 - Development of Analytical Models for Energy Consumption and Roughness in Inner Layer Scrubbing Process in PCB Manufacturing

You-Jin Park, Department of Business Administration, Chung-Ang University, Korea, *Gyu-Bong Lee*

The printed circuit board (PCB) is an essential part of the electronic circuit packaging system that interconnects the electronic components for specific tasks. The PCB provides the mechanical support and the necessary connections between the components attached. The modern PCBs should be smaller, highly integrated, and should have faster operating speed, higher power ranges, and higher reliability. As one of the important PCB manufacturing processes, in inner-layer processing stage, each layer is processed in a printed circuit structure by resist or film application, imaging, and developing, followed by copper etching and resist stripping. To ensure adhesion between the layers and the additional layers, all layers are chemically treated by oxidation or scrubbed by brushes or buffs. In this research, we consider the inner layer scrubbing process in PCB manufacturing, and develop analytical models to describe the behavior of energy consumption as well as a change of the quality, that is, roughness in that process, and then apply a heuristic approach to the problem of finding the optimal operating condition which minimizes the energy consumption while keeping the quality. The performance of several different analytical models and optimization techniques are investigated and compared by using numerical results with real-field data.

2 - Optimizing cost efficiency and energy efficiency in batch production for strategic planning

Christian A. Hochmuth, Industrial Engineering, Bosch Rexroth AG, *Jörg Lässig*

Energy efficiency is an important aspect for companies to be considered for strategic decisions. This paper focuses on strategic planning of technical capacities in batch production with a wide range of products, and how to join the often conflicting objectives of cost efficiency and energy efficiency. The question to be answered is how are these objectives optimized in the strategic planning stage. In particular, in batch production it must be decided where to produce if there is a multitude of possible routings through a pool of machines which are all allocated by a wide range of products. To answer this question, in the first part of the paper a graphical, intuitive way is outlined how to model complex routings in batch production and how to transform this graphical model to a purely mathematical one. The graphical model is defined by the production planner. It is minimal by its set of symbols and at the same time capable of mastering the complexity. After the transformation, the mathematical model can be optimized instantly using a standard linear program solver. The innovative nature of this approach, in use at Bosch Rexroth, lies in its set of algorithms to perform this transformation. In the second part of the paper, the effectiveness of this approach is illustrated by optimizing cost efficiency and energy efficiency. Examples show that depending on the volume of products, these objectives may be conflictive or conform. In the conflictive case, an economic decision must be made. But in the conform case, it is immediately clear how to plan the flow of products along all possible routings. Therefore, just by showing if cost efficiency and energy efficiency are conflictive or conform for expected volumes, the decision where to produce is supported considerably.

3 - A Semidefinite Optimization Approach for Complex Facility Layout Structures

Philipp Hungerländer, University of Klagenfurt, *Miguel Anjos*, *Franz Rendl*

Facility layout is concerned with the optimal location of departments inside a plant according to a given objective function reflecting transportation and construction costs of a material-handling system. Recently competitive semidefinite approaches to the Multi-Row Facility Layout Problem (MRFLP) and the Directed Circular Facility Layout Problem (DCFLP) were provided. The MRFLP is concerned with optimizing the placement of departments along one or several rows. The DCFLP searches for the optimal arrangement of departments on a circle and contains several layout problems extensively discussed in the literature, namely the Equidistant Unidirectional Cyclic Layout Problem, the Balanced Unidirectional Cyclic Layout Problem and the Directed Circular Arrangement Problem, as special cases. In this talk we show that all these layout problems can be modeled as Quadratic Ordering Problems and hence can be solved to global optimality using a general semidefinite programming approach. Throughout the talk we compare our semidefinite approach with competing exact methods using linear programming relaxations, pointing out their specific strengths and weaknesses. We report optimal solutions for several single-row instances from the literature with up to 42 departments that remained unsolved so far. Furthermore we provide high-quality global bounds for double-row instances with up to 16 departments and optimal arrangements for directed circular instances with up to 100 departments. Finally we report high-quality global bounds for complex facility layout structures containing both multiple rows and circles.

■ WC-09

Wednesday, 14:00 - 15:30, Room F102

Maintenance and Rework

Chair: *Ralf Gössinger*, Business Administration, Production and Logistics, University of Dortmund

1 - Integrating Maintenance and Production Scheduling on Parallel Machines with Stochastic Failures and Non-Resumable Jobs

Wiebke Christiansen, Supply Chain Management, Christian-Albrechts-Universität zu Kiel, *Gudrun Kiesmüller*

The problem of allocating and scheduling a given number of n jobs on m identical parallel machines is discussed in literature since a long time. Most authors assume the machines to be always available and no unexpected breakdowns can occur. However, stochastic failures cannot completely be avoided and they can have a large impact, especially if jobs are non-resumable and have to get repeated after an interruption through machine failure. In this paper we study a production system consisting of m identical machines subject to stochastic failures. After a breakdown the affected machine is repaired to be "as good as new" through corrective maintenance and the interrupted job has to get restarted, which both lead to an increase of the makespan. To avoid machine failures, preventive maintenance activities are planned on all machines between the jobs. They also restore the corresponding machine to be "as good as new", but a preventive maintenance action results in a shorter downtime of the machine as a corrective maintenance action. In this paper a model is derived to allocate an order of n jobs to the machines and build a schedule for the jobs and preventive maintenance activities. We derive a formula for the expected makespan to be minimized in our optimization problem. With the established objective function we are able to solve the problem by using an Ant Colony Algorithm for major instances. In a numerical study we compare our approach to other heuristics and we illustrate the value of the joint determination of a production and maintenance schedule.

2 - Condition-based release of maintenance jobs in a multi-stage production/maintenance system with decentralised decision-making

Ralf Gössinger, Business Administration, Production and Logistics, University of Dortmund, *Michael Kaluzny*

Condition-based release of maintenance jobs is analysed for a three-stage production system and one separate maintenance unit. The conditions of the machines deteriorate as a function of multiple production parameters. If the task of maintenance is to keep up predefined operational availabilities of the production stages, two aspect have to be determined: (1) Optimal machine conditions that trigger the release of a preventive maintenance job. (2) Sequence of maintenance jobs. Problem-specific characteristics are: (a) There is an information asymmetry between production and maintenance. (b) Waiting time between triggering the release and carrying out a maintenance job is determined by different stochastic processes. (c) During waiting time, production can be continued with a modified production parameter setting. (d) Triggering and sequencing decisions regarding maintenance jobs influence the performance of production and maintenance. In the paper a continuous condition monitoring and a suitable information exchange protocol is developed. On this basis factors determining the waiting time are operationalised, economic effects induced by the triggering conditions are presented, a stochastic approach to calculate the triggering condition based on a chance constrained formulation is proposed and alternative priority rules for sequencing maintenance jobs are identified. Finally, the solution quality of priority rules and their impact on the triggering conditions are analysed and conclusions about suitable application areas of priority rules are drawn. Thereby, the strength of the production bottleneck is varied systematically. The results may enable decision makers to select suitable priority rules and to determine appropriate triggering conditions depending on situation.

3 - A New Approach to Rework in Merge Production Systems

Sadia Samar Ali, Institute of Management Studies,, Assoc Prof & Area Chair : Operations, *S. Kannan*

The present paper introduces and incorporates the concept of rework in modelling of a merge production system under random conditions. Merge and split production stages are common in assembly lines. Merging of components can be performed correctly or otherwise. If not done properly, merging operation can be redone. i.e., merging operation can be reworked. This paper explains the modelling of a two stage merge production system subject to rework using semi regenerative stochastic processes. The modelling has been done to obtain various busy period durations over a finite time duration for transient state analysis. Also, the modelling and analysis has been carried out without any particular assumption on the distributions of processing times. All the processing times involved have been assumed to be arbitrarily distributed.

■ WE-09

Wednesday, 17:00 - 18:30, Room F102

Lotsizing

Chair: *Stefan Bock*, WINFOR (Business Computing and Operations Research) Schumpeter School of Business and Economics, University of Wuppertal

1 - Dynamic capacitated lot-sizing problem with parallel common setup operators and time windows

Karina Copil, Supply Chain Management and Production, University of Cologne

We observed a capacitated lot-sizing problem with linked lot-sizes, multiple machines and sequence dependent setup costs and times in a German food company. Setup operations are carried out by common setup operators. As a common setup operator can perform only one setup at a time, setup operations must be synchronized to avoid intersections. In addition, production must take place in a given time window to fulfill shelf-life restrictions. Based on the CLSP with setup carry-overs and sequence dependent setup costs and times proposed by James and Almada-Lobo (2011), a mathematical model was formulated to consider the relevant restrictions. Due to the model's complexity, a fix-and-optimize heuristic was developed, whose computational results will be discussed.

2 - Linear programming models for the stochastic dynamic capacitated lot sizing problem

Timo Hilger, Department for Supply Chain Management and Production, University of Cologne

A stochastic multi-item capacitated lot-sizing model with finite horizon fill-rate and setup carry-over is presented. Considering the randomness of demand it is assumed that, according to the static-uncertainty strategy of Bookbinder and Tan (1988), all decisions concerning the time and the production quantities are made in advance for the entire planning horizon regardless of the realization of the demands. The resulting non-linear optimization model of the stochastic dynamic capacitated lot sizing problem can be reformulated as a solvable linear program by approximating the non linear functions of backlog and inventory with a series of piecewise linear segments. The model is solved using a Fix-and-Optimize heuristic as introduced in Helber et al. (2012).

3 - A Real-time Approach for the Capacitated Lot-sizing and Scheduling Problem with Sequence-dependency and Backorders

Rudolf Bauer, WINFOR (Business Computing and Operations Research) Schumpeter School of Business and Economics, University of Wuppertal, *Stefan Bock*

We consider a real-world mass customization production process of an automotive supplier. Due to the significant variant variety in the production program and the implemented standardization of parts, production planning has to cope with considerable differences in sequence-dependent setup times. Therefore, lot sizing decisions may have significant impact on the overall efficiency of the production process. In order to increase flexibility, job due dates are integrated as soft time restrictions with individual tardiness costs. Consequently, the real-world problem is modeled as a dynamic capacitated lot-sizing problem with linkage, sequence dependency and backorders (CLSPL-SDBO). Dynamism in the considered problem results from various sources. For instance, production planning has to deal with dynamic incoming new requests as well as with machine breakdowns, short-term due date modifications of the customer demands and delayed material deliveries. Since these deviations may have significant impact on the efficiency of the ongoing production process, we propose a new real-time control approach that allows a continuous plan adaptation. Specifically, infeasible production plans are quickly repaired by simple priority rules in order to allow an instant feasible continuation of the process execution. Afterwards, a continuous optimization of the adapted plan is performed using a fast Tabu Search heuristic with an efficient shifting scheme. Therefore, the entire execution time of the production process is utilized for an efficient disturbance integration and plan adaptation. This two-stepped disturbance handling is implemented on the basis of a rolling horizon scheme. First results of applying our procedure to real-world instances from the automotive supplier are presented.

■ TA-09

Thursday, 9:00 - 10:00, Room F102

Ethics and Sustainability

Chair: *Jack Kanet*, University of Dayton

1 - Portfolio selection models and sustainable development

Marius Radulescu, Mathematical Statistics, Institute of Mathematical Statistics and Applied Mathematics, *Constanta Zoie Radulescu*

Economic growth is frequently considered to be in conflict with sustainable development and environmental quality. With increasingly stringent environmental regulations, there is a growing need for efficient production planning models that take into account the trade-off between return and environmental costs and therefore reduce the penalties paid for overcoming the pollution levels. In the paper several portfolio selection models for sustainable development are presented. The models are from the domain of production planning and crop planning. Several multiobjective programming models for sustainable industrial and agricultural production are formulated. Some of them are in continuous variables and others are in discrete variables. The two multiobjective models for the industrial production planning are illustrated with practical examples from the textile industry. A multiobjective model for sustainable crop planning in agriculture is presented. It takes into account weather risks, market risks and environmental risks. Input data include historical land productivity data for various crops and soil types and yield response to fertilizer/pesticide application. Several environmental levels for the application of fertilizers/pesticides, and the monetary penalties for overcoming these levels, are considered.

2 - Ethics in Operations and Supply Management

Jack Kanet, University of Dayton, *Hans-Ulrich Küpper*

Caused by several scandals in big companies and by the different crises (2001, 2007/8), business ethics has become a relevant issue in the last 10 years. Till now, problems of ethics in operations and supply (OPS) management have not been in the core of interest. But, as OPS are essential and pervasive business activities it seems necessary to analyze the relevance of ethics in this area. In this paper we first characterize ethics and its relationships to corporate social responsibility (CSR) and sustainability. Then we develop a "matrix' of ethical issues in OPS management. In one dimension its components are the functions of OPS management like purchasing and procurement, production scheduling, product design, program planning, inventory management, quality assurance, etc. In the second dimension issues of ethics are classified by fundamental moral problems of a social, economic, and ecological nature. These issues are manifested by worker satisfaction and employee motivation, safety for workers and consumers as well as the risks of different stakeholders. This provides an analysis of values and norms, the resulting moral problems and their impact on the functions of OPS management. This systematization allows one to integrate issues like child labour, workforce management, employee relations, and codetermination, as well as problems in supply chains, pollution issues, corruption, and the influence of competition and its (lack of) rules in a globalized world. The goals of this paper are to provide a systematic survey of moral problems in OPS management and based on this to integrate results of the literature in order to disclose important areas of further research and methods for developing new insights in the ethics of operations and supply.

■ TA-11

Thursday, 9:00 - 10:00, Room F107

Stocks and Inventories

Chair: *Markus Siepermann*, Business Information Management, TU Dortmund

1 - A Production-Inventory System with both Patient and Impatient Demand Classes

Mohsen Elhafsi, School of Business Administration, University of California

We consider a production-inventory system with two customer classes, one patient and one impatient. Orders from the patient class can be backordered if needed while orders from the impatient class must be rejected if they cannot be fulfilled from on-hand inventory. Orders backordered incur a backorder cost while orders rejected incur a lost sales cost. The objective is to minimize the sum of inventory holding cost and the costs of backorders and lost sales. We formulate the problem as a Markov decision process and use this formulation to characterize the structure of the optimal policy. We show that the optimal policy can be described by two threshold functions that depend on the level of backorders from the patient class. These threshold functions specify (1) when it is optimal to produce, (2) how to allocate units produced to either increase inventory or reduce backorder, and (3) when to fulfill orders from on-hand inventory and when to backorder (in the case of the patient class) and when to reject them (in the case of the impatient class). We show that the priority in inventory allocation among the two classes is not static and instead depends on the backorder level from the class of patient customers. In particular, it is possible to start out fulfilling orders from the impatient class and backordering orders from the patient class and then to switch to fulfilling orders from the patient class and rejecting orders from the impatient class. In addition to characterizing the structure of the optimal policy, we also describe an effective heuristic that retains the essential features of the optimal policy but is significantly simpler to implement. This heuristic performs nearly as well as the optimal policy and significantly outperforms other plausible heuristics.

2 - How to deal with alternative cutting lengths in a one-dimensional cutting stock problem

Markus Siepermann, Business Information Management, TU Dortmund, *Richard Lackes*, *Torsten Noll*

In the steel industry tubes are rolled out of solid bars of steel. Customers order a number of tubes with a desired length and diameter. These tubes are the output material of a complex production process. With the length and the diameter as input parameters the needed lengths of input material can be calculated. Due to several degrees of freedom within the production process it is possible to produce the same output with different lengths of input material the so-called alternative cutting lengths. For example, it is possible to fulfil customer order A with 10 pieces of input length X or with 14 pieces of input length Y. Aggravating, the relation between the desired output and the possible input lengths gets lost during the production process. That means, that the cutting department only knows the number and lengths of the needed input material in total but they do not know what output will be produced with the cutting lengths. The general problem is a classic one-dimensional cutting stock problem which can be solved by several well known algorithms that lead to good results in an acceptable computational time. But all these approaches are limited to one input length per customer order. In this paper we will present an algorithm that solves the specialised problem. First, we will describe the formal optimisation model. Due to practical relevance, we can ease some side constraints (i.e. restricting the number of alternative cutting lengths) but without simplifying the problem. As the specialised problem is as complex as the general problem we will introduce a heuristic based on the Delayed Column Generation approach of Gilmore and Gomory.

■ TC-09

Thursday, 11:30 - 13:00, Room F102

Airport Operations Management

Chair: *Jens Brunner*, TUM School of Management, Technische Universität München

1 - A model for the transfer baggage problem at airports

Torben Barth, DTU Management / Fraport AG

This work deals with the handling of luggage from passengers changing aircrafts at an airport. For each arriving aircraft it is necessary to decide how to handle the transfer luggage. After the unloading of the bags from the aircraft the bags are transported with vehicles to entry points to the airport infrastructure. For each trip it is necessary to choose the best entry point. We consider an airport setup where several entry points in the internal transportation system on the infrastructure level, e.g. a conveyor belt system, exist. The selected entry point has critical influence on the overall connection time for each piece of luggage. For every connecting bag the connection time depends on the position of the arriving aircraft, the selected entry point and the handling location from the outbound flight. Since each connection has another available time period for the connection process, it is important to find a good assignment of the different trips to the entry points in such a way that as many bags as possible hold their connection. In this work we show a static mixed integer model for the presented problem. The model can be solved with a standard commercial solver. The objective function combines several criteria in linear objective. The most important one is to minimize missed connections. We identify the objectives of the different processes and players. The criteria of the objective are modeled in such a way that a robust solution is calculated for this very dynamic airport context. The talk illustrates challenges occurring during the implementation at one of the major European hubs and how the challenges were handled. The model runs successfully as part of a near real-time decision support system at Frankfurt airport for several years.

2 - Comparison of solution approaches for multiskilled workforce scheduling at airport check-in counters

Emilio Zamorano de Acha, Chair of Production Management, Univerisity of Mannheim, *Raik Stolletz*

This work addresses the assignment of agents to shifts and days-off to meet the time-dependent employee requirements in check-in counters at airports. In addition to this, our application addresses an heterogeneous workforce of multiskilled employees to cover skilled-constrained tasks. That is the case for check-in counters at airports since airlines operate with different check-in computer systems and, therefore, require to assign only employees qualified to operate them. To this extend, we propose a MILP model based on the reduced set-covering formulation for the tour scheduling problem to minimize assignment costs. Additionally, we developed several heuristic approaches and compare their performance using real-world demand scenarios from a ground-handler at a German airport.

3 - A new linear integer formulation for the ground delay program with misconnections

Jens Brunner, TUM School of Management, Technische Universität München

In this paper we address the rescheduling problem by an airline when a ground delay program (GDP) is issued. The objective of the airline is to minimize delay measures and cost for crew and passenger misconnections subject to several individual and general restrictions. We present a new linear integer model for this problem that can be solved with standard software. Using a real-world example we show the efficiency of the modeling approach. High quality solutions can be found quickly, i.e. within seconds. Additionally, airline management can use the model to evaluate the trade-off between delays and misconnections. In general, the consideration of passenger connections when performing rescheduling will save some real dollar and will increase customer satisfaction. The latter is crucial for customer loyalty which is of great interest for the airline.

■ TD-09

Thursday, 14:00 - 15:30, Room F102

Product Variety and Structure

Chair: *Martin Grunow*, TUM School of Management, Technische Universität München

1 - Managing product variety through customer choice modelling

Tilak Raj Singh, Industrial Engineering and Operations Research, Indian Institute of Technology, *Narayan Rangaraj*

In the environment of customized products (e.g. automotive, computer) their exists large number of components, many of them comes in more than one version. Customer may be able to specify some component variants, and other components may need to be then specified to satisfy engineering and legal dependencies, some of which can be quite complex. In order to fulfil individualized customer demands in a short period of time, manufacturers need to maintain an efficient portfolio of components. In this paper we have proposed an approach for product variety management by identifying such efficient portfolios from the past behavior of customer. This method will improve customer order fulfilment process and demand planning of components in logistics and assembly.

2 - Management of product portfolios with optimal product architectures

Urs Pietschmann, Faculty of Management and Economics, Ruhr-University Bochum, *Brigitte Werners*

The increasing demand for customer-specific and configurable products leads to a wide range of variants in product programs and thus to different challenges for manufacturing companies. Certainly customer satisfaction and sales revenues of the offered product program can be improved by customization strategies, but also risks of product development and complexity will grow. Customer individual products will not automatically increase the company's profits because rising complexity creates higher cost items, especially for research and development, procurement and production. Modular product architectures are considered to deal with these challenges. Modules can be used for product customization through standardization of components and interfaces. Compared to an integral design the concepts of cost leadership and product differentiation may thus be simultaneously achievable. Respective publications are mainly in the field of engineering science or marketing oriented. The application of mathematical optimization models promises a lot of potential, especially for controlling and management of product complexity and the selection of appropriate modules and supplier relationships. To support management decisions in the context of product policies demand forecasts can be used for module selection and product design in mixed integer programs. This paper presents the application of quantitative models for optimizing the product architecture of a product portfolio in the context of an operational and strategic planning approach. Example results illustrate purchasing and production decisions against the backdrop of an uncertain environment.

3 - A Branch-and-Price Algorithm for the Option Bundling Problem in the Automotive Industry

Radu Constantin Popa, Lehrstuhl für Produktion und Supply Chain Management, Technische Universität München, *Martin Grunow*, *Thomas Staeblein*

In the automotive industry, the allocation of options to bundles is a common approach used to limit product variety. An efficient option bundling algorithm should take customer preferences into account to avoid customer dissatisfaction and, consequently, a sales decline. To this end, the current paper provides a quantitative method for the option bundling problem which can be used as part of a decision support tool when designing bundles. The focus is on minimization of the total dissatisfaction of customers who must pay for the undesired options in their selected bundles. An according MIP model is proposed. A tailored branch-and-price algorithm is designed to optimally solve the model for a real-life case of three car types. It is shown that the introduction of appropriate bundles can contribute to a considerable reduction of the number of car variants without significantly increasing the customer dissatisfaction.

■ FA-09

Friday, 9:00 - 10:00, Room F102

Capacity Management and Contracts

Chair: *Kei Takahashi*, Dept. of Ind. & Manage. Systems Eng., Waseda University

1 - Optimal Capital and Labor Investment in Price Regulated Service Firms Facing Cyclical Demand

Mustafa Akan, administrative sciences, halic university

Service companies such as railroads and utilities face cyclical demand and they are price regulated. They are also required to meet the demand.These companies often can not fire labor.Therefore,excess capacity problems both in machinary(capital) and labor are to be expected and optimally managed. This study analyzes optimal capital and labor management problem of such companies over the full demand cycle by solving the appropriate Optimal Control Theoretic cost minimization model. The results depend on the parameters such as the form of demand function,depreciation rate of active and nonactive capital,and the attrition rate of labor.Eight possible phases are identified to be optimally synthesized.They are: 1.Investment in both capital ,both(Capital and Labor) are fully utilized 2.Investment in capital,no investment in labor,both are fully utilized 3.No investment in capital,investment in labor,both are fully utilized 4.No investment in capital and labor,capital is not fully utilized,labor is fully utilized 5.No investment in capital and labor,capital is fully ut?lized,labor is not fully utilized. 6.No investment in capital and labor,neither is fully utlilized. 7.Invesment in capital,no investment in labor,capital is fully utilized,labor is not fully utilized. 8.No investment in capital,investment in labor,capital is not fully utilized,labor is fully utilized. The optimal solution,which depend on the the parameters in the previous paragraph, involves the selection from among the eight phases above and their optimal synthesis and the swithcing times.

2 - The Newsvendor Problem as a Real Option Game

Kei Takahashi, Dept. of Ind. & Manage. Systems Eng., Waseda University

In this paper, the newsvendor problem with a contract is captured as a real option game. In the simple newsvendor problem, there are two firms, a supplier and a retailer. Only at the initial period, the retailer chooses an order quantity or a supply contract such as the wholesale-price contract or the option contract. If the retailer rejects the contract, a game between two firms ends and each firm earns a default payoff or implements a noncoordinating contract. However, coordination chance between two firms is not only at the initial period. Though the retailer rejects the contract at the initial period, the retailer has the chance to renegotiate contract terms with the supplier later. It is nothing else but a real option for the retailer. The supplier also has an option modifying contract terms. Therefore, this game can be seized as a real option game with demand uncertainty. Postponement of the retailer's contract acceptance leads to the opportunity cost for the retailer, but chance to accept better contract or reduction of excess stock. Therefore there is a tradeoff between acceptance or not, and the optimal contract timing for the retailer. As well as the retailer, there is the optimal contract term for the supplier. I verify occurrence of Pareto improvements from the noncoordinating contract by using various contracts. In concrete terms, the buyback and the option contracts are compared with only the noncoodinating contract. I reveal which contract is the best for the supplier or the retailer in various market situations, for example high volatile demand or not, long product life cycle or not. As well as the traditional newsvendor problem, some contracts improve two firms' profit via overcoming double marginal problems from the noncoordinating contract.

RENEWABLE ENERGY AND NEW MOBILITY

■ WB-19

Wednesday, 11:30 - 13:00, Room F309

Energy Production and Fossil Energy Saving

Chair: *Ansgar Stührmann*, Institut für Meteorologie und Klimatologie, Leibniz Universität Hannover

1 - 100 % Renewable Fuel in Germany 2050: a Quantitative Scenario Analysis

Maria-Isabella Eickenjäger, Institut für Wirtschaftsinformatik, Leibniz Universität Hannover, *Michael H. Breitner*

In a quantitative scenario analysis ways, in which the consumption of fossil fuel in the German transport sector (about 700 TWh p.a.) can be replaced by renewable fuel until 2050, are discussed. Especially the impact of policies on the replacement of fossil fuels with renewable fuels is investigated. A linear optimization model is developed with the objective to minimize yearly total cost of fuel, taking into account total demand and capacities of various fuels, e.g. production capacities. The implementation of the model is done in Excel and the optimization is automated using VBA. For the creation of scenarios various parameters are modified: energy taxes' exemptions, penalties on the emission of carbon-dioxide-equivalents and major restrictions for renewable fuels. Parameter dependent results show optimized fuel combinations for every year until 2050. Results from scenario analyses show further that it is possible to increase the share of renewable fuel sources in total consumption to 100% until 2050. This can be achieved by a declining population, by constant mobility preferences and by more efficient vehicles. Furthermore, it is necessary to support the substitution of fossil fuels with biofuels, hydrogen and renewable electricity by using policies for a sustainable change. Simulations show that long-term energy taxes' exemptions with long-term taxes on emissions of carbon-dioxide-equivalents lead to significantly better results.

2 - The impact of navigational services on public transportation networks

Michael Schroeder, Optimization, Fraunhofer Institute for Industrial Mathematics, *Lucienne Guenster*

Navigational services in public transportation are currently under development. SMART-WAY (www.smart-way.mobi) is a system that tries to implement the comfort and easiness of car navigation in public transportation. Funded by the European Commission, SMART-WAY is currently available to several hundred test users in the cities of Dresden and Torino. A smartphone and the SMART-WAY App are the only requirements to use navigation. We have developed a simulation model that allows studying public transportation networks under the assumption of a broad availability of navigational services. Their impact on performance indicators like number of missed connections, total travel time, average delay at destination, etc. can be investigated under varying scenarios. Furthermore, navigation enables new services for public transportation users. Customer-oriented delay management takes the known routes of passengers into account when deciding whether a connecting vehicle should wait for a delayed one. The simulation model enables the measurement of the overall benefit of such value-adding services. In the talk we will present the navigational services of SMART-WAY, the simulation model we have developed to research its potential future impact and the results obtained in our simulation experiments.

3 - Determination of irradiance on tilted PV systems by spectral radiance distributions

Ansgar Stührmann, Institut für Meteorologie und Klimatologie, Leibniz Universität Hannover, *Gunther Seckmeyer*, *Stefan Riechelmann*, *Holger Schilke*

We performed calculations of irradiance on tilted surfaces for cloudless and cloudy skies. This is achieved by modelling the spectral radiance, followed by a weighted integration over the angles of incident and the wavelength. Such calculations are necessary to determine an optimum yield of electrical power produced by photovoltaic (PV) systems after deployment. The tilt angles and the meteorological conditions, especially different types and amount of cloudiness, have a great impact on the performance of PV systems when deployed in mid-latitudes. In recent years several studies have been performed to provide realistic estimations of PV performance under different meteorological and geographical conditions. These factors greatly affect the optimum tilt and azimuth angle of a PV system. Even if the orientation is predefined e.g. by rooftops a prediction the PV performance of a planned PV system is often desired. Tools for the calculation like the Photovoltaic Geographical Information System (PVGIS) are based on measurements of horizontal global and diffuse irradiance. However, to accurately calculate the incident solar radiation on the tilted PV surfaces the spatial distribution of the diffuse radiance is needed. In the European climate this component is often the largest source of estimation error (Muneer, 1990). Diurnal deviations of the incident radiation for a set of surface azimuth and zenith angles for various sky conditions are presented. Our calculations will be compared with integrating models like the one used in PVGIS. The results may be exploited to reduce the uncertainty of current PV system performance calculations and may help planning the installation of PV-systems with various orientations.

■ WC-19

Wednesday, 14:00 - 15:30, Room F309

Optimization in Energy Usage

Chair: *Christian Hinrichs*, Environmental Informatics, University of Oldenburg

1 - Multi-Objective Planning of Large-Scale Photovoltaic Power Plants

Ingmar Schüle, Optimization, Fraunhofer ITWM, *Martin Bischoff*, *Hendrik Ewe*, *Kai Plociennik*

Photovoltaic (PV) power plants play a decisive role in switching the global energy supply from fossil to renewable energies. Despite recent cut-backs in feed-in tariffs in Germany, growth rates in countries like the U.S., South Africa, Israel and South-East Asia are high. Compared to the typical roof-top installations that can be found on many private and commercial buildings, the layout of a large-scale power plant is a complex task with a variety of free optimization parameters, many interdependent goals, and rather complex design principles. It is very hard for the responsible engineers to estimate the impact of their design decisions on the plants overall economic efficiency. While this is already the case with a single objective function to be optimized, the situation gets even more difficult when trying to balance different objectives, which are often contradicting. We present the problem of designing a large-scale PV power plant and describe our solution approaches for several of the inherent subproblems. Examples of these subproblems are the placement of the plant's service ways and cable ways, of the tables carrying the PV modules, and of the inverters. In order to approximate the Pareto-set and to achieve a well-balanced set of feasible layouts, we systematically explore the optimization parameters. For each parameter combination used, we create a plant layout by solving the subproblems in a sequential manner with specialized fast heuristics. We demonstrate the superiority of our multi-objective approach compared to the best single-objective solutions with the help of some examples and report on the practical usage of our software tool at Siemens Energy.

2 - Towards a Decision Support System for Real-Time Pricing of Electricity Rates: Design and Application

Cornelius Köpp, Institut für Wirtschaftsinformatik, Leibniz Universität Hannover, *Hans-Jörg von Mettenheim*, *Michael H. Breitner*

The share of renewable energy in today's power grids is continually increasing. However, it is notoriously difficult to accurately forecast renewable electricity sources like wind and solar production with the granularity that energy providers require. To compensate for the fluctuating production and forecast errors, energy providers have to use expensive control energy. This partly negates the positive effect of renewables. Various ideas for load smoothing on the production side have been suggested. Here, we focus on load shifting on the consumer side: electricity rates that may vary in hourly intervals can influence smart devices in private consumer households. With real-time pricing (RTP) the energy provider can send high prices when production is behind forecasts. On the other hand, prices should be cheap when the production exceeds the forecast. Cheap rates would incite electricity consumptions. The challenge is to identify the price signal that will result in the desired load shift at consumers. As the behavior of smart devices is still unknown today we use a simulation prototype and train an artificial neural network with simulation data. As it turns out the neural network leads to good results and achieves hit rates in the task of mapping the desired load shift to a price signal. This hit rate only slightly decreases when we submit the price model to some constraints that increase consumer-friendliness. The advantage of using a neural network is that it can adapt to a slowly changing mix of smart devices in households. By regularly retraining the network we are able to react to the future reality.

3 - A Decentralized Heuristic for Multiple-Choice Combinatorial Optimization Problems

Christian Hinrichs, Environmental Informatics, University of Oldenburg, *Sebastian Lehnhoff*, *Michael Sonnenschein*

We present a decentralized heuristic applicable to multi-agent systems (MAS), which is able to solve multiple-choice combinatorial optimization problems (MC-COP). First, the MC-COP problem class is introduced and subsequently a mapping to MAS is shown, in which each class of elements in MC-COP corresponds to a single agent in MAS. The proposed heuristic "COHDA" is described in detail, including evaluation results from the domain of decentralized energy management systems.

■ WE-18

Wednesday, 17:00 - 18:30, Room E242

Electricity Markets

Chair: *Jan Michalski*, Lehrstuhl für Controlling, TU München

1 - The combination of forecasts for RES-E trading

Dietmar Graeber, Qunatitative Methoden, Universität Hohenheim, *Andreas Kleine*

Abstract: The legal framework of the German Renewable Energy Sources Act (Erneuerbare Energien Gesetz, EEG) led to a strong rise of renewable energy sources for electricity generation (RES-E). The last amendment of the EEG which entered into force on January 1th 2012 strengthened the market integration of RES-E. The trading of RES-E is therefore becoming important for more and more market players. Concerning the costs of trading fluctuating RES-E like wind- and PV-power, the quality of short-term power forecasts is essential. Major forecast errors can cause high losses. Different forecast methods for power forecasts have been developed in the last years; however none has shown superior in all situations yet. The combination of different forecasts thus is a method for improving forecast quality. A method which not only combine different forecasts but also takes into account real-time measurements of RES-E production hast been developed jointly by the department of Quantitative Methods at University of Hohenheim and EnBW TransnetBW GmbH. In relation to the costs of RES-E trading the forecast is combined minimizing both, forecast error for different forecast horizons as well as forecast fluctuations between different horizons. The presentation describes the main ideas, the algorithmic challenges and the results of the method.

2 - Market Modeling in an Integrated Grid and Power Market Simulation

Torsten Rendel, Electric Power Systems, Leibniz Universität Hannover

Followed by the liberalization of the European power market, the amount of transmitted power between the countries increases and thus affects electricity prices. Therefore, the loads of the weakly built interconnection lines between countries approach their physical limits. Furthermore, the construction of decentralized generation units, especially renewable power generation, changes the generation structure as a whole. In order to analyze the effects of this change in the European power system, the Institute of Electric Power Systems in Hannover is developing an integrated grid and power market simulator to analyze possible future scenarios in electric power systems. The simulation tool is designed in a way, which allows usage in other market areas, if the necessary base data is embedded. The base data consists of power plant information as well as grid and load data for the analyzed market area. The simulation creates an optimized power plant schedule which is based on the marginal costs of the generation units and the topological constraints of the power grid. The schedule is planned by the combination of a long and short term market model which includes costs of carbon dioxide emissions and start-up processes of the power plants. The cross boarder energy trades are included by an evolutionary algorithm in order to minimize the energy costs in the whole market area. With the help of the integrated grid and power market simulation, future power supply scenarios can be analyzed. In addition to the analysis of future power systems, upcoming changes of the present systems can be studied. Possible results of the simulation are power line loads and shortages in power supply as well as voltage instabilities.

3 - Investment Decisions in Imperfect Electricity Markets with Storage of Renewable Electricity through Hydrogen Production

Jan Michalski, Lehrstuhl für Controlling, TU München, *Gunther Friedl*

With more than 20 GW of wind power capacity installed in Northern Germany and more to come when offshore wind power expands, there are periods when the available wind power exceeds the grid capacity or even the electricity demand in reach. This excess wind power could be utilized for the electrolytic production of hydrogen based on the power-to-gas technology. Hydrogen can be either stored for re-electrification or used as a transportation fuel for fuel cell electric vehicles (FCEVs) or converted into methane for natural gas pipeline injection. In this paper we analyze the impact of hydrogen as energy storage on production and investment decisions in an electricity market when market participants behave strategically. We develop a game-theoretic two-stage model consisting of an investment game under the open-loop information structure in the first stage and a Cournot oligopoly game for electricity generation in the second stage. This framework is implemented as a mixed complementarity problem and applied to the German case assuming the phase-out of the German nuclear power plants, rising renewable energy supply and increasing energy demand for electric vehicles. The numerical results indicate that the profitability of the hydrogen technology depends on the wind supply volatility and conventional generation flexibility. Adding demand for hydrogen as a fuel for FCEVs allows for a synergetic use of the technology and changes the investment incentives for energy storage. Although the power-to-gas technology as energy storage has a price-smoothing effect and changes investment decisions of individual firms the overall generation capacity is higher with energy storage providing additional supply security in markets with a large amount of intermittent energy production.

■ WE-19

Wednesday, 17:00 - 18:30, Room F309

Electric Vehicles and Car Sharing

Chair: *Kevin Zemmer*, ETH Zurich

1 - A Quantitative Car Sharing Business Model for Students

Michael H. Breitner, Leibniz Universität Hannover, Institut für Wirtschaftsinformatik, *Judith Klein*

The actual discussion of new mobility concepts mirrors the changing public aware-ness regarding a re-thinking of tomorrow's mobility. Car sharing has become an im-portant topic in the last years. Market dynamic has grown recently due to the car sharing market entry of renowned, big automobile manufacturers. These manufac-turers recently have noticed the potential of car sharing to introduce new technolo-gies like e-mobility or mobile systems' car integration. While car sharing already has many and various customers, the Leibniz Universität Hannover now focuses on de-veloping new ways to interest students in this form of individual and new mobility. The discussed quantitative car sharing model for student customers is developed from a general business model for car sharing in Hannover (Quicar by Volkswagen). Facing student customers the business model has to deal with two basic challenges. On the one hand, different needs of mobility must be addressed and on the other hand it is necessary to meet the students' willingness to pay. The development of a student specific quantitative price model includes rates for driving as well as parking on a minute by minute pay per use basis. In the first step use cases are identified in order to illustrate typical situations of individual student mobility. Then these cases provide the basis for a student online survey to analyze the students' willingness to pay (about 500 responses). Finally the calculation of student rates maximizing the car sharing providers' revenue is solved as an optimization problem under the con-straints that (a) student rates must not exceed their willingness to pay and that (b) students rates must not deviate by more than 25% from the general car sharing rates.

2 - Optimization strategies for combined heat and power range extended electric vehicles

Heiko Juraschka, Hochschule Hannover, *Lars-Oliver Gusig*, *Kary Thanapalan*, *Giuliano C Premier*

Range limitations of battery electric vehicles (BEV) require new approaches to overcome usability re-straints. To reduce size, cost and mass of battery-packs some manufacturers integrate small combustion engines into their concepts. These range-extended electrical vehicles (REEV) recharge high-voltage batteries when driving long distances. The range of a REEV is strongly dependent on climate conditions and applied driving cycles. To ensure temperature conditions in passenger compartment and battery packs a significant amount of energy is needed for cooling and heating. Temperature distribution profiles have been developed based on statistical data, thermal masses of compartment and batteries in a simplified car model were taken into account. Combining new European and ex-urban driving cycles (NEDC/EUDC) for a vehicle in the Golf-class an amount of 12-19% of energy is needed for conditioning over a yearly temperature distribution. Thus it is sensible to take improved techniques to generate thermal energy inside the car into account like combined—heat-and-power generation (CHP). Dynamic simulation of three alternative REEV-concepts has been conducted in comparison to conventional BEV and internal combustion engine vehicles. A pure range-extender (REEV, no connection to heating and cooling) an exhaust heat coupled range-extender (EXH-RE) and a CHP range-extender (CHP-RE) with di-rectly linked climate compressor have been examined. It was found, that EXH-RE can reduce CO2-emissions by 3%. Applying CHP-RE and optimizing output power to climate profile and driving cycle 14% in CO2 could be saved in com-parison to standard REEV. Thus significantly smaller RE-solutions should be fur-ther investigated.

3 - Efficient Trip Planning for Electric Vehicles

Kevin Zemmer, ETH Zurich

Electric vehicles (EVs) play a key role in future mobility concepts, and are already a viable alternative to internal combustion engine vehicles for common daily travel patterns. Nonetheless, their adoption is hindered by several issues, including range, availability of charging stations, and charging time. A careful planning of the charging decisions is thus very important with EVs. When dealing with charging decisions, the interplay between charge and travel time introduces an additional layer of complexity. For example, at some point taking a longer but more energy-efficient route might allow to globally save time, because charging can be delayed or avoided. Due to these interactions, traditional routing approaches with separate charging planning are not well suited for EVs. This talk presents a method for devising efficient travel plans for a set of sequential trips. Unlike traditional vehicle routing, an EV-specific consumption model is used, and dependencies between routing and charging are taken into account. Each instance is transformed into a directed multigraph, where optimal solutions can be determined by finding shortest paths adhering to additional constraints. Due to multiple conflicting objectives, each with individual restrictions such as battery capacity or time frames, Pareto-optimal solutions are obtained with a multi-objective label correcting algorithm, similarly to what is done for restricted shortest path problems. Even though the algorithm has exponential worst-case running time, most instances that arise in practice can be solved efficiently.

■ TC-19

Thursday, 11:30 - 13:00, Room F309

Wind Energy and Other Energy Sources

Chair: *Anne Bechtel*, Institute for Steel Construction, Leibniz University Hannover

1 - Decision Support Tool for Offshore Wind Parks in the Context of Project Financing

André Koukal, Leibniz Universität Hannover, Institut für Wirtschaftsinformatik, *Michael H. Breitner*

Offshore wind energy has developed rapidly in the last twenty years. However, the development of the technical aspects has been in the foreground for most of the time. Due to high costs of more than EUR 1 billion the majority of the realized projects has been implemented within the framework of corporate finance. Further goals concerning the expansion of renewable energies have been set by governments in various countries. In this context the importance of the economic viability of alternative financing concepts like project financing is becoming increasingly evident. This paper provides a decision support tool (DST) for analyzing and evaluating the project value of offshore wind energy projects within the framework of project financing. The DST is based on a cash-flow model in which the project value is calculated by applying the discounted cash-flow (DCF) method. A Monte Carlo-simulation is used to take the project risks into consideration. In the course of that the cash-flow-at-risk (CFaR), an adjustment of the value-at-risk (VaR) approach, is used to quantify the influence of risk factors and the effects on the project value. In order to be able to consider the requirements of debt capital providers in the context of project financing key figures like the debt service cover ratio (DSCR) are calculated. Therefore, a data base that supports decisions of many project participants is provided. Finally, a case study for a fictitious offshore wind park in the German North Sea is conducted. It is shown that in the framework of the existing feed-in tariff in Germany an offshore wind park project generates adequate returns for investors and provides sufficient debt service coverage.

2 - The Canola Oil Industry and EU Trade Integration: A Gravity Model Approach

Dirk Röttgers, Institute for Environmental Economics and World Trade, Leibniz University of Hanover, *Anja Faße*, *Ulrike Grote*

Abstract: The major producers as well as consumers of canola based biodiesel are EU countries. Quickly increasing production and consumption in these countries also prompt increasing trade flows. In this context it is worthwhile analysing if the EU trade integration among members hampers trade with outsiders or not. Additional factors that could shed light on the issue are measures for political intervention and sector specific value chain variables. A common way to analyse flows is the so-called gravity model, which also is employed here. Because of zero-inflated trade data, the presented model had to be expanded with the Heckman approach. To control for omitted multilateral resistance AvW concept for multilateral resistance terms is used. Furthermore, countering spatial autocorrelation is accomplished by the introduction of spatial weights. The obtained results suggest that there is a strong tendency to import canola oil from outside the EU, even though the EU generally has a strong domestic market and though it is by far the biggest canola producer.

3 - Sustainability Assessment and relevant Indicators of Steel Support Structures for Offshore Wind Turbines

Anne Bechtel, Institute for Steel Construction, Leibniz University Hannover, *Peter Schaumann*

Environmental and operational loads are the design drivers of steel support structures for Offshore Wind Turbines (OWT). Besides design and installation a holistic design includes sustainability aspects dominating decision process and cost effectiveness of future renewable constructions. Within a large research project with 3 research institutions consulted by over 30 industrial partners sustainability issues for renewable energies are investigated. Hence, this paper deals with special indicators developed to evaluate the sustainability of the steel support structures of OWTs. Regarding the structural design of buildings sustainability aspects are already taken into account. Established rating systems as e.g. the German DGNB system facilitates the evaluation and certification of buildings. Due to missing methods for other constructions, this paper makes a contribution to establish a rating system for steel constructions for renewable energy systems. In a first step, proven indicators originating from the building industry and characteristics reported in literature were used to determine relevant indicators. Beside environmental, economic and social indicators effects of the process and technical quality were taken into account. In a second step, composed characteristics were transferred to the specification of steel support structures for OWT. Investigations focussed on environmental effects resulting from a life cycle assessment. Recycling aspects of the constructions as well as deconstruction costs were included. Focussing on the applicability of developed indicators selective reference structures were chosen and analysed. Results will be shown in the paper and first ideas about a full sustainability assessment method for renewable constructions will be given.

■ TD-19

Thursday, 14:00 - 15:30, Room F309

Electric Mobility

Chair: *Andreas Pfeiffer*, Winfor - Wirtschaftsinformatik und Operations Research, RWTH Aachen University

1 - The impact of different strategies on charging behavior of electric vehicles

Maren Kier, Lehrstuhl für Energiewirtschaft, Universität Duisburg-Essen, *Christoph Weber*

This paper focuses on intelligent charging strategies (CS) for electric vehicles. Especially the electrification of the vehicle fleet of an enterprise requires particular attention. From business background, there is the need to avoid increasing the contractual peak load. Therefore different CS are investigated with respect to the resulting system's cost efficiency. These strategies are achieved by a mixed integer optimization program which considers economical and technical restrictions. Starting from a basic model various CS like priority variation, cost minimization and consideration of the charging curve are compared. For the model we assume that the electricity costs, the residual load and the time interval of charging are known. For all CS we implement restrictions on company's peak load and vehicles' battery capacity as well as maximal receivable load. Furthermore various priorities are externally assigned to the different vehicles within a fleet. Charging level is maximized in the basic model without considering any economical restrictions. As extension to the basic model, the priority variation strategy shows three different methods how to charge the vehicles within the same priority. Modifying the objective function of the basic model leads to the cost minimization strategy. Still the maximal charging level is intent of this strategy. The consideration of the load curve uses a piecewise linear approximation of the batteries convex load curve as restriction for the maximal receivable load quantity. Further on, combinations of several CS are analyzed. Depending on how various terms of the objective function of different CS are weighted, different objectives can be achieved. Later on the user interface of the charging station will be combined with the CS.

2 - E-mobility infrastructure - assessing the market potential of public and private charging service

Robert Rieg, Faculty of Business, Aalen University, *Stefan Ferber*, *Sandrina Finger*

E-mobility is discussed to date predominantly in terms of alternative drive systems, consumer preferences or the necessity to subsidize e-vehicle purchases. However, e-vehicles need an adequate infrastructure to operate and to convince individuals and firms to switch; one important infrastructure component is the charging station system. Since not all e-vehickes will charge at home, a significant part of that infrastructure will be public charging stations. However, private investors will only install and operate such an infrastructure if there are profitable prospects. Because of a low prevalence of e-vehicles to date no in-depth empirical research is possible. Therefore, we propose building a system dynamics model to capture factors and policies facilitating or impeding the buildup of public charging infrastructure. We identify a re-inforcing causal loop between the level of charging stations and the stock of e-vehicles which form basically a "chicken-egg' problem. Without infrastructure diffusion and growth of the e-vehicle market will not start off. Without enough market potential, investors will be reluctant to invest in infrastructure. We concentrate on so called Alpha Cities like Singapore, because they will presumably lead the way for e-mobility. Our analysis shows factors that allow us to estimate potential market size of public charging infrastructure depending on the city and several endogeneous and exogeneous variables. An important finding isthe need to combine multiple business models linked to the charging infrastructure. The latter comprises of: • charging Service for the private driver or the fleet operator • energy demand side management for the utility • advertizing opportunities on the display or co-branding of charging stations

3 - An e-Clearinghouse for energy and infrastructure services in e-mobility

Andreas Pfeiffer, Winfor - Wirtschaftsinformatik und Operations Research, RWTH Aachen University

Sustainable mobility, based on battery-powered electrical propulsion concepts, is on the recovery. Since 2009 a charging infrastructure for transportation on the basis of electrified powertrains has been developed all over Europe — partially state subsidised — and is provided by municipal utilities privately as well as publicly. Access to the charging stations is monitored by intelligent Triple-A-Systems (AAA — Authentication, Authorisation and Accounting) for reasons of security, customer loyalty and accounting. These systems are usually regionally operated by different providers, resulting in the development of local charging station networks, which are mostly inaccessible for customers of other providers. Similar to roaming in mobile communications, it should be possible for pioneers of e-mobility to have access to public charging stations of different operators. To achieve this, an interoperability and connection between the numerous charging station management systems has to be created. This article describes an efficient and future-oriented solution of a central interface of a European Clearinghouse of e-mobility.

■ FA-19

Friday, 9:00 - 10:00, Room F309

Mathematics and New Energy

Chair: *Vladimir Tsurkov*, Complex Systems, Dorodnicyn Computer Centre of Russian Academy of Sciences

1 - Application of a model with uncertain estimates in energy planning

Elham Ghazimatin, Management and accounting, Allameh tabataba'ee University, *Ali Khatami firouzabadi*

The vast need of human being to energy sources is an essential element of his life and reaching to an endless source of energy has always been his desire. Since Iran has huge source of gas and oil, it has turned to a fossil fuel oriented country. But as it is now declared clearly to everyone, oil and its derivatives are invaluable national capitals and wasting them will cause irreparable damages. Scientists believe that by use of renewable energy sources such as wind, solar, geothermal, biomass, etc instead of fossil fuels, we can prevent so many environmental problems and save national fossil fuel sources for economical and social developments. In the past, the choice among alternative sources was based on cost minimization, but ranking the renewable energy options is a complex task, considering the different aspects such as technological, environmental, social and economical ones. So the objective of this paper is determining the best renewable energy alternative for Iran by using ARIADNE method. In many cases, decision makers may be able to express a range for the alternative importance of one alternative or criterion over another without being that confident of a precise numerical value. This model allows decision makers to input ranges for relative advantage or performance. The idea behind ARIADNE model is that for each alternative, a small linear programming model is run to determine the maximum value function for that alternative, as well as the minimum value function for that alternative, given the range of alternative weights for each criterion. As the results of the model are interval numbers, a method has been used to rank them according to their negative intervals. In the application of the proposed methodology the most appropriate renewable energy alternative is determined wind power for Iran.

2 - Sharp peak density solutions of conservation laws for Bose-Einstein condensate near energy minimum

Vladimir Tsurkov, Complex Systems, Dorodnicyn Computer Centre of Russian Academy of Sciences

In the previous works of the author classical solutions of Eulerian hydrodynamic equations in one spatial variable for so-called degenerate gas obeying Bose-Einstein statistics on the temperature near absolute zero (i.e. entropy, energy also near zero) were studied. The behavior of the solution can be described as follows: if we consider a sequence of certain initial entropy (temperature, energy) distributions, such that their minimums tend to zero then the density maximum of the corresponding solution tends to infinity while spatial and time domains tend to zero. In other words, we have sharp peak density solutions. In this presentations the state equation of the degenerate ideal Bose gas is used in the two-component hydrodynamic equations, where there are normal and superfluid velocities and densities. Singular (i.e. sharp peak density) solutions take place in this case too, however the behavior is different. Although the superfluid equations are not applied to ideal degenerate Bose gas, these solutions may be considered as close to non-ideal Bose-Einstein condensate.

REVENUE MANAGEMENT AND PRICING

■ WB-21

Wednesday, 11:30 - 13:00, Room F128

Revenue Management I

Chair: *Jochen Gönsch*, Department of Analytics & Optimization, University of Augsburg

1 - A Comparison of Dynamic Programming Approaches for Airline Revenue Management with Integrated Upgrade Decision-Making

Claudius Steinhardt, Department of Analytics & Optimization, University of Augsburg, *Jochen Gönsch*

In this talk, we first give an overview of three different existing dynamic programming modeling approaches that integrate revenue management and upgrade decision making. The first model assumes that upgrades are decided ad-hoc at the time of sale. The second model postpones the upgrading decision to the end of the sales horizon. The third model, which we call the surrogate approach, originates from practice and modifies the resource network and the consumption matrix to include artificial surrogate resources that are jointly used by multiple products in order to consider the incorporation of upgrades. We then analytically relate the models to each other. In this context, we focus on upgrading in the airline industry, where the upgrade decision is made individually for each leg a passenger's itinerary consists of. Whereas the ad-hoc and the postponement formulation are in general only equivalent for single leg problems, we analytically show that this relation also holds for airline networks. Moreover, we formalize the surrogate approach and prove that it is indeed equal to the other two formulations in the airline case. While all three formulations are equal regarding the optimal solutions of the exact dynamic programs, applying dynamic programming decomposition techniques leads to different approximations. This is shown in the last part of the talk, including results from a simulation study using typical airline revenue management scenarios, in which we examine the resulting approaches regarding computational complexity and revenue performance.

2 - An Algorithm for Computing Inexact Nash Equilibria in General Network Capacity Management Games

Waldemar Grauberger, Mercator School of Management, University of Duisburg-Essen, *Alf Kimms*

In revenue management problems, allocating capacity to different products in a network optimally is impossible except for very small problems. In (algorithmic) game theory, computing exact Nash equilibria is also hard in a computational way. Applying an exact algorithm to compute Nash equilibria in a competitive network setting, one has to cope with both problems; the huge amount of strategies on the one hand and the huge amount of computational steps needed to find an equilibrium point on the other hand. An existing algorithm that computes Nash equilibria iteratively employing linear models is guaranteed to converge only under "suitable conditions" in a certain type of game. We present an algorithm that, in case it cannot converge to an exact Nash equilibrium, computes an approximation to it (a so-called inexact Nash equilibrium) in general network capacity allocation problems under competition. Our model and algorithm ensure discrete decision variables (booking limits) leading to a straightforward game theoretic interpretation, which cannot always be said for existing approaches. Further, using the same basic model, we investigate the question whether it is worth taking competition into account when making (network) capacity management decisions. The results show that the payoffs in the inexact equilibria are very close to those in exact ones and that taking competition into account leads to a higher revenue on average, no matter what the competitor does. Since we apply linear continuous models computation time is very short.

3 - Integrating Conditional Value-at-Risk into Dynamic Programming for Revenue Management

Michael Hassler, Department of Analytics & Optimization, University of Augsburg, *Jochen Gönsch*

While classical revenue management approaches try to maximize the expected revenue, the perspective of a risk-averse decision maker is particularly appropriate when regarding rare events or acting in a volatile and fast changing environment. Consequently, there is a small but increasing stream of revenue management literature taking risk aversion into account. We present an approach for risk-averse capacity control based on stochastic dynamic programming where the Conditional Value-at-Risk (CVaR) serves as risk measure. The CVaR is an intuitively appealing measure commonly used in financial applications and is an important example from the class of coherent risk measures. However, to the best of our knowledge, this is the first model for risk-averse capacity control using CVaR. We show how the resulting dynamic program with partially continuous state space can be approximately solved. The resulting time-consistent formulation enables us to consistently optimize and evaluate multi-period revenue streams. Furthermore, on the basis of an illustrative numerical example, we compare control policies resulting from using the expected revenue as target criterion with policies resulting from our approach.

■ WC-21

Wednesday, 14:00 - 15:30, Room F128

Revenue Management II

Chair: *Claudius Steinhardt*, Department of Analytics & Optimization, University of Augsburg

1 - Computing Protection Levels for Capacity Control with Planned Upgrades

Jochen Gönsch, Department of Analytics & Optimization, University of Augsburg, *Sebastian Koch*, *Claudius Steinhardt*

We consider the revenue management problem of capacity control with integrated upgrade decision making. The dynamic programming formulation of this problem is hard to solve to optimality even in the single-leg case, because multiple hierarchical resource types must be considered simultaneously. Therefore, we propose a new heuristic approach that generalizes the well-known single-leg EMSR-a procedure to multiple resource types. Similar to EMSR-a, our approach is based on the computation of protection levels but additionally allows for the integrated consideration of upgrades. Furthermore, we perform a number of computational experiments to investigate the performance of the new approach compared with other capacity control methods that incorporate upgrades, considering typical airlines' single-leg scenarios. The results show that our approach can significantly outperform existing methods in terms of the total achieved revenue, including dynamic programming decomposition approaches that are proposed in the literature as well as successive planning approaches that are widely used in commercial revenue management systems.

2 - On the value of supplier-driven flexibility in revenue management

Sebastian Koch, Department of Analytics & Optimization, University of Augsburg, *Jochen Gönsch*, *Claudius Steinhardt*

We consider the integration of flexible products into revenue management's capacity control approaches. Flexible products allow the selling firm to assign the purchaser to one of several predefined execution modes at a later point in time. Therefore, flexible products allow supply-side substitution between resources. Examples include applications in passenger air transport, where customers may be notified of their specific itinerary or travel time only shortly before the start of their journey. As several authors have shown, flexible products can easily be incorporated into the traditional deterministic linear program (DLP) which is widely used in practice in order to perform capacity control. However, due to the static nature of the DLP, the fact that flexible products may be reallocated to every possible execution mode at any point in time after acceptance cannot appropriately be captured. The decision is only made based on the immediate revenue, which is mostly lower than that of regular products. Thus, the existing approaches underestimate the "value of flexibility'. In this talk, we first give an illustrative example demonstrating that the extensions of the DLP proposed so far do not take into consideration the full potential of flexible products. Based on this observation, we formally derive and investigate the "value of flexibility'. We then propose a new DLP-based approach based on the idea to artificially increase the value of flexibility by increasing the revenue of flexible products within the linear approximations, leading to additional acceptance decisions. In order to determine the adjusted revenues, we use a simulation-based optimization method. Numerical examples show the potential benefits of the new approach in terms of achieved revenue.

3 - Optimal seat allocation for revenue management models with two substitutable resources

David Sayah, Chair of Logistics Management, Gutenberg School of Management and Economics, Johannes Gutenberg University Mainz, *Stefan Irnich*

In the airline industry, revenue management means controlling the process of selling shared seat inventory to heterogeneous customers. Traditionally, a product is fully specified by its resource-fare class combination. However, it has been observed that additional demand segments can be addressed through the sale of flexible products which enable airlines to allocate an accepted booking to a pre-defined set of resources. Here, analysis of optimal booking policies is not straightforward since flexible capacity control models with substitutable resources can, in general, not be reduced to multiple traditional models. Existing revenue management literature provides structural results for dynamic revenue management models with two resources and multiple fare classes, where accepted flexible customer requests are assumed to be assigned at the instant of their occurrence. Particularly, due to the propagation of certain structural properties of the value functions, switching-curves have been proved to be a proper means of optimal booking control in this setting. Our first result allows to derive a complete characterization of switching-curves in dynamic revenue management models with less effort using the concept of multimodularity. Moreover, we are able to extend the above result of switching control optimality to a static capacity control model with two resources and multiple fares. Due to its modelling assumptions, applying switching control is computationally more advantageous in the static than in the dynamic case. Furthermore, classical results such as nested seat allocations are shown to be preserved in this flexible environment.

■ WE-21

Wednesday, 17:00 - 18:30, Room F128

Revenue Management III

Chair: *Andreas Matzke*, Institute of Automotive Management and Industrial Production, Technische Universität Braunschweig

1 - Dynamic Pricing in öffentlichen Fahrradverleihsystemen

Henrik Heitmann, School of Business, Economics and Social Science - Institue for Operations Research, University of Hamburg, *Dennis Ahrholdt*

In öffentlichen Fahrradverleihsystemen werden Fahrräder an einer Vielzahl zugänglicher Stationen zur Verfügung gestellt. Die Entleihung und Rückgabe der Räder erfolgt dabei ausschließlich an diesen festen Stationen. Derartige Systeme sind in der Regel defizitär, speziell auch durch den häufigen und kostenintensiven Transport von Rädern zwischen den Stationen, die durch unausgewogenes und zeitlich variierendes Nachfrageverhalten nach Fahrstrecken notwendig werden, um einen ausreichenden Servicegrad an den Stationen zu gewährleisten. Nichtsdestotrotz ist ein geringer Servicegrad ein weiteres betriebswirtschaftliches Problem solcher Fahrradverleihsysteme. Die Verbindung von Dynamic Pricing zur situativen Anpassung von Fahrpreisen an den im Zeitablauf variierenden Räderbestand je Station mit der Möglichkeit (ggf.) monetäre Anreize für Kunden zu bieten, die Zielstation der geplanten Fahrstrecke zu ändern, könnte das Defizit verringern und den Servicegrad erhöhen. Zur Beurteilung der Vorgehensweise kommt eine Simulationsstudie zum Einsatz. Zunächst wird der Dynamic-Pricing-Ansatz eingeführt und mit empirischen Daten zum Kundenverhalten bei monetären Anreizen verknüpft. Im Rahmen der Simulation eines kleinen künstlichen Fahrradverleihsystems werden die Auswirkungen auf Kostenreduktion und Servicegrad untersucht. Erste Ergebnisse und numerische Analysen werden präsentiert und diskutiert.

2 - Auction-based coordination of retailers and manufacturer in the sale of configurable products

Andreas Matzke, Institute of Automotive Management and Industrial Production, Technische Universität Braunschweig, *Thomas Volling*, *Thomas Spengler*

We propose a mechanism to improve channel coordination in the sale of configurable products. Given a perishable capacity that limits the availability of a critical product option, the approach combines two selling mechanisms. In a first phase, the manufacturer offers the option at a static list price for the initial configuration of products by its retailers. In a second phase, excess capacity is offered to the retailers to upgrade existing configurations using an uniform-price auction. The duration of the auction, capacity and list price are exogenously given. Each retailer maximizes her own surplus, given her private expectation on the marginal revenue of adding the option to a product configuration. The retailer has to decide to either buy the option without risk at the list price or to participate in the auction. The auction might result in a lower price but participating retailers bear the risk of a losing bid. We formulate a game-theoretic model to derive an equilibrium strategy in retailer behavior. Based on this equilibrium strategy we provide a numerical study to analyze the expected supply chain surplus under various conditions. As compared to static list prices, the approach allows for improving the supply chain surplus. Under certain conditions both, the manufacturer and the retailers, benefit.

3 - An Integrated Approach to Pricing, Inventory, and Market Segmentation Decisions with Demand Leakage

Syed Asif Raza, Management and Marketing Department, Qatar University

Differentiated pricing is among the widely practised Revenue Management (RM) tactics in which a firm offers its products/services at differentiated prices to distinct markets. Earlier researches have shown that the benefits from differentiated pricing are evident when the market segmentation is assumed perfect which are regarded as distinct markets with deterministic demands. In perfect market segmentation customers associated with a market segment do not cannibalize (move) between market segments. However, it is not uncommon to notice that the market segmentation a firm exercises is seldom prefect, and due to imperfect segmentation customers cannibalize between market segments which is also referred as demand leakage. In addition to this, the demand is often uncertain, and thus a firm also experiences short sales and leftovers due to uncertain demand. This research addresses the issue of establishing an integrated framework to optimize price differentiation strategy, pricing, and order quantity for a firm that experiences demand leakage. The models to determine the optimal market segmentation strategy, pricing, and order quantities for a firm are developed facing price dependent deterministic demand, stochastic demand, and when the demand is stochastic, yet the distribution is unknown. The models are analyzed to identify the optimal pricing, order quantities, and price differentiation strategy. Numerical experimentation show that optimizing the price differentiation strategy (market segmentation) along with optimizing the joint pricing and order quantity decisions price significantly improve the revenue to a firm although it experiences customer cannibalization.

■ TD-21

Thursday, 14:00 - 15:30, Room F128

Revenue Management IV

Chair: *Sandra Transchel*, Kuehne Logistics University

1 - Airline Alliance Revenue Management — Current Practice and New Approaches

Max Gerlach, Information Systems, Freie Universitaet Berlin, *Catherine Cleophas*, *Natalia Kliewer*

Code-sharing, i.e. the concept of one carrier selling seats on flights operated by another carrier, plays a central role in today's airline business. The number of code-shared flights as well as the bookings on these flights is constantly growing, as we illustrate based on data collected at a large European carrier. At the same time, state-of-the art revenue management systems — a key component in the sales process of many airlines - do not incorporate code-sharing in their forecast and optimization methods. The first part of this talk considers current industry practice and highlights its implications on the revenue management process. We present several challenges arising in the practical implementation of airline alliance revenue management and relate them to recent theoretical advances in the field. The second part of the presentation suggests a game-theoretic framework to analyze alliance performance and introduces innovative approaches that incorporate these ideas in a realistic setting. Using stochastic simulations, benchmarks on the benefits of code-sharing are provided and used to evaluate the methods introduced previously.

2 - Frenemies: Price Competition Between Codesharing Airlines

Sandra Transchel, Kuehne Logistics University, *Robert Shumsky*

A codeshare agreement allows a flight operated by one airline to be marketed under another airline's name and flight number. Codesharing and other interline agreements allow airlines to expand their networks without additional capacity investments. We study a problem where two codesharing airlines operate parallel flights, i.e. flight legs between the same origin and destination that operate at roughly the same time. Because the flights are close substitutes the airlines are competing for many of the same customers. The airlines, however, are also cooperating by selling (codeshared) tickets on each others' flights. We formulate a closed-loop dynamic game under which each codeshare partner dynamically adjusts the prices for seats on its own flight as well as seats on its partner's flight. We capture consumer behavior using the multinomial logit (MNL) model. The rules for sharing the revenue generated by codeshared flights vary widely among airline partnerships. We use our model to examine the effectiveness of particular transfer fee schemes as well as the effects of those schemes on pricing behavior.

3 - Optimization of strategic flight ticket purchase

Kathrin Armborst, Faculty of Management and Economics, Ruhr-University Bochum, *Brigitte Werners*

Current results of Revenue Management and pricing policy research enable organizations to identify and realize optimal sale strategies and decisions. In response, enterprises which have to deal with the results of pricing policies are compelled to optimize their purchase. New developments in the aviation sector and airline industry along with a highly competitive flight ticket market and the importance of strategic purchase reveal the necessity of creating new solutions based on quantitative models. The evolution and implementation of a purchase strategy according to airline tickets is able to influence corporate profitability and perform activities due to pursue the overall business units' objectives. A decision-making process is outlined in order to support travel contract negotiations, an optimal supplier selection and allocation of flight tickets considering traditional airlines trade off against low-cost carriers, which provide less routes but usually lower costs. The short term decision for a certain airline product with lowest price may induce losses when volume discount margins are missed. In order to support in decision-making for a complex strategic purchase situation, different quantitative models under consideration of several airlines, different routes, unit- and revenue-based volume discounts, varying tiers and targets and corresponding dependencies are presented. Numerical examples and computational results are reported which demonstrate the influence and effects of volume discount implications and features on optimal purchase solutions. The analysis of characteristics referring to flight ticket purchase situations and integrated types of volume discounts provides the basis for further developments according to firms' strategic procurement.

■ FA-21

Friday, 9:00 - 10:00, Room F128

Revenue Management V

Chair: *Waldemar Grauberger*, Mercator School of Management, University of Duisburg-Essen

1 - Capacity allocation and pricing for take-or-pay reservation contracts

Mehdi SharifYazdi, Mathematical Sciences, Chalmers University of Technology and University of Gothenburg, *Hoda Davarzani*

This paper uses a bi-level optimization model to formulate a specific type of capacity reservation contracts, namely take-or-pay contracts, where a buyer reserves a portion of a supplier's capacity before demand is realized with discounted price. At first, we formulate the lower-level problem and solve a non-linear optimization model where a buyer decides on the amount of capacity to be reserved given the discounted and normal unit capacity price, demand probability distribution and maximum available capacity. Afterwards, we construct the upper-level model where there are a supplier and multiple buyers and the supplier must choose the discounted price and maximum available capacity for each of the buyers. We prove that the objective function is neither convex nor uni-modal in general. Therefore, at last, we create a bi-level meta-heuristic algorithm to find good solutions for the model.

2 - Advertisement Scheduling - Revenue Management with TV break preference-based cancellations

Michael Mohaupt, Dresden University of Technology, *Andreas Hilbert*

In broadcasting advertisements, commercial breaks (characterized by length, broadcasting time, price) are offered to heterogeneous clients with uncertain demand. The efficient utilization of its limited airtime inventory is a crucial success factor for the service provider. Therefore, the TV station has to decide simultaneously which requests to accept or to deny and when ad spots from accepted requests should be scheduled. In addition, there may be customers that have preferences for specific ad slots (time and weekday of airing, during or between specific TV shows, short vs. long slots) with cancellation rates depending on the provider's slot assignment decisions. The goal is to maximize total revenues over all TV breaks. But the traditional optimization problem does not account for these preferences possibly leading to the abortion of reservations or even relationships with the service provider - by strategically important customers in worst case. Therefore, we provide a mathematical model considering both combinatorial aspects of the problem and said customer preferences. Furthermore, a simulation is performed in order to test the efficiency of the proposed approach.

SCHEDULING AND PROJECT MANAGEMENT

■ WB-15

Wednesday, 11:30 - 13:00, Room F303

Project Scheduling I

Chair: *Carolin Kellenbrink*, Institut für Produktionswirtschaft, Universität Hannover

1 - Numerical Experiments of Randomized Approximation Scheme for Calculating Expected Length of Critical Path in Stochastic PERT Network

Jun Hioki, Department of Information and System Engineering, Chuo University, *Daisuke Yamaguchi*, *Tomomi Matsui*

The Program Evaluation and Review Technique (PERT) is a classical method of project management. PERT represents a project with a directed acyclic network whose arcs show tasks needed to complete. We set a length of an arc to duration of the corresponding task. A longest path in the obtained directed acyclic network is called a critical path. Stochastic PERT is a variation of PERT such that arc lengths are independent random variables. In this paper, we assume that each arc length follows a discrete uniform distribution defined on k possible values. In 2010, Yamaguchi and Matsui proposed a FPRAS (fully polynomial-time randomized approximation scheme) to estimate the expectation of the critical path length in a stochastic PERT network. Their algorithm is based on the Markov chain Monte Carlo method, which returns an approximate length of the critical path. They also proposed a perfect sampling algorithm for the critical path length. The expected running time of their algorithm is bounded by a polynomial of number of arcs (tasks) and k (number of possible values of each arc length). In this paper, we simplified their perfect sampler and implemented their algorithm. We give some results of numerical experiments and confirm the effectiveness.

2 - A Facility Layout Model for Resource Constraint Project Scheduling Problem

Hassan Taheri, Mathematics, Khayyam University, *Hossein Taghizadeh Kakhki*, *Hamed Reza Tareghian*, *Eric Taillard*

Resource constrained project scheduling problems (RCPSP), have been extensively studied. Many mathematical formulations for this problem including time indexed integer programming and 0-1 linear programming formulations, packing models, a constraint integer programming approach, and event based MILP models have been presented. Here we consider the problem with one resource and a single mode as a facility layout problem, and cast the problem as a two dimensional strip packing problem similar to the one previously discussed by Schrage (1970) and Hartmann (2000). We then present a new formulation based on the models used for the facility layout problem by van Camp et.al. (1991). Extensions to multiple resources and modes are also discussed, and computational results are presented. We also developed a computer application for generating random RCPSPs by considering Coefficients of Network Complexity and Complexity Index.

3 - First results on resource-constrained project scheduling with model-endogenous decision on the project structure

Carolin Kellenbrink, Institut für Produktionswirtschaft, Universität Hannover

In projects with alternative modalities, the jobs that actually have to be executed are not known beforehand, i.e. the project structure is unknown. However, established formulations of the resource-constrained project scheduling problem (RCPSP) assume the project structure to be given in advance. In this talk, the RCPSP is extended by a model-endogenous decision on the project structure in order to include those alternative modalities. The requirements on the project structure decision problem are explained and it is shown that this problem occurs, e.g., with scheduling the turnaround at airports. As a solution approach aspects of a genetic algorithm are presented.

■ WC-15

Wednesday, 14:00 - 15:30, Room F303

Scheduling

Chair: *Rainer Leisten*, Operations Management, University Duisburg-Essen in Duisburg

1 - Minimizing Weighted Earliness and Tardiness on Parallel Machines Using a Multi-Agent System

Sergey Polyakovskiy, Information Process Engineering (IPE), FZI Forschungszentrum Informatik an der Universität Karlsruhe, *Rym M'Hallah*

We address the weighted earliness and tardiness parallel machine scheduling problem (WETP) where jobs have different processing times and distinct due dates. This NP hard problem is very important and frequent in just-in-time production environments. We solve it using an agent technology. Opposite to traditional optimization approaches which solve a problem through a sequential or iterative or treelike process and are therefore centralized, multi-agent based methods solve it in a decentralized manner. Decentralization makes the problem partitioned into a number of simpler components which are delegated the process of distributed solution construction. The components, which are agents, are endowed with a state, decision rules, and goals. Each agent employs the most appropriate paradigm for solving its own problem: at every time epoch, it assesses the potential of available actions and uses one that optimizes its reward. Striving to achieve its goal, each agent contributes to the improvement of the overall objective function and influences the final result. Thus, the activities of the agents define the solution process' dynamics. We develop a multi-agent system (MAS), apply it to WETP, investigate its performance, and highlight its advantages. The intelligent agents of MAS are related to free jobs or to groups of already assigned jobs while the idle times of parallel machines play the role of resources. The agents choose their actions based on "if-then" decision rules strengthened by MIP-based local search and timing algorithms. MAS federates the agents' decisions via a special competition and negotiation based model. Computational results show the competitiveness of MAS which obtains better local optima than state-of-the-art approaches within far reduced run times.

2 - Scheduling a flow-shop with simultaneously loaded stations

Frank Herrmann, Innovation and Competence Centre for Production Logistics and Factory Planning, University of Applied Sciences Regensburg

In recent years, a considerable amount of interest has arisen for the no-buffer flow-shop scheduling problem. Technological restrictions may reduce the set of feasible schedules even more. As an example transportation limitations are presented, so that the products are only moved from one station to the next at the end of a cycle; the cycle time is the maximum of the durations of the jobs in a cycle. A survey about existing algorithms solving the no-buffer flow-shop scheduling problem is presented; normally the makespan is minimised. Since this scheduling problem is integrated in the usual hierarchical planning, the tardiness is minimised. This NP-hard problem is solved by priority rules, identified as successful in literature, because of a high number of jobs and an addressed dynamic environment. Due to the load-restriction, the duration of a job A on the flow-shop depends on the other jobs processed on the flow-shop in the same cycle. Realistic processing times are achieved by a simulation of the scheduling of A which includes the next jobs until A has left the flow-shop. The usage of such realistic processing times instead of net processing times improves the priority rules by around 16%. Experiments show that a class of rules achieves a small value of the average tardiness, but under high pressure produces very large delays of a small fraction of the jobs. Another class avoids excessive delays at the expense of a markedly increased average tardiness. With exponential weighting of the slack the best results are achieved. There are pools of jobs where a large variance of the cycle times is beneficial and pools of jobs where a small variance is better. This is partially detected even by the best rule. Outliers of the cycle times occur and their occurrence is analysed.

3 - Uniformity in (flowshop) machine scheduling — An alternative objective function

Rainer Leisten, Operations Management, University Duisburg-Essen in Duisburg

Uniformity is an important issue in production and service systems. Lean management approaches, e.g., might be dominated explicitly or implicitly by uniformity considerations. However, there is a large variety of clues to define, identify, manage and control uniformity in manufacturing systems. In machine scheduling, to the best of our knowledge, aspects of uniformity have been addressed only to a very limited extent, e.g. when discussing completion time variance (CTV) as objective function. We introduce a new objective function referring explicitly to a specific kind of uniformity in scheduling and give some results of interpreting this objective function in a flowshop setting. However, all results might be transferred to more general machine scheduling settings as well as to scheduling aspects in supply networks.

■ WE-15

Wednesday, 17:00 - 18:30, Room F303

Project Scheduling II

Chair: *Julia Rieck*, Operations Research Group, Clausthal University of Technology

1 - PERT is dead!

Wolfgang Tysiak, FB9 Wirtschaft, FH Dortmund

The well known PERT method was introduced in project management more than 50 years ago to show a way of how to use distributions for the estimates of the durations of the different tasks of a project. Up to now it is also still explained in most of the common textbooks about project management — but unfortunately it does not offer the results it claims. Or to say it more frankly: The results are just wrong! PERT systematically underestimates the duration that is needed to complete a project! This can easily be shown even in very simple examples. But this systematic underestimation of the duration leads to the worst case that could happen in practice: The underestimation of the real risk! The experience that in practice the use of distributions of durations only has a low acceptance is therefore quite reasonable: Using a method that produces systematically wrong results leads to the conviction that the whole approach of using distributions makes no sense. With this the use of PERT has even damaged the whole stochastic approach in the duration planning of a project. But the stochastic approach is still very useful! You just have to use the appropriate tools. One of these tools is the Monte Carlo approach. The main purpose of this contribution to this conference is to show that the PERT approach really does not work and what can be done instead.

2 - Planning and Scheduling in project management under vagueness

Wolfgang Anthony Eiden

Projects are often characterized by complexity, singularity, novelty, and interdisciplinary. This results in vagueness that is unknown in traditional scheduling, e.g. in industrial production. Examples of this vagueness are vagueness in temporal aspects, preferences, and evaluations. Hence, scheduling in project management is subjected to conditions other than classical scheduling. Thus, the corresponding methods and their solutions are not directly portable. Nevertheless, methods based on crisp data and conditions are mainly used in the practice of project management. Real-existent inherent vagueness is frequently ignored. There exist just few approaches considering vagueness of non-stochastic origin. Unfortunately, those approaches are often too theoretical for practical applications. A holistic approach - i.e. an approach considering vagueness starting with modeling through processing and appraisement of results - does not yet exist in literature. Besides this topic there are also other issues to scrutinize in the state-of-the-art methods concerning project management. These issues include the modeling approaches (especially from the point of view of project managers), assumptions about the quality of information, dealing with conflicts of objectives, and concerns like transparency, understandability and flexibility. This talk demonstrates that for scheduling in project management under vagueness, a practical, applicable, holistic approach is possible which can be an opportunity for scheduling closer to reality. The purpose of this talk is to show how theory and practice can be linked considering the particular conditions in project management.

3 - MIP formulations for solving the total adjustment cost problem

Stefan Kreter, Clausthal University of Technology, *Julia Rieck*, *Jürgen Zimmermann*

We discuss project scheduling problems subject to general temporal constraints, where the fluctuation of resource utilizations within the planning horizon is to be minimized (resource leveling). Particularly, we consider a special resource leveling objective function that coincides with the cumulative costs arising from increasing or decreasing the requirements of resources. The resulting "total adjustment cost" function has achieved little attention in the academic literature, although it seems to be of considerable importance in practice. An interesting application of resource leveling that substantiates the total adjustment costs occurs if the resources represent different kinds of manpower and the people must be brought to their workplaces using expensive means of transportation, e.g. airplanes, helicopters or boats. First, we discuss structural properties of the problem. In contrast to the classical resource leveling objective function, the total adjustment cost function is not r-monotone which leads to relatively weak lower linear programming bounds. Furthermore, positive jumps in the resource requirements can only occur at points in time at which at least one real activity is started. This property is used in an entirely new MIP formulation. Altogether, we present three different mixed-integer linear programming formulations. The second one is based on a discretization of the time horizon and the third one is adapted from an event-based MIP formulation that was developed for the RCPSP. In order to strengthen the formulations, upper bounds for the adjustment of resource requirements at particular points in time are applied. In a comprehensive performance analysis we use CPLEX 12.4 to solve medium-scale instances with different project deadlines.

■ TA-15

Thursday, 9:00 - 10:00, Room F303

Recent Results in Scheduling

Chair: *Nicole Megow*, Max-Planck-Institut für Informatik

1 - Models and bounds for preemptive project scheduling with generalized precedence relationships

Christoph Schwindt, Institute of Management and Economics, Clausthal University of Technology, *Tobias Haselmann*

We study a resource-constrained project scheduling problem where the activities can be interrupted at any point in time during their execution and generalized precedence relationships between the activities have to be taken into account. The precedence relationships define minimum and maximum time lags between points in time when given parts of the activities have been executed. Whereas there exists a considerable body of papers dealing with the case of job preemptions in machine scheduling, preemptive project scheduling has received much less attention. On the other hand, there exist many practical scheduling problems where resource units have to be allocated to divisible activities over time. After providing a formal problem statement, we reduce the problem to a canonical form only containing nonpositive completion-to-start minimum time lags. Next, we develop a novel MILP formulation that encodes a schedule as a sequence of time slices with associated sets of activities that are in progress during the respective slice. Moreover, we consider an optimization model that combines a large-scale linear program with a single machine scheduling problem. The linear program contains one decision variable for each feasible antichain of the precedence order induced by the generalized precedence relationships. Finally, we report on the results of an experimental performance analysis comparing upper bounds obtained with the MILP model and lower bounds that arise from solving the linear program by a column generation procedure.

2 - Nearly optimal solutions for universal sequencing problems

Nicole Megow, Max-Planck-Institut für Informatik

Dual-value sequencing with an unknown covering or packing constraint appears as a core subproblem, e.g., when scheduling on an unreliable machine or when determining a universal knapsack solution. A sequence is called alpha-robust when, for any possible constraint, the maximal or minimal prefix of the sequence that satisfies the constraint is at most a factor alpha from an optimal packing or covering. It is known that the covering problem always admits a 4-robust solution, and there are instances for which this factor is tight. For the packing variant no such constant robustness factor is possible. In this work we aim for more meaningful, instance-dependent robustness guarantees. We present an algorithm that constructs for each instance a solution with a robustness factor arbitrarily close to optimal. This implies nearly optimal solutions for universal knapsack and scheduling on an unreliable machine. The crucial ingredient is an approximate feasibility test for dual-value sequencing with a given target function. This result may be of independent interest. We show that deciding exact feasibility is strongly NP-hard, and thus, our test is best possible, unless P=NP.

■ TC-14

Thursday, 11:30 - 13:00, Room F435

Scheduling Theory

Chair: *Nicole Megow*, Max-Planck-Institut für Informatik

1 - A New Approach to Online Scheduling: Approximating the Optimal Competitive Ratio

Elisabeth Günther, Institut für Mathematik, TU Berlin, *Olaf Maurer*, *Nicole Megow*, *Andreas Wiese*

This talk is about the novel concept of online approximation schemes—a new approach to competitive analysis in online scheduling. Such a scheme algorithmically constructs an online algorithm with a competitive ratio arbitrarily close to the best possible competitive ratio for any online algorithm. The technique is best explained for the problem of scheduling jobs online to minimize the weighted sum of completion times on parallel machines. It can be generalized to related and unrelated machine settings as well as to arbitrary monomial cost functions and the makespan objective. Our method relies on an abstract characterization of online algorithms combined with various simplifications and transformations. The derived (deterministic and randomized) algorithms are almost best possible among all online algorithms of the respective settings. We also contribute algorithmic means to compute the actual value of the best possible competitive ratio up to an arbitrary accuracy. This strongly contrasts all previous manually obtained competitiveness results for algorithms and, most importantly, it reduces the search for the optimal competitive ratio to a question that a computer can answer.

2 - Robust Appointment Scheduling

Sebastian Stiller, TU Berlin

We consider the problem of appointment scheduling in a robust optimization framework. The appointment scheduling problem arises in many service operations as well as in basic timetable problems. Our model is in particular motivated by scheduling for resources with high investment costs, e.g., an operation theater in a health care facility. For each job, we are given its minimum and maximum possible execution times. The objective is to find an appointment schedule for which the cost in the worst case realization of the processing times of the jobs is minimized. In our model the cost is comprised of a delay cost for each job starting later than scheduled, and an opportunity cost whenever the resource is left idle. This leads to a new model of robustness with practical and theoretical advantages against classic robust optimization models. We present a global balancing heuristic, which gives an easy to compute closed form optimal schedule when the opportunity costs of the jobs are non-decreasing. Unlike prior stochastic work this closed form solution allows to optimize the order of execution of the jobs, too. Here we give simple heuristics to find a near-optimal sequence of the jobs.

3 - Non-Preemptive Speed Scaling

Antonios Antoniadis, Institut für Informatik, Humboldt Universität zu Berlin, *Chien-Chung Huang*

We consider the following variant of the speed scaling problem introduced by Yao, Demers, and Shenker. We are given a set of jobs and have a variable-speed processor, which is associated with a power function, to process them. The higher the processor speed, the higher the energy consumption. Each job is associated with its own release time, deadline, and processing volume. A schedule is said to be feasible if the volume of each job is completely processed not before its release time but before its deadline. The objective is to

find a feasible schedule that minimizes the energy consumption. Moreover, no preemption of jobs is allowed. Unlike the preemptive version that is known to be in P, the non-preemptive version of speed scaling is strongly NP-hard. In this work, we present a constant factor approximation algorithm for it. The main technical idea is to transform the problem into the unrelated machine scheduling problem with Lp-norm objective.

■ TC-15

Thursday, 11:30 - 13:00, Room F303

Scheduling Applications I

Chair: *Sigrid Knust*, Institute of Computer Science, University of Osnabrück

1 - A genetic algorithm for the slab scheduling problem

Matthias Wichmann, Institute of Automotive Management and Industrial Production, Technische Universität Braunschweig, *Thomas Volling*, *Thomas Spengler*

We propose a genetic algorithm for the problem of scheduling slabs at continuous casters. Since more than 95% of the worldwide produced steel is continuous casted, slab production at continuous casters is the central process in the steel industry. The determination of a sequence to produce slabs requires solving a combined lot sizing and scheduling problem, which can be formulated as MILP (see Wichmann et al., 2012). This MILP is unique in terms of four specific requirements which comprise flexible job specifications, continuously adjustable in-situ control parameters, material supply in batches and different types of machine setups. To solve the MILP, we propose a genetic algorithm, incorporating crossover, mutation and selection operators. The most special feature of the approach is the handling of the problems' characteristics in each of the operators. Thus, crossover as well as mutation operators take the material supply in batches into account. The selection operators aim to keep diversity within the evolving population. We analyze the performance of the approach in a numerical case study with known numerous data sets generated from real world data. To evaluate the performance, we compare the solutions to a given lower bound as well as reference solution procedures. As a result, for problems of real world size solutions with an average gap to the lower bound with less than 20% can be obtained within reasonable computing time.

2 - Two Dedicated Machines Scheduling Problem in Two-Sided Assembly Lines

Evgeny Gafarov, Institute of Control Sciences of the Russian Academy of Sciences, *Alexandre Dolgui*

Two dedicated parallel machines scheduling problem with precedence constraints to minimize makespan is considered. Given a set N of n jobs that must be processed on two parallel machines. Jobs from the subset N1 have to be processed on the first machine, jobs from N2 on the second one. All the jobs are assumed to be available for processing at time 0. For each job j a processing time is known. Furthermore, arbitrary finish-start precedence relations are introduced between the jobs according to an acyclic directed graph G. The objective is to determine the starting time in such a way that the given precedence relations are fulfilled and the makespan (the maximal completion time) is minimized. This problem originally appeared as a sub-problem of the well-known two-sided assembly line balancing problem (TSALBP-1). Denote this problem P2|N1,N2,prec|Cmax. The following Lemmas are proven: Lemma 1. A special case of the problem P2|N1,N2,chain|Cmax is NP hard in the strong sense, where G consists only chains of jobs. Lemma 2. A simple assembly line balancing problem(SALBP-1) can be reduced P2|N1,N2,chain|Cmax in polynomial time. Lemma 3. A special case with equal-processing-times of jobs P2|N1,N2,p_j=1|Cmax is NP hard in the strong sense. Lemma 4. The problem P2|N1,N2,prec|Cmax –> max with opposite optimization criterion is NP-hard in the strong sense. We showed as well that List Scheduling Algorithm with some domination rules (Critical Path, Largest Processing Time, etc.) has an approximation ratio almost equal 2.

3 - Tabu Search and Lower Bounds for a Combined Production-Transportation Problem

Sigrid Knust, Institute of Computer Science, University of Osnabrück, *Alessandro Condotta*, *Dimitri Meier*, *Natalia Shakhlevich*

We consider a combined production-transportation problem, where n jobs have to be processed on a single machine at a production site before they are delivered to a customer. At the production stage, for each job a release date is given; at the transportation stage, job delivery should be completed not later than a given due date. The transportation is done by m identical vehicles with limited capacity. It takes a constant time to deliver a batch of jobs to the customer. The objective is to find a feasible schedule minimizing the maximum lateness. After formulating the considered problem as a mixed integer linear program, we propose different methods to calculate lower bounds. Then we describe a tabu search algorithm which enumerates promising partial solutions for the production stage. Each partial solution is complemented with an optimal transportation schedule (calculated in polynomial time) achieving a coordinated solution to the combined production-transportation problem. Finally, we present results of computational experiments on randomly generated data.

■ TD-14

Thursday, 14:00 - 15:30, Room F435

New Scheduling Models and Algorithms

Chair: *Dirk Briskorn*, University of Siegen

1 - Multiprocessor scheduling with availability constraints

Liliana Grigoriu, Operations Research / Control and Computers, University Siegen / Politehnica Univ. Bucharest

When scheduling on parallel machines, these may exhibit periods of unavailability, due to maintenance or failures, or due to jobs that must be executed at certain predefined times. We consider the problem of non-preemptively scheduling a given set of tasks on identical processors with periods of unavailability to minimize the maximum completion time. This problem is strongly NP-hard, thus polynomial approximation algorithms are being studied for its solution. Often considered approximation algorithms for multiprocessor scheduling and generalizations thereof are LPT (largest processing time first) and Multifit with their variants. We give a simple polynomial Multifit-based algorithm, the schedules of which end within 1.5 the maximum between the end of the optimal schedule and the latest end of a downtime. Even when there is at most one downtime on each machine, no polynomial algorithm can insure a better worst-case bound for this problem unless P=NP. For the case when there is at most one downtime on each machine we also present a simple LPT-based algorithm which has the same property, and for the case when there are at most two downtimes on each machine we present another Multifit-based algorithm which has it as well. We also give details of the upper bound proofs.

2 - A new algorithm and complexity results for the Traveling Repairman Problem

Stefan Bock, WINFOR (Business Computing and Operations Research) Schumpeter School of Business and Economics, University of Wuppertal

This talk considers a special case of the well-known Traveling Repairman Problem. In this problem a predefined number of customers that are located on a straight line at different given locations have to be serviced under predetermined time restrictions. Specifically, while processing times at the customer locations are neglected, each customer has to be serviced not before a predetermined release date and, depending on the considered problem variant, not after a given due date. The objective function pursues the finding of schedules that minimizes the weighted sum of job completion times. Clearly, the basic structure of this problem applies to various applications in production and transportation. For instance, typical applications are just-in-time material supplies of specifically located production systems along predetermined transportation paths as well as distribution processes of customers that are located along a shoreline. In this talk, the complexity status of different problem variants is examined. In order to solve the problem, a new best first Branch&Bound approach is proposed. Its efficiency is validated by means of computational tests. Specifically, the performance of different lower bounds and dominance rules is analyzed for various scenarios and test instances with different numbers of customers and locations.

3 - A Branch and Bound approach for a single machine environment with sequence-dependent setup times and inventory constraints

Paul Göpfert, WINFOR (Business Computing and Operations Research) Schumpeter School of Business and Economics, University of Wuppertal, *Stefan Bock*

By reducing buffers along the automotive supply chain, automotive suppliers are forced to efficiently handle a significantly higher number of smaller customer orders and material supplies. Moreover, the adoption of mass customization by the manufacturers results in a considerable product variety even for one functional components at the automotive supplier site. In order to fulfill customer demands efficiently and to cope with the increasing variety in the product portfolio under these adversely conditions, sophisticated production scheduling approaches have to be applied. In this talk, a real-world production process is considered that can be modeled as a single machine scheduling problem with sequence-dependent setup times. Moreover, inventory constraints for needed components and materials are integrated. Two different objectives are pursued and evaluated. In order to provide a high service level demanded by the customers, the first objective function pursues the minimization of the total weighted tardiness. Alternatively, by minimizing the total weighted completion time, the second objective function seeks the finding of schedules that attain large throughputs with a high production efficiency. In order to generate optimal schedules, we propose a new sophisticated branch and bound approach. By using multiple dominance rules and different bounding schemes, even instances of larger size can be solved to optimality in reasonable time. Furthermore, the method makes use of a special preemptive schedule handling. In this talk we give an overview on first computational results validating the performance of the proposed algorithm.

■ TD-15

Thursday, 14:00 - 15:30, Room F303

Scheduling Applications II

Chair: *Takashi Masuko*, Department of Information and System Engineering, Chuo University

1 - Scheduling the Professional Baseball League of Japan

Takashi Masuko, Department of Information and System Engineering, Chuo University, *Tomomi Matsui*

Baseball is one of the most popular sports in Japan with large attendance. There are two baseball leagues in Japan, which are called Central League and Pacific League, respectively. This paper deals with a problem for finding schedules in Pacific League. There are 6 teams in Pacific League. Every year, each team plays 144 games consisting of 120 league games (24 games against 5 teams in Pacific League) and 24 interleague games (4 games against 6 teams in Central league). The annual number of audience of league games is over seven million. Schedules for Pacific League are prepared by ad hoc procedures. We discuss a problem for constructing a schedule which maximizes attendance of league games. We examined the number of gate receipts of every team in 2010 and guessed how many audiences could be expected by using a method of linear regression analysis. We divided one season into four periods and constructed a schedule for each period independently. We formulate the problem as an integer linear programming problem and solved by commercial software. As a result, we obtained schedules for all the periods whose total expected attendance increase to more than eight million.

2 - Designing Innovative Financial Services by using manufacturing procedures

Maria Mavri, Business Administration, University of the Aegean

Nowadays, the global economic crisis has changed rapidly the financial system and the way that financial markets operate. Financial institutions are forced to change their operational systems in order to handle the huge number of changes that are provoked both by external factors, such as deregulation, technology, growing competition etc and by the increased and exigent needs of their customers. In this study we borrow methods, tools, systems from the manufacturing industry and we try to employ them in a service organization. In other words we suggest that systems like "Just in Time' or "Job Shop', could significantly be used in service operations in order to design and provide a new/innovative product or service. We claim that manufacturing procedures can be used to facilitate managers to allocate tasks to people, to design services and instruments, to develop a more efficient structure for providing their customers with "tailor made' products. We suggest that applying procedures from manufacturing to service operations could improve the efficiency of financial institutions and upgrade the quality of products which are offered to their clients. More specifically a range of innovative services would be available to customers, if an institution changes the used methods of products preparation. The scope of the paper is to develop a framework that (a) implements manufacturing procedures to service industry in order to produce innovative services and (b) measures the increasing or decreasing impact of this achievement in institutions' efficiency.

3 - Design and Implementation of a Decision Support System for Complex Scheduling of Tests on Prototypes

Tim A. Rickenberg, Institut für Wirtschaftsinformatik, Leibniz Universität Hannover, *Hans-Jörg von Mettenheim*, *Michael H. Breitner*

Timing and allocation of resources for testing prototypes is a complex problem. Often hundreds of tests (hardware as well as software tests) have to be performed on a technical product before it can go into mass production. In this context, resources are limited: Next to a limited number of prototypes, a given number of testers with different sets of skills have to perform various tests with limited testing equipment within a certain period of time. It is necessary to assign tests to equipment and testers according to their availability. Tests have to be put in an appropriate order. For this complex task, decision support is needed in order to accelerate the manual planning process and the actual testing phase. Shortening the total test time can reduce costs and helps in achieving the start of production (SOP). For scheduling tests on prototypes, we design, implement, and evaluate a decision support system (DSS). More precisely, our DSS enables the scheduling of tests on network components. With given sets of real world data of a leading manufacturer of data transmission systems, we suggest a formal description of the problem. We apply operations research (OR) methods to solve the underlying formal model and to generate optimized test sequences. Due to problem size and the number of variables and restrictions, we use heuristic methods in a multi-stage algorithm. The scheduling algorithm combines several heuristics in order to minimize the multi-criteria objective function. The graphical user interface (GUI) allows the user to interact with the DSS and to configure the optimization process. Also, the GUI can output scheduling results and timetables to screen and files in html or xls format.

■ FA-14

Friday, 9:00 - 10:00, Room F435

Scheduling and Practice

Chair: *Sigrid Knust*, Institute of Computer Science, University of Osnabrück

1 - Down-time minimization in electricity network maintenance

Frank Meisel, Martin-Luther-University Halle-Wittenberg, *Asvin Goel*

We consider a routing and scheduling problem of workers that perform maintenance jobs in electricity networks. The goal is to find work plans that minimize the total down-time of those sub-networks that have to be shut down for the maintenance operations. Since a job can comprise multiple tasks, minimizing its down-time means to minimize the difference between the earliest start time and the latest completion time among its tasks. This requires a careful scheduling of worker activities with respect to the processing times of maintenance operations, the travel times between geographically dispersed task locations, and the skills of maintenance workers. We propose for this problem two mixed-integer programming models. An arc-based routing model is used in case of a homogeneous worker team whereas a more complex second model also supports heterogeneous workers. For solving large instances of the problem, we combine a Large Neighborhood Search that delivers routes for the workers (sequences of maintenance tasks) with a scheduling stage that is either solved by a forward-backward iteration heuristic or by an exactly solved LP. Both approaches are assessed with respect to the involved computational effort and the achieved solution quality. The complete planning approach is evaluated using data provided by a large electricity company, which operates a network of about 7000 facilities in central Germany.

2 - A general classification scheme for integrated staff rostering and scheduling problems

Mareike Paul, University of Osnabrück, *Sigrid Knust*

We consider integrated staff rostering and task scheduling problems. While scheduling problems and staff rostering problems are well researched in the OR-community, their combination is considered seldom. Nevertheless, the problem is relevant for applications like production, as solutions of this problem do not only schedule tasks of projects, but also design feasible staff rosters and assign employees to the tasks. In this talk we present a new classification scheme for these combined problems, generalising existing classification schemes for project and maschine scheduling. Based on this classification we will show some elementary reductions and determine the border between polynomially solvable and NP-hard problems.

■ FA-15

Friday, 9:00 - 10:00, Room F303

Scheduling and Rostering

Chair: *Marco Lübbecke*, Operations Research, RWTH Aachen University

1 - Examination Timetabling with Invigilator Criteria

Carl-Friedrich Klinck, Department of Business Studies & Economics, Chair of Logistics, University of Bremen, *Tobias Buer*, *Herbert Kopfer*

Models of examination timetabling problems at universities usually focus on the student perspective. That is, exams are to be scheduled such that examination dates are well spread with respect of the schedules of individual students. However, the interests of the invigilators, i.e. research assistants who watch the exam candidates to prevent cheating, are often neglected. To overcome this deficit we extend a well-known examination timetabling model used during the Second International Timetabling Competition 2007. That is, we take into account different preferences of invigilators for different time slots, a heterogenous number of invigilation hours per research assistant (e.g. depending on career level or financing status), and we allow different seating arrangements. The latter may lead to a reduction in the number of required rooms and thus the number of required invigilators. Nevertheless, for this reason the quality of the exam schedule from the students point of view might decline. In order to reflect a schedule's quality additionally from the invigilators point of view, we use a second, lexicographic weighted objective function. In a first attempt, the extended model with two lexicographic objective functions is solved by variable neighborhood search. By means of a computational study we compare the performance of different neighborhood structures and study factors that make the problem hard to solve.

2 - Appointment Scheduling in a Hospital Environment

Sarah Kirchner, Operations Research, RWTH Aachen, *Marco Lübbecke*

Currently appointments for patients are scheduled locally in most german hospitals. In every hospital unit a scheduler assigns appointments sequentially to incoming treatment requests. As the settlement amount for a patient is determined by his diagnoses and received treatments and not by the length of his hospitalization it is desirable for hospitals to reduce the average length of hospitalization. Therefore it is necessary to coordinate appointments for all treatments on a patients care pathway. This problem can be seen as a new variant of the well known job shop scheduling problem where patients correspond to jobs and treatments for patients correspond to tasks of jobs. The problem is also related to scheduling problems with calendars, as resources in a hospital are mostly not available at night and treatments can not be interrupted when the resource becomes unavailable. The objective of our problem is to minimize the average number of days of hospitalization. In this talk we introduce this new scheduling problem and present first models and solution approaches.

SIMULATION AND SYSTEM DYNAMICS

■ TA-20

Thursday, 9:00 - 10:00, Room B302

Strategic Management and Innovation Processes

Chair: *Bo Hu*, Department of Management, Universität der Bundeswehr München

1 - System Dynamics und Agenten-basierte Modellbildung im strategischen Personalmanagement

Joachim Block, Institut für Theoretische Informatik, Mathematik und Operations Research, Universität der Bundeswehr München

Leistungsfähiges und leistungsbereites Personal ist einer der Erfolgsfaktoren für jede Organisation. Der demografische Wandel und der „Kampf um die Talente" stellen besondere Herausforderungen an das strategische Personalmanagement. Nachhaltige Entscheidungen in diesem Bereich bedingen eine Antizipation und Analyse der zukünftigen Entwicklung des Personalkörpers. Simulationsmodelle können strategische Entscheidungsprozesse wirksam unterstützen. Einerseits wird das Verständnis über Abhängigkeiten und Einflussgrößen in einem System gefördert. Andererseits lassen sich Handlungsalternativen ohne Gefahr für das reale System und im Zeitraffer bewerten. Der Personalkörper einer Organisation befindet sich durch Auf- und Ausstiege in einem stetigen Fluss. Die Modellierung derartiger Veränderungen ist ein typisches Einsatzgebiet von System Dynamics (SD). Andererseits zeichnen sich die Beschäftigten durch einen eigenen Willen und individuelles Verhalten aus. Mit Hilfe der Agenten-basierte Modellbildung und Simulation (ABMS) kann dies virtuell nachgebildet werden. Durch die Integration von SD und ABMS lassen sich möglicherweise neue Einsichten für das strategische Personalmanagement generieren. Basierend auf den Beförderungsketten im öffentlichen Dienst wurde ein Demonstrator erstellt, der die unterschiedlichen Sichtweisen von SD und ABMS in einem Modell zusammenführt. Mit SD werden die Beförderungspositionen und -regeln als Speicher und Flüsse modelliert. Die betroffenen Elemente (Bedienstete) und deren Verhalten werden ergänzend durch ABMS abgebildet. Es zeigt sich, dass die Integration möglich ist und nutzbringend für das strategische Personalmanagement im öffentlichen Dienst sein kann.

2 - A business simulation game in innovation management education: Lessons learnt

Markus Günther, Department of Business Administration and Economics, Bielefeld University, *Christian Stummer*

Business simulation games provide an excellent opportunity for participants to assume the role of decision-makers and, thus, to obtain valuable first-hand experience in a "safe' artificial environment. This is of particular value in a field such as innovation management, which usually involves substantial risk, significant time lags between a managerial decision and its effects, and in which large amounts of resources are at stake. Since back in 1996 no proper simulation has been available with an emphasis on innovation management aspects, the business simulation game MERLIN needed to be developed from scratch. It focuses on planning of research and development (R&D) investments, anticipation of market demand for existing products and introducing new products in a competitive market. Over the past decade, the model and the software tool have evolved in various ways (e.g., with respect to its applicability in both offline and online settings). MERLIN has been used in several courses at universities in Austria and Germany with extraordinarily favorable student evaluations in all instances. In our talk, we will describe the underlying didactical concept, introduce the most prominent features of MERLIN, and discuss their impact in class. Thus, we aim to share our experiences with business simulation games in general and MERLIN in particular as an effective tool in innovation management education.

■ TC-20

Thursday, 11:30 - 13:00, Room B302

Energy Markets

Chair: *Grit Walther*, School of Business and Economics, Chair of Operations Management, RWTH Aachen

1 - Residential Balancing of Energy Supply and Demand

Martin Bock, Schumpeter School of Business and Economics, Chair of Production and Logistics, Bergische Universität Wuppertal, *Grit Walther*

Power demand of private households shows daily fluctuations and is expected to rise with the introduction of power intense technologies like battery electric vehicles and heat pumps. This additional demand, especially when it remains unmanaged, may even lead to an increase in fluctuations. To balance demand, price incentives and direct control of devices — known as demand side management (DMS) — may be deployed by utilities. Against this background, the aim of this paper is to present a model of household energy demand under consideration of demand side management. The model considers both, a structural as well as a behavioral level. On the structural level, energy usage and flows are modeled as a mathematical network flow problem. The model allows for usage of provided energy (electricity, gas) in order to cover energy demand of private households (devices for lighting, heating, cooling, E-mobility). Energy can be converted (e.g. by CHP) or stored (battery, heat). Energy demand of certain devices can also be reduced or shifted. The behavioral level is represented as an agent-based simulation, where utilities as well as (heterogeneous) consumers are modeled as interacting agents. While the utilities send prices and signals for direct control of devices, the households respond with their energy demand. Thereby, households can react to price changes by adjusting their energy demand patterns (reduction, shifting) based on their objective function and the incentives given. This paper is structured as follows: First, a brief motivation is given. Then, DSM as an instrument is described. Finally, the model is presented and first results of the simulation are discussed.

2 - Market Penetration of Alternative Fuel Vehicles in Iceland: A Hybrid Modeling Approach

Hlynur Stefansson, School of Science and Engineering, Reykjavik University, *Ehsan Shafiei*, *Eyjolfur Asgeirsson*, *Brynhildur Davidsdottir*

The transition towards a sustainable alternative fuel vehicle system is a complex process, which requires a comprehensive analysis of the interaction between energy supply system and transportation sectors. In this paper, an integrated agent-based (AB) and system dynamics (SD) model is developed to study the market share evolution of light duty vehicles in Iceland. The model takes into account the conventional internal combustion engine vehicles that are currently dominant in the market and the alternative fuel vehicles including various types of electric vehicles, bio-fuels, CNG and fuel cell vehicles. SD approach is used to simulate the development of continuous, homogenous and macro-level variables of energy supply system over time. On the energy system side, possibilities to switch from conventional to alternative fuels are evaluated. The AB approach is employed to study the consumer behaviors and market share evolution of passenger vehicles. Different vehicles compete for market penetration through a vehicle choice algorithm that accounts for social influences and consumers' attractiveness for vehicle attributes. The linking variables between AB and SD components are identified and then these two bottom-up and top-down approaches are integrated together to provide a comprehensive framework. The main results provided by the application of this modeling approach for the case study of Iceland energy and transport sectors are market share evolution of various vehicle types and consumers' fuel demand during the period 2013-2040.

3 - IT-Based Decision Support for Turning on Germany's energy transition - The Impact of the Nord.Link : Complex Decision Support with System Dynamics

Bo Hu, Department of Management, Universität der Bundeswehr München, *Armin Leopold*, *Stefan Pickl*

This contribution focusses on an innovative IT-based decision support concept for turning on Germany's energy transition. Considering the historical development of renewable energy in Germany over the last 20 years, the success story of "green energy' has to be interpreted to understand Germany's beginning energy transition. Being a core part of the actual electricity economy, renewable energy sources are still discussed and consequently bring new challenges for the interaction with the energy system itself. By modeling the latest project "Nord.Link" within the actual electricity system with the help of System Dynamics, the active public should be able to understand the complex interactions. System Dynamics modeling supports the comprehension about the main interdependencies related to the successful market integration of new sustainable technologies, which are essential for Germany's energy transition in the next 20 years. Therefore it can be mentioned that System Dynamics is trying turning on the energy transition process in Germany. This contribution focusses especially on the IT-based decision support component.

■ TD-20

Thursday, 14:00 - 15:30, Room B302

Complex Systems

Chair: *Stefan Pickl*, Department for Computer Science, Universität der Bundeswehr München

1 - Monte Carlo Strategy for Trading Card Game

Masashi Urushibata, Department of Information and System Engineering, Chuo University, *Tomomi Matsui*

Recently, Monte Carlo strategy is attracting much attention in game programming. The Monte Carlo strategy has a number of achievements in the complete information games such as Go. On the other hand, whether the Monte Carlo strategy is valid in the incomplete information games is an interesting problem. We applied the Monte Carlo strategy to a trading card game which is one of the imperfect information games to confirm its performance. We apply Monte Carlo Strategy to Yu-Gi-Oh! TRADING CARD GAME, which is one of the most famous trading card games in the world. We constructed a game simulator following basic rules of Yu-Gi-Oh! and implemented variations of machine players based on Monte Carlo strategy. We have found that Monte Carlo tree search algorithm finds appropriate strategies, comparing to a naïve Monte Carlo strategy, in many cases. The results of our experiments show that Monte Carlo Strategy has a possibility of improving a performance of imperfect information games.

2 - A simulation study on maintainer resource utilization in availability contract

Partha Datta, Operations Management, IIM Calcutta

A major shift in support and maintenance logistics for complex engineering systems over the past few years has been observed in defence and aerospace industry. Availability contracting, a novel approach in this area and a special type of performance based contract, is replacing traditional service procurement practices. The service provider is measured against an equipment availability target set by the customer and rewarded on savings achieved. The performance of such contracts depends on proper utilization of right mix of labour resources. Contemporary literature on resource modelling has not attempted at modelling the entire aircraft maintenance line along with the labour resources. This research work tries to address resource utilisation issues in availability type contracts, and aims to improve it using simulation technique. These types of service and support contracts can be managed efficiently with a proper assessment of the resource requirements. The research studies the impact of variability in human resources by simulating human resources and processes in an aircraft maintenance line.

3 - Adaptive Supply Chain - Agent-based Modeling, Integration and Simulation of Supply Chain Visibility

Stefan Pickl, Department for Computer Science, Universität der Bundeswehr München

In the current business climate organizations are forced to adapt to procedural shifts in order to be competitive and survive. These changes in business landscape are from dynamic and complex nature, impacting the entire supply chain. Consequently, the need for transformation exists, leading to the vision of "adaptive supply chain networks'. This presentation deals with so-called adaptive supply chain networks. It introduces a conceptual model of adaptive supply chain networks, by applying complex adaptive systems theory to supply chain networks. Furthermore, it deals with a distinguished agent-based modeling and simulation as an approach to model real world systems using software agents in order to understand the behavior of an observed phenomena. These phenomena are comprised of individual, autonomous entities that interact with each other. Their aggregate actions emerge quite often in a non-linear manner, such as in an adaptive supply chain network. However, in order to integrate a holistic decision making and to adapt to unexpected circumstances, visibility has to be available in a supply chain. Yet, achieving supply chain visibility remains a problem within a comfortable IT-based decision process. A prototype for such a comfortable decision making process in the area of humanitarian logistics will be presented.

SOFTWARE APPLICATIONS AND MODELING SYSTEMS

■ WB-22

Wednesday, 11:30 - 13:00, Room E001

Supply Chain Management

Chair: *Debora Mahlke*, BASF SE

1 - Rail car fleet design: Optimization of structure and size

Steffen Klosterhalfen, GVM/S, BASF SE, *Josef Kallrath*

In the chemical industry, rail cars represent an important means of transportation. Due to safety regulations many products are not allowed to be transported on the road. Moreover, rail cars can carry larger volumes than trucks. The transported product poses certain minimum requirements on a rail car with respect to material, valve model, heating, etc. The combination of these characteristics specifies a certain rail car type and determines its cost. Types with higher quality characteristics can be used as substitutes for lower ones and thus are more flexible. At the company, which motivated this research, the task of the fleet management team is to secure the supply with rail cars while at the same time optimally solve the trade-off between (i) minimizing the cost for rail cars and (ii) minimizing the number of different rail car types. A small set of different rail car types enables a parking strategy where the types are sorted by track. This keeps the handling easy. As the number grows, space limitations require a chaotic parking strategy. This causes an increase in the switching effort for providing a certain type. Further, the smaller the number of different types, the smaller the required safety stock due to a larger risk pooling effect. These benefits have to be traded off against the higher cost for more flexible rail car types. We develop a mathematical model that provides a suggestion for how to design the rail car fleet in terms of structure and size in order to solve the above-mentioned trade-off. First, we use a MILP model that minimizes the total rail car cost under given availability constraints on the rail cars of a specific type. Second, safety stocks are computed approximately based on the rail car type-request assignment found by the MILP solution.

2 - Supply chain simulation in practice: Applications and opportunities

David Francas, Camelot Management Consultants

Owing to its inherent modeling flexibility, simulation is an effective tool to support analysis and decision making in real-world supply chains. Especially the opportunities to create transparency and evaluate alternative supply chain options even in complex and dynamic environments make the use of simulation highly appealing for companies. We provide an overview on typical applications for simulation in supply chain management. Based on a case study from the pharmaceutical industry we show how simulation can successfully support the development of effective supply chain configurations. At last, we discuss approaches and key success factors for simulation projects in practice.

3 - NetworkAnalyzer — A framework for optimizing flexible production networks

Holger Stephan, Strategic Network Planning, Daimler AG, *Katharina Mariel*

The strategic design of flexible production networks has been addressed in various publications. In collaboration with German automotive manufacturers a number of strategic planning models and processes have been researched to capture the specifics of the automotive industry. The planning approaches developed at the Daimler AG were consolidated into an advanced decision support system for designing global production networks, the so-called NetworkAnalyzer. The NetworkAnalyzer is based on a generic framework and allows for the integration of different mathematical planning models, algorithms, and solvers, depending on the specific project requirements, e.g. local content, CO2, or quotas. Over the past decade, the NetworkAnalyzer was applied to a multitude of different strategic planning projects at Daimler and has become the standard planning system for the design of global production networks. In this talk we will present the generic NetworkAnalyzer framework along with specialized planning models required to address the global challenges automotive OEMs face today.

■ WB-23

Wednesday, 11:30 - 13:00, Room F142

Algebraic Modeling Languages I

Chair: *Lars Beckmann*, University of Paderborn

1 - Comparison Optimization Modeling Software for Python

Sandip Pindoria, Maximal Software Ltd, *Bjarni Kristjansson*

We will start with a quick overview, that will demonstrate the many features of Python that make it good language for optimization and scientific computing, comparing it with other programming languages such as C/C++, Java and C#. Then we will demonstrate few examples on to how to build and deploy optimization applications, using some of the component libraries currently available in Python, such as MPLPY, GUROBI, CPLEX, GAMS, LPSolve, PYOMO, and PULP-OR, while pointing out the main differences between them.

2 - Object Oriented GAMS API: .NET and Beyond

Clemens Westphal, GAMS Software GmbH, *Michael Bussieck*, *Lutz Westermann*

The recently developed object oriented API provides the possibility of controlling GAMS from within different programming languages like C#, Java and Python. The first implementation was done for Microsoft's .NET framework and its numerous programming languages. This offers a seamless integration of GAMS into .NET based IT systems. The API extends the capabilities of GAMS by the addition of the rich features provided by the .NET framework. The powerful in-memory representation of a GAMS model can increase performance when solving a model multiple times with slightly changed data by performing the model creation only once. Convenient data structures allow random access to data as well as data iteration.

3 - Optimization.Framework - An introduction to the Algebraic Modeling Language for .NET

Lars Beckmann, University of Paderborn

The Optimization.Framework is a math modeling language for .NET. After a brief introduction, in which we will cover the most important constructs of the Optimization.Framework, we will explain the usage of these constructs by discussing a few sample models. One major part of this talk will be the demonstration of the benefits (the author's opinion) of the Optimization.Framework and the toolset that will be used throughout the talk. We will talk about strong-typing, lambdas, domain models and behavior-driven modeling and how they can help you create models faster and provide a structured way of testing the resulting models. We will show how to debug models and how to use the available solver bindings in order to use standard solvers like Cplex, Gurobi and more to compute a solution for a model instance. The final part of this talk will show a few benchmarks on model instantiation times for various standard models.

■ WC-22

Wednesday, 14:00 - 15:30, Room E001

Modeling Applications in European Energy Markets

Chair: *Olaf Syben*, ProCom

1 - Design- And Dispatch Optimisation Of Heat Accumulators In Large District Heating Grids

Christoph Koch, Vattenfall, *Andreas Christidis*, *Lothar Pottel*, *George Tsatsaronis*

Vattenfall is operating one of Europe's largest district heating systems in Berlin. The heat demand is covered by nine thermal power plants all working according to the principle of combined heat and power production. This permits a fuel utilisation factor higher than for separate generation of heat and power, but also implicates a lower flexibility since the heat and power load cannot be adjusted independently. On the one hand the heat load dependent power loss factor in extraction-condensing turbines causes a profit loss in times of high electricity prices. On the other hand the need to cover the heat demand also forces plants to be kept on stream during times of low power prices which causes an increase of costs. District heating accumulators may represent an expedient solution to this issue, as they may help to partly or entirely decouple electricity production from heat demand. More electrical energy could be marketed in periods of high electricity prices if the heat production of a cogeneration plant could be temporarily decoupled from heat demand by way of using a heat accumulator. In addition load setbacks could be performed for unprofitable units at times of low power prices, provided the buffer is sufficiently sized to close the gap in heat supply. In order to optimize the number and type of heat accumulators, their locations within the district heating grid, their volumes and operating temperatures Vattenfall uses both the commercial dispatch tool BOFIT and an in cooperation with TU Berlin developed mixed integer program, formulated in GAMS and solved with CPLEX. This article focuses as well on these approaches as on the analysis of the influence of the heat accumulators on the dispatch of the combined heat and power plants.

2 - Simulation von Preisen im europäischen Strom- und Gasmarkt

Eike Spang, ProCom, *Olaf Syben*

Bei der Durchführung von Planungsaufgaben in der Energiewirtschaft wird der Anwender immer wieder mit unsicheren Eingangsdaten in seiner Planung konfrontiert. Für die Berücksichtigung dieser Unsicherheiten z.B. in stochastischen Optimierungsverfahren werden Prognosen bzw. Simulationen solcher Daten benötigt. Die wichtigste Quelle für Unsicherheiten im Planungsprozess sind dabei die Preise für Strom und Brennstoffe. In diesem Vortrag wird eine Simulationsfunktion vorgestellt, die multiple Szenarien der betrachteten unsicheren Größen im Strom- und Gasmarkt erzeugt. Abweichend von den aus der Finanzmathemtik bekannten Vorgehensweisen werden auch negative Preise und die deutliche tageszeitliche und saisonspezifische Prägung der (Strom-)Preise abgebildet. Zusätzlich werden die Zusammenhänge bei der Entstehung der Preise erläutert und die daraus folgenden Konsequenzen für den Simulationsalgorithmus hergeleitet.

3 - CHP power plant portfolio operation using recursive stochastic optimization

Christoph Weber, University Duisburg-Essen, *Oliver Woll*

In liberalised electricity markets, the operation of CHP systems has to take into account uncertain power prices in addition to uncertain heat and electricity demand. Given these multiple uncertainties, adequate problem formulations and solution algorithms have to be sought to achieve tractable optimization problems. This contribution reviews various planning tasks of CHP operators in the short to medium term and discusses potentials for deriving improved solutions using stochastic optimization. A particular focus is thereby put on yearly or monthly operation planning problems, since here the computational limitations are severe, while at the same time uncertainty is particularly relevant. The former is especially true since a separate consideration of each plant "mark-to-market' is not possible for CHP portfolios in contrast to conventional power plant parks. In order to cope with this issue, a combination of a recursive approach (as in dynamic programming) with a stochastic optimization for each decision point has been developed. A lattice mapping the stochastic evolution of power prices and heat demand is built up, based on Monte-Carlo simulations. We take a two-stage stochastic optimization with a planning horizon of two days at each node. Unique values are taken for electricity and heat demand in the first stage (first day), whereas various scenarios on demand and prices are taken into account in the second stage. This approach is applied in each node of the lattice for the planning period, weighting the different nodes with their respective probabilities. By working backwards through the lattice, this approach allows accounting for day-to-day power price fluctuations while still a whole year of power plant operation can be considered.

■ WC-23

Wednesday, 14:00 - 15:30, Room F142

Learning Modeling and Optimization

Chair: *Hans Achatz*, University of Passau

1 - OREX-J: towards a universal software framework for the experimental analysis of optimization algorithms

J Christian Lang, -, *Thomas Widjaja*

The Operations Research EXperiment Framework for Java (OREX-J) is an object-oriented software framework that helps users to design, implement and conduct computational experiments for the analysis of optimization algorithms. As it was designed in a generic way using object-oriented programming and design patterns, it is not limited to a specific class of optimization problems and algorithms. The purpose of the framework is to reduce the amount of manual labor required for conducting and evaluating computational experiments: OREX-J provides a generic, extensible data model for storing detailed data on an experimental design and its results. Those data can include algorithm parameters, test instance generator settings, the instances themselves, run-times, algorithm logs, solution properties, etc. All data are automatically saved in a relational database (MySQL) by means of the object-relational mapping library Hibernate. This simplifies the task of analyzing computational results, as even complex analyses can be performed using comparatively simple Structured Query Language (SQL) queries. Also, OREX-J simplifies the comparison of algorithms developed by different researchers: Instead of integrating other researchers' algorithms into proprietary test beds, researchers could use OREX-J as a common experiment framework. This talk describes the architecture and features of OREX-J and exemplifies its usage in a case study. OREX-J has already been used for experiments in three different areas: Algorithms and reformulations for mixed-integer programming models for dynamic lot-sizing, a simulation-based optimization approach for a stochastic multi-location inventory control model, and an optimization model for software supplier selection and product portfolio planning.

2 - A practical course on modeling real world problems using IBM ILOG CPLEX

Melanie Reuter, Institute for Operations Research, Karlsruhe Institute of Technology (KIT), *Hans Schlenker*, *Stefan Nickel*

After the integration of ILOG into IBM a stronger focus to education is given which can be seen for example in the IBM Academic Initiative. In a joint project KIT and IBM have been developing a course on modeling in the OR context in order to teach students not only the foundations of mathematical programming, but also its power and beauty. One main topic of the course is for the students to gain experiences in how to model real world problems interlinking research and (industrial) practice. Therefore, in most of the exercises, problems are described textual and students have to first derive a mathematical formulation and then implement the OPL model. Finally, they have to fill it with data, run the optimization and analyze the results. The course is currently given at the Karlsruhe Institute of Technology and the University of Augsburg. The cooperation can be expanded to other interested Universities.

3 - Teaching Experiences with Modeling Systems

Hans Achatz, University of Passau

Over the last ten years we have made teaching experiences with modeling systems at master level. Our objective is to enable students to model and solve problems with given tools. Lectures alone are not the best way to get facts across. There are reports that about 30 minutes is a reasonable maximum to expect attention during a lecture. Lectures are interrupted by supervised exercises on given problems which match up with the actual content of the course. The construction of personal knowledge is a personal activity. Therefore students are working with real world problems. It is even more motivating if these problems also have local aspects for example an optimization problem of a local factory. Students often don't like to work alone. We build small groups (2-3 students) to work on problems in class. It is a kind of competition between these groups with onsite help. Sometimes we confront students with problems which are too difficult to solve in class. Students have to model partially or try to gain help from outside their small group. They have to go through a process of stepwise refinement like in real world applications. During the course different tools and modeling systems are presented but in the exercises students only have to deal with one modeling system. Most often building the model is not the problem but the syntax of the tools. Therefore they only have to learn one model representation and syntax of this system. Courses are frequently evaluated by students.

■ WE-22

Wednesday, 17:00 - 18:30, Room E001

Selected Algorithms and Applications I

Chair: *Rafael Velásquez*, Logistics Optimisation, INFORM - Institut für Operations Research und Management

1 - Scheduling the Flows of Pilgrims for the Hajj

Knut Haase, Institut f. Verkehrswirtschaft, Lehrstuhl BWL, insb. Verkehr, Universität Hamburg

The Hajj is the pilgrimage to Mecca, Saudi Arabia, and a religious duty of every able-bodied Muslim. Every year, around 1,7 millions pilgrims are located several days in the tent city of Mina. On each day almost all pilgrims go to the 5-levelled Jamarat bridge to stone the devil by throwing pebbles against three pillars. The time preferences of the pilgrims for the stoning rituals vary in dependence of the day, of the origin country, and on religious grounds. For enabling save flows of pilgrims, i.e. avoiding risky overcrowded gatherings, a mathematical model has been developed by which the flows of pilgrims are spatiotemporally balanced and the time preferences are maximized. The model has been implemented and solved using GAMS and been successfully applied over the last 7 years.

2 - Collection And Disposal Operations Planning Of Urban Slimy Waste: A Business Case

Francesco Orzo, Università di Roma "Tor Vergata", *Pasquale Carotenuto*

This paper aims to optimize the collection and disposal operations planning problem of urban slimy waste. A service company realize transport planning of urban slimy waste from a set of waste production plants to a set of disposal plants. Each production plant have a daily different capacity and compatible only with a sub set of disposal plant. Transport requests are satisfied by transportation firms that have two different type of truck to execute the transports according to the specific characteristic of the production plant. The problem concerns the optimization of transport and disposal costs taking into account several constraints as compatibility between production and disposal plants, the facilities and the capacities of each transporter involved in the plan and the capacities of each single disposal plant. Analysing the use of the facilities we have separated the main problem in two sub problems. In first one we use a single truck as facilities during a travel between a single origin (production plant) to a single destination (disposal plant); in the second one we use a truck with towing as facilities for a travel in which the facilities (truck with towing) load the waste in two different plants before to discharge the waste in the disposal plant. We have approached the problem using a LP model we have realized a software application to solve daily instance of the problem. To realize the software application we have combined a relational database, a LP solver and a spreadsheet as data form. This allows us to store correctly large set of data, write them in the spreadsheet and run the LP solver in very easy way. The results stored in the database allow the company easily to manage the travel planning, minimize the costs, and reduce operational planning times.

3 - Solving the operative train loading optimisation problem with SyncroTESS Intermodal

Rafael Velásquez, Logistics Optimisation, INFORM - Institut für Operations Research und Management

The current growth and importance of cargo transportation in international trade has opened new challenges for efficient intermodal operations at intermodal terminals. With the rail freight market reaching new heights, an efficient handling of the train loading will distinguish intermodal terminals. The operative train loading optimisation problem consists in providing a solution that maximises the amount of load units that are transported on a train, given a set of load units and rail wagons that will be dispatched from the intermodal terminal. This talk aims at describing the problem in real life situations and how it is solved with SyncroTESS Intermodal. The novel approach applied in SyncroTESS Intermodal resides in a decision support tool with a mathematical programming model as its core. It gives the dispatcher the possibility to set several dispatching constraints that influence the feasible set, and solves the remaining problem to a desired level of optimality. The resulting solution is visualized in SyncroTESS Intermodal, allowing the dispatcher to make isolated adjustments as perturbations occur in practice. In this talk the decision support tool of SyncroTESS Intermodal for the operative train loading optimisation problem will be presented. Moreover, experiences gathered from its use at two intermodal terminals in Germany will be discussed.

■ WE-23

Wednesday, 17:00 - 18:30, Room F142

Stochastic Programming

Chair: *Lutz Westermann*, GAMS Software GmbH

1 - Structure-Exploiting Parallel Interior Point Method for Multistage Stochastic Programs

Jens Hübner, Institut für Angewandte Mathematik, Leibniz Universität Hannover

Highly specialized and structure-exploiting solvers for the primal-dual system are essential to make interior point methods competitively applicable to multistage stochastic programs. In the underlying sequential direct approach, depth-first based recursions over the scenario tree and usage of hierarchical problem structures are the key ingredients to achieve memory-efficiency and reduce computational costs. Our parallel approach is based upon a node-distributing preprocess that applies a depth-first based splitting of the scenario tree. The node-related problem data are statically distributed among participating processes. Proper computation orders lead to little idle times and communication overhead. This way only few communication routines are required to parallelize the sequential algorithm for distributed memory systems without loosing its benefiting features. Proper memory management has crucial impact on the algorithm perfomance. Throughout our implementation we make use of C++'s generic features to maintain the data distribution of the structure-defining KKT system. This way conforming distributions can be adapted to IPM data and problem data, and distributed memory systems can be used to solve even huge problems exceeding shared-memory capacities. An intermediate interface layer of MPI resembling routines allows the exploitation of well-performing MPI implementations if desired without restricting the communication to MPI. Theoretical concepts and numerical results will be presented.

2 - DDSIP - a code for mixed-integer linear two-stage stochastic programming

Ralf Gollmer, Mathematics, University of Duisburg-Essen, *Rüdiger Schultz*

Starting with the ideas outlined in the joint paper of Carøe, C.C.; Schultz, R.: "Dual decomposition in stochastic integer programming", published in OR Letters 24(1999), and the subsequent thesis of A. Märkert the software DDSIP (Dual Decomposition in Stochastic Integer Programming) was developed for solving two-stage MIPs. DDSIP is a C implementation of the decomposition by scenarios: - the first-stage variables are replaced by one copy per scenario and nonanticipativity is represented by a set of equations, - Lagrange-relaxation of these nonanticipativity constraints yields independent problems for each scenario, - a branch & bound procedure and C. Helmberg's conic bundle code are used to reestablish nonanticipativity. The CPLEX Callable Library is used to form and solve the single scenario problems. The input format a single scenario MPS or LP in connection with a text file format for the stochastic entries. DDSIP comprises algorithms for mean-risk problems with different risk functions: expected excess of a target, excess probabilities, absolute semideviation, worst-case-costs, tail value-at-risk, value-at-risk, and standard deviation. The algorithm works for problems with integer variables in both stages and works best if the first stage variables are mainly integer ones. The code is open source, avaliable at http://www.uni-due.de/ hn215go/ddsip.shtml and is available for testing at the NEOS server http://www.neos-server.org/neos/solvers/slp:ddsip/MPS.html

3 - Stochastic Programming in GAMS

Lutz Westermann, GAMS Software GmbH

Recently GAMS made a first cut at supporting stochastic programming. With a few changes uncertainty can be added to an existing deterministic model. For this, the Extended Mathematical Programming (EMP) framework is used to replace parameters in the model by random variables. This way multi-stage recourse problems and chance constraint models can be formulated.

■ TA-22

Thursday, 9:00 - 10:00, Room E001

Revenue Management

Chair: *Thomas Winter*, Department of Mathematics, Physics, and Chemistry, Beuth Hochschule für Technik Berlin

1 - Large Scale Revenue Management Optimization: Algorithmic and Technical Aspects

Philipp Kemmer, Lufthansa Systems AG, *Ivo Nowak*

Optimization systems for airline revenue management try to maximize the total OD network revenue by finding the best capacity allocation of number of seats to aircraft compartments and the best availability control strategy. Recent optimization systems include customer choice options and require frequent reoptimization. Due to the size and complexity of huge airline networks and the limited computation time, the development of such an optimization system for solving real-world problems is challenging for both the algorithms and the underlying software architecture We present a decomposition and dynamic programming approach for computing parameters for optimal availability control. Furthermore, we discuss technological aspects how this approach can be parallelized, in order to fulfill the computational requirements. We report numerical results for huge real-world problems.

2 - Controling several leg compartments in airline revenue management

Thomas Winter, Department of Mathematics, Physics, and Chemistry, Beuth Hochschule für Technik Berlin, *Nicola Winter*

In traditional airline revenue management, leg compartments are typically controlled separately, for instance by applying bid price control. With the inclusion of the impact of customer choice behavior, the pure separation of the control of leg compartments is no longer completely feasible. The demand models for customer choice options may include demand overlap between products offered for different compartments and even a demand overlap between different itineraries between origin an destination. We investigate the impact on costumer choice behavior on optimal control policies for each compartment. Based on a standard dynamic programming formulation on leg level including costumer choice options, we motivate a combined dynamic programming model where a revenue opportunity function is solved for each compartment simultaneously including the buy-down and sell-up potentials for the depending control options per leg compartment. We discuss options of how to include this approach into the solution for practical real-world applications and for network scenarios.

■ TA-23

Thursday, 9:00 - 10:00, Room F142

Nonlinear Programming

Chair: *Toni Lastusilta*, GAMS Software GmbH

1 - Computing derivatives with high accuracy: The AD package ADOL-C

Andrea Walther, Institut für Mathematik, Universität Paderborn, *Kshitij Kulshreshtha*, *Andreas Griewank*

The provision of exact derivative information for a function defined by an evaluation procedure in a high level computer language like Fortran or C forms an important task for numerous applications comprising for example optimisation, parameter estimation, and data assimilation. The technique of algorithmic differentiation (AD) [1] offers an opportunity to provide derivatives of any order for the given code segment by applying the chain rule systematically to statements of computer programs. Complexity estimates for the two basic approaches, i.e. the forward mode and the reverse mode, will be given in this talk. This includes for example the "cheap gradient result", i.e. that computational complexity for evaluating the gradient of a scalar-valued function can be bounded above by a computational complexity of the function evaluation multiplied by a small constant. The package ADOL-C [2] uses operator overloading for the algorithmic differentiation of C and C++ codes. This talk presents recent developments including an advance structure exploitation and the differentiation of programs that are MPI-parallel. Furthermore, the application of ADOL-C to challenging optimisation problems arising in aerodynamics and nano optics will be shown. [1] A. Griewank and A. Walther: Evaluating Derivatives: Principles and Techniques of Algorithmic Differentiation, Second Edition. SIAM (2008). [2] A. Walther and A. Griewank: Getting started with ADOL-C. In U. Naumann and O. Schenk, Combinatorial Scientific Computing, Chapman-Hall CRC Computational Science, pp. 181-202 (2012).

2 - Chromatographic Separation using GAMS Extrinsic Functions

Toni Lastusilta, GAMS Software GmbH

In chemical and pharmaceutical industries the problem of separating products of a multicomponent mixture can arise. The objective is to efficiently separate the mixture within reasonable costs during a cyclic operation. To optimize the process a boundary value problem that includes differential equations needs to be solved. The presented Mixed-Integer NonLinear Programming (MINLP) model solves an instance of the chromatographic separation process in GAMS by using extrinsic functions. The function library facility that was recently introduced in GAMS 23.7 provides a convenient way of modeling it. The problem has been earlier studied in "Comparisons of solving a chromatographic separation problem using MINLP methods' by Stefan Emet and Tapio Westerlund.

■ TA-24

Thursday, 9:00 - 10:00, Room F428

Selected Algorithms and Applications II

Chair: *Roland Schuster*, RWTH Aachen

1 - Variable resource consumption and dynamic activity duration in the resource-constrained project scheduling problem

Torben Schramme, DS&OR Lab Paderborn, University of Paderborn, *Leena Suhl*, *Stefan Bunte*

The resource-constrained project scheduling problem (RCPSP) has been discussed in literature for decades, although there was only little focus on handling dynamic resource consumption for activities. We will present an extension of this problem considering dynamic resource allocation for every execution period of an activity, which leads to activities with a fixed workload but variable duration. We will show some related practical problems with such requirements. An extended RCPSP model which includes these new requirements will be introduced. Because of the new decisions about activity duration and resource distribution, current RCPSP solving methods are not applicable for solving this extended model and due to the consequent increased complexity, a pure MIP approach has been turned out as too slow for solving instances of practical size. As an alternative, we will suggest a new method in which the augmented MIP is embedded into a tabu search algorithm for enabling reasonable solving times and multiple solutions. We will provide implementation details of that method in a state-of-the-art optimization framework and give some benchmark results.

2 - Proximal Bundle Methods in Unit Commitment Optimization

Roland Schuster, RWTH Aachen, *Tim Drees*, *Albert Moser*

The unit commitment optimization is a tool to determine the optimal power plant schedule to cover the demand for electrical energy under minimal costs. At this, the schedule is identified for a predicted load and for the available thermal and hydro power plants. It needs to observe all technical and economic constraints of each power plant. The major disturbance of the optimization problem is the residual load. It consists of the difference in demand for electrical energy and the feed-in of renewable energy sources (RES) or must-run. The augmented use of RES will increase the volatility of the residual load in the next few years. Under these circumstances, the existing numerical methods for solving the unit commitment problem reach the performance limits in terms of their robustness. Due to the increased load gradients the rate of convergence is slowing down. Therefore new methods with a higher convergence are necessary in the unit commitment optimization. This paper intends to exemplify the use of Proximal Bundle Methods in unit commitment. Hence, in a first step the mathematical model based on a Lagrange-Relaxation is illustrated. After-wards, the new iterative approach of the relaxed problem is demonstrated. Finally it is compared to the existing approach based on a gradient descent method in terms of the robustness, the rate of convergence, the computation time and the number of iterations. Besides these evaluations the article gives an outlook on necessary and possible extensions of the method. The main topics of this paper are: - Limits in the unit commitment optimization due to the increased feed-in of RES - Implementation of the Proximal Bundle Method in unit commitment optimization - Examination of the convergence behavior

■ TC-22

Thursday, 11:30 - 13:00, Room E001

Software in Traffic Management

Chair: *Karl Nachtigall*, Faculty of Transport and Traffic Sciences, Institut for Logistics and Aviation, Technical University of Dresden

1 - The importance of automatic timetabling for a railway infrastructure company

Daniel Pöhle, I.NMF 3, DB Netz AG

The DB Netz AG is the most important railway infrastructure company in Germany and operates a railway network with a total length of about 34000 km. One of the main tasks is to generate timetables to sell train-paths or enhance the infrastructure by eliminating bottlenecks. The creation of a timetable for the complete network is complex and time-consuming so there are efforts to atomize this process in essential parts. TAKT, a software-system of the professorship "Verkehrsströmungslehre" at the TU Dresden, automatically generates timetables for complex railway networks on the base of periodic event scheduling problems (PESP) by using specialized algorithms. It provides practically useful solutions in appropriate runtimes because of its up to date techniques like a SAT-solver and an innovative routing-algorithm, which finds a well-suited train-path in the network automatically. To calculate a timetable for the German long-distance traffic the solver needs a computation time of only few minutes. In summary with the use of TAKT at DB Netz timetables for passenger and freight traffic can be generated automatically with a great quality in a very short time.

2 - Automatic Scheduling of Periodic Event Networks by SAT Solving

Peter Großmann, Faculty of Computer Science, TU Dresden

In this paper, periodic event scheduling problems (PESP) are encoded as satisfiability problems (SAT) and solved by a state-of-the-art SAT solver. Both the encoding, based on order encoded domains, and the valid use in terms of a proof are presented. The experimental evaluations suggest that the SAT-based approach outperforms constraint-based PESP solvers, which were considered to be the best solvers for PESP. This opens the possibility to solve more complex and larger real-world instances, such as timetabling for public railway transport networks.

3 - A novel approach to strategic planning of rail freight transport

Reyk Weiß, TU Dresden, Faculty of Transportation and Traffic Sciences "Friedrich List", Institute of Logistics and Aviation, Chair of Traffic Flow Science, *Jens Opitz*, *Karl Nachtigall*

Railway traffic now and in future faces ever-growing challenges. On the one hand, infrastructure measures must be planned and in the medium respectively long term corresponding operating programs have to be generated. On the other hand, in the short term economical and political reasons exert increasing influence on the requirements of timetabling as well. Hence, they can hardly be efficiently handled with manual effort. Consequently, it exists the need for highly optimized, automated algorithms and its corresponding intelligent conjunction. A state-of-the-art realization is reflected in the software system TAKT, which is developed in close cooperation with the German railway company DB Netz AG. The implementation offers a complete new approach to solve the problems like computing conflict-free, optimized time tables or searching, optimizing and maximizing rail freight transport train paths based on an existing operating program. In this work, the focus is on a novel approach to strategic planning of rail freight transport. This results in different variants of transportation strictly timed and non-conflicting time tables.

■ TC-23

Thursday, 11:30 - 13:00, Room F142

Algebraic Modeling Languages II

Chair: *Robert Fourer*, AMPL Optimization

1 - CMPL - Coliop — Coin Mathematical Programming Language

Mike Steglich, University of Applied Sciences Wildau

CMPL is a mathematical programming language and a system for mathematical programming and optimization of linear optimization problems. CMPL is a COIN-OR project initiated by the Technical University of Applied Sciences Wildau and the Institute for Operations Research and Business Management at the Martin Luther University Halle-Wittenberg.

2 - Tools to increase model quality and knowledge sharing

Wietse Dol, Data, Landbouw-Economisch Instituut

There is a difference between building a scientific model and building a model used for consultancy (e.g. giving the European Commission advice on their Agricultural Policy). When working as a large group in different locations you need a lot of communication and software to help you realize your project goals. The quality of the model as well as the possibilities to share each other's knowledge greatly depends on having the right software tools. In this paper we will discuss some strategies to build complex models and show how certain tools can help you. All tools discussed can be freely downloaded and used in your own research.

3 - Alternatives for Scripting in Conjunction with an Algebraic Modeling Language for Optimization

Robert Fourer, AMPL Optimization

Modeling languages for formulating and analyzing optimization problems are essentially declarative, in that they are founded on a symbolic description of a model's objective function and constraints rather than a procedural specification of how a problem instance is to be generated and solved. Yet successful optimization modeling languages also offer ways to write interpreted scripts that offer many of the same facilities as procedural, high-level programming languages. How can scripting benefit the user of a declarative language, and what does scripting in a modeling language offer in comparison to modeling in a general-purpose scripting language? This presentation suggests a variety of answers, through examples in which the AMPL modeling language is applied to parametric analysis, solution generation (via cuts and via solver options), heuristic optimization, pattern generation, and decomposition. Concluding comments propose enhancements to the AMPL scripting facility motivated by experience with large and ambitious applications.

■ TD-22

Thursday, 14:00 - 15:30, Room E001

Applications in Logistics

Chair: *Frauke Böckmann*, Fraport AG

1 - Introducing Operations Reserach and GAMS in a fast growing medium size business: Challenges and lessons learned

Sascha Herrmann, zooplus AG

As a leading online retail company zooplus.com sells pet supplies directly to private customers all over Western Europe via the internet. Within the last five years the total sales grew more than 30% per year. Operations Research can make a significant contribution to manage this growth. In this talk we will present some ideas on how Operations Research can be introduced into small and medium size businesses. Modelling systems like GAMS play an important role in this context. First, they allow you to manage incomplete and fast changing requirements easily. Second, they provide a quick insight into the solvability of real world problems. Third, they support a rapid development of decision support systems for in-house customers. Finally, we will present some of our design patterns we use to organize and enhance our modelling projects.

2 - Balancing load distribution on baggage belts at airports

Frank Delonge, Airport Division, INFORM GmbH

When baggage is disposed to baggage belts to be picked up by passengers, we often face situations of imbalanced load distribution throughout belts. Thus, passengers might be unnecessarily crowded tightly around some belts whereas other belts remain unoccupied at the same time, which is an unpleasant situation for both passengers and airport staff. Moreover, imbalanced load distribution over a longer period of time leads to unsynchronized maintenance intervals. To address this problem within an existing Constraint Programming approach, we present measures for both kinds of imbalance which are equivalent to minimizing the variance of load distribution but allow for monotonous lower and upper bounds as well as for effective (partial) computation. Results of our approach are illustrated with real planning data of a german airport.

3 - Optimization solutions at Frankfurt Airport

Frauke Böckmann, Fraport AG, *Alexander Schäfer*, *Torben Barth*

Today many established airports operate their business within limited physical parameters and at the limit of their capacity. Thus it is very important to use the existing resources as efficiently as possible. To deal with these limitations at Frankfurt Airport optimization solutions based on MIPs have been implemented to provide decision support for dispatching processes i.e. baggage handling. The main focus of these solutions is real-time planning on the day of operation — partly automatic, partly as decision support. To get best results in cooperation with the dispatcher team transparency is an important feature. The main challenges are logistic processes with several interacting stakeholders, adjustments to changing business processes and best-results-demanding stakeholders. The optimization solutions need to provide best results with high adaptability and at the same time high user acceptance. This talk illustrates, on the basis of implemented dispatching decision support systems, best practices to turn a demand into an optimization idea and consequently into a highly accepted running optimization solution.

■ TD-23

Thursday, 14:00 - 15:30, Room F142

MI(N)LP Software

Chair: *Stefan Vigerske*, GAMS Software GmbH

1 - Solving MINLPs with an MIP-solver

Bjoern Geissler, Mathematics, FAU Erlangen-Nürnberg, Discrete Optimization, *Alexander Martin*, *Antonio Morsi*, *Lars Schewe*

In this talk we present techniques which turn any general purpose MIP-solver into a general purpose solver for MINLP-problems. To this end we show how to construct arbitrary tight MIP-relaxations of a given nonlinear problem. For the construction of the MIP-relaxations we extend some well-known MIP-techniques for piecewise linear functions and make use of convex underestimators to construct these relaxations such that any point which is feasible for the relaxation satisfies all nonlinear constraints up to some arbitrary small, a priori given error bound. In addition we present an algorithm which iteratively solves adaptively refined MIP-relaxations in order to determine the global optimum of a given MINLP. These algorithms are implemented in Lamatto++, a software framework for solving gas network optimization problems. To confirm the suitability of our approach, we present computational results on some large-scale real-life instances from this area.

2 - SCIP Optimization Suite 3.0 - It's all in the bag!

Matthias Miltenberger, Optimization, Zuse Institute Berlin

We present the latest release of the SCIP Optimization Suite, a tool for modeling and solving optimization problems. It consists of the modeling language ZIMPL, the LP solver SoPlex, and the constraint integer programming framework SCIP. Besides being one of the fastest MIP solvers available in source code, SCIP can also be used as a branch-cut-and-price framework. Furthermore, SCIP is able to solve a much wider range of optimization problems including pseudo-boolean optimization, scheduling, and non-convex MINLP. Its plugin-based design allows to extend the framework to tackle even more kinds of problems and to customize the optimization process. We report on current developments and new features of the SCIP Optimization Suite 3.0 release, including enhanced MINLP support, a framework to parallelize SCIP and the new exact solving capabilities for MIPs.

3 - A Generic Branch-Price-and-Cut Solver

Marco Lübbecke, Operations Research, RWTH Aachen University, *Martin Bergner*, *Gerald Gamrath*, *Christian Puchert*

We implemented GCG, a branch-price-and-cut solver based on the branch-price-and-cut framework SCIP. Given a MIP, the solver performs a Dantzig-Wolfe reformulation (based on user input, or in some cases the solver suggests a reformulation), does column generation and full branch-price-and-cut. GCG inherits advanced MIP solving features from SCIP, like presolving, propagation, (combinatorial) cutting planes, pseudo-costs etc. A number of additional plugins are implemented which are specific to exploiting the availability of having an original compact and an extended column generation formulation, like primal heuristics or branching rules. We report on computational experiments on a number of applications and discuss what can be learned from a generic solver.

■ FA-22

Friday, 9:00 - 10:00, Room E001

Selected Algorithms and Applications III

Chair: *Tuukka Puranen*, Department of Mathematical Information Technology, University of Jyväskylä

1 - Study of a process of task accumulation and distribution in a GRID-System

Zoia Runovska, HSHL

By means of Sub-Markov process, a problem of rational organisation of task processing scheduling is solved for a GRID-System, where algorithms are realized, in which a task package is accumulated prior to resource allocation or intermediate pools of tasks from global queues are formed in accordance with task priorities. Optimisation of scheduling depends essentially on task flow features and intermediate pool volume. Description of the considered system: time intervals between tasks entrances are mutually independent random values, which duration distribution function has an arbitrary form; an amount of simultaneously entering tasks is a certain integer-valued random value. Task package is either accumulated up until its volume does not exceed a certain limit value; or portions of tasks specified by a broker size are selected from a global queue. As soon as the package volume exceeds certain limit value (a pool is full), resources are allocated in accordance with the introduced algorithm. Verification of an optimal package size (pool volume) is connected with the study of a random process, which underlies the task accumulation and distribution process in the system: tasks amount in a queue at a certain time moment. It is a sub-Markov process, where stage durations are distributed by a law specifying time intervals between task entrances into a system, and probabilities of transitions from one stage to another are defined by means of a distribution of a random value, which describes an amount of entering tasks. Verified distribution of amounts of tasks waiting for resources to be allocated, is used to specify a goal function as a function of a package size limit value. An optimal package size value is specified as a point of minimum of an introduced function

2 - Implementation Considerations for Hyperheuristics in Generic Routing Systems

Tuukka Puranen, Department of Mathematical Information Technology, University of Jyväskylä, *Jukka Kemppainen*, *Jussi Rasku*

Vehicle routing is an important theoretical problem with numerous practical industry applications. Several commercial implementations exist and a number of academic toolsets have been provided for different problem variants. Although very efficient implementations have been constructed, the industry trends seem to point into increased requirements for expressiveness, flexibility, and maintainability. This is due to the need for increased fidelity in practical use, as well as software providers' increased need to achieve cost efficiently using mass customization. In addition, the demand for more automation in adapting the systems for differing problem variants has resulted in a need for hyperheuristic solution approaches which select and utilize, e.g., several metaheuristics according the problem characteristics. These latest requirements pose a challenge to current implementation practices as the increase in the aforementioned attributes often leads into decrease in performance. In this talk, we introduce an experimental implementation of generic and flexible routing system. We utilize an approach which abstracts the case-specific properties of the optimization problems to promote separation of concerns and reusability while keeping performance high. We provide a comparison of several implementation strategies and provide numerical tests to demonstrate the benefits of the proposed approach. In addition, we provide a framework for classifying critical properties of different routing problem variants from the implementation viewpoint. The results and observations can be used in implementing efficient and flexible optimization systems and to provide a generic and maintainable base for additional algorithm layers such as hyperheuristics.

■ FA-23

Friday, 9:00 - 10:00, Room F142

Deploying Optimization Software

Chair: *Bjarni Kristjansson*, Maximal Software, Ltd.

1 - Cloud Solver Service

Toni Thenhausen, University Paderborn

Traditionally solvers like Gurobi and Cplex are products which come in the form of a DLL file or an executable application. The traditional license models usually allow the usage on a specific machine or a number of machines or it is bound to an individual person or a number of people. As an addition to these traditional license models Gurobi recently started an offering for cloud server instances which is billed based upon the actual usage (per hour). In this talk, we propose a service-oriented way of accessing solver technology through a generic REST interface. This interface allows application developers to programmatically start up as many cloud instances with a solver of their choice preinstalled (if a compatible license model is available, such as the cloud server model by Gurobi) in order to solve their models in the cloud. The interface gives users access to the status of the solution process as well as other Metadata. One of the benefits is that customers do not have to buy hardware in order to solve optimization problems. Furthermore they can switch from one solver code to another without changing their application or even have their problem solved by many solvers independently. One further advantage is that as soon as a solver gets updated to a higher version, this can be done by the service provider and again the application does not need to be changed. Additionally we developed a solver which can break up MIPs into multiple sub problems and distribute those to a number of compute instances, so that multiple solvers can work together on the solution of a MIP model. For the Optimization.Framework, which is a modeling language for .NET, we also provide a wrapper class for the REST service, so that it is even easier to use the service.

2 - Deploying MPL Optimization Models on Servers and Mobile Platforms

Bjarni Kristjansson, Maximal Software, Ltd., *Sandip Pindoria*

The IT industry is currently undergoing a major shift, away from traditional standalone applications, to new platforms such as tablet computers and mobile phones. In this presentation, we will demonstrating for the first time, a new server-based version of MPL OptiMax, that makes writing mobile applications relatively quick and easy process. We will demonstrate how to integrate optimization models seamlessly with online data, and then deploying them on a server for servicing both web and mobile clients, using standard programming languages, such as CSharp, VB, C/C++ or Python.

■ FA-24

Friday, 9:00 - 10:00, Room F428

Selected Algorithms and Applications IV

Chair: *Adiwijaya*, Science, Telkom Institute of Technology

1 - Hybrid Algorithm For Blind Equalization Of Qam Signals

Abdenour Labed, Computer science, Ecole Militaire Polytechnique

In digital communication systems, blind equalizers are used to combat signal impairments such as inter-symbol interference (ISI), by only exploiting some statistical and geometrical properties of the transmitted signals. One of the first schemes of blind equalization is the constant modulus algorithm (CMA) which is known to be robust and requires simple hardware implementation. However, for quadrature amplitude modulations (QAM), used in high data-rate communications, the CMA leads to not sufficiently low residual errors for a correct recovering of transmitted signals. Other algorithms like the multi-modulus algorithm (MMA) and the extended CMA (ECMA) have been proposed to overcome these limitations. Unfortunately, for high-order QAM modulations, even these algorithms are unable to provide low residual ISI. Hence, hybrid approaches combining the CMA (MMA or ECMA) cost function with a term based on alphabet-matching functions (AMF), have been proposed and the stochastic gradient algorithm used to minimize the resulting cost function. The idea is that the CM term governs the initial equalization phase, and that the AM term can provide a more accurate final equalization. Our contribution presents a scheme based on the combination of the ECMA and a modified version of a Gaussian AM criterion. The derived algorithm is tested on 512-QAM signals, where significant improvements in terms of mean square error (MSE) are obtained.

2 - Multiple Watermarking on Digital Medical Image for Mobility and Authenticity

Adiwijaya, Science, Telkom Institute of Technology, *T. A. B. Wirayuda*, *B. Purnama*

Digital medical images must be stored or transmitted via internet in a secure way to ensure authenticity and preserve image quality to avoid mistake in medical diagnosis. A multiple watermarking scheme can serve these purposes. The multiple watermark consists of a robust part and a fragile part. The robust part is embedded in Region of Non-Interest within a medical image, usually containing ownership and medical record of a patient. Meanwhile, a fragile part is embedded in Region of Interest within a medical image which it can detect a tampering or modi

cation in the medical image. In this paper, we implement Reed Muller Code and Message Authentication Code in multiple watermarking based on Wavelet and Hash Block Chaining to achieve the purposes mentioned above. We show that the proposed scheme can detect some tampering or modi

cation in medical image and the system can increase the endurance of the robustness from various attacks such as sharpening, blur, gaussian noise and JPEG compression.

SUPPLY CHAIN MANAGEMENT, LOGISTICS AND INVENTORY

■ WB-26

Wednesday, 11:30 - 13:00, Room E214

Diverse Issues I

Chair: *Herbert Meyr*, Department of Supply Chain Management, University of Hohenheim

1 - Models and Algorithms for Tactical Logistics Network Optimization

Jannik Matuschke, Institut für Mathematik, Technische Universität Berlin, *Tobias Harks*, *Felix G. König*, *Alexander Richter*, *Jens Schulz*

In global logistics operations, tactical planning aims at laying the groundwork for cost-efficient day-to-day operation by deciding on transport modes, routes, and delivery frequencies between facilities in the network. Large shipments usually yield lower per-unit shipping cost, while high delivery frequencies reduce capital commitment and storage cost. This crucial trade-off encourages the consolidation of shipments, which may take place spatially by combining goods at hub locations, and temporally by accumulating goods over time for shipping. We propose a transportation model for tactical logistics network optimization taking into account spatial and temporal consolidation effects, while being able to represent tariff schemes commonly used in practice. For this model, we present a broad set of heuristics combining well-known combinatorial concepts such as network flows, shortest paths, network design, and a multi-dimensional covering sub-problem for tariff selection, which is addressed in detail in a separate talk. To evaluate the quality of these approaches, we present a computational study on a set of large-scale real-world instances from automotive, chemical and retail industry provided by our industrial cooperation partner 4flow. Our results also comprise lower bounds obtained from using mixed integer programming techniques, proving that most of our solutions are within a single-digit percentage of the optimum. The model and the obtained results are part of the MultiTrans project, a cooperation between the COGA group at TU Berlin and 4flow AG, a market leader in logistics and supply chain management consulting.

2 - Supply chain risk identification strategy using scenario-based simulation and operational supply chain planning

Iris Heckmann, FZI Forschungszentrum Informatik

As today's supply chain networks are worldwide-spread complex systems, disruptions and unexpected deviations can lead to devastating and far-reaching consequences. The literature on supply chain risk analyses is mostly of anecdotic nature, while few authors present empirical research. Unfortunately, not much effort has been done for the quantification of supply chain vulnerability drivers. A combined simulation and optimization approach is proposed to identify the relevant factors enhancing this vulnerability, i.e. factors which have a significant negative effect on supply chain performance indicators. We present an efficient scenario generation strategy, which sequentially applies different experimental designs and which identifies all main and all relevant two-factor interactions in a multi-echelon, multi-product and multi-period supply chain network. We present preliminary computational results along with implications for further research directions.

3 - Allocation Planning in Make-to-Stock Environments

Stephanie Eppler, Department of Supply Chain Management, Prof. Dr. Herbert Meyr, University of Hohenheim, *Herbert Meyr*

In make-to-stock environments, if demand (of multiple customer classes) exceeds the amount of finished products, a decision has to be made about accepting an incoming order or rejecting it, in anticipation of a more profitable future order. This analogy to service industries implies the transfer of Revenue Management ideas to make-to-stock environments and leads to so-called allocation planning problems. In contrary to service industries, finished products in make-to-stock environments (e.g. in consumer goods industries) are storable which further increases the complexity of the allocation planning problem. Inventory holding costs as well as backlogging costs have to be considered. We will present stochastic linear programming models as an approach for (multi-period, multiple classes) allocation planning models in make-to-stock environments taking demand uncertainty into account. Furthermore, we focus on interactions between the allocation planning process and the subsequent consumption process, in terms of anticipating consumption rules (applied in the consumption process) in the allocation planning process for attaining better allocations.

■ WB-27

Wednesday, 11:30 - 13:00, Room F342

Inventory I

Chair: *John J. Kanet*, Operations Management - Niehaus Chair in Operations Management, University of Dayton

1 - Two-stage versus Single-stage Inventory Models with or without Repair Ability

Ismail Serdar Bakal, Industrial Engineering, Middle East Technical University, *Z. Pelin Bayindir*, *Serkan Ozpamukcu*

In this study, a real life inventory control problem of a single item, which is being used in the military operations, is considered. The item has a critical importance in military operations and it is supplied by a single domestic supplier. In the current system, there is a two-echelon inventory setting which consists of a single stock point, the central depot, in the upper echelon and several stock points, the bases, in the lower echelon. The users are the military units which are very close to the operation sites. The demand originates from the item failures in the users, which are regarded as the end customers, and it is modeled as a Poisson process. The depot replenishes the bases and orders from an outside supplier. The depot and the bases are connected via military ring services. Any unsatisfied demand is backordered at all stock points. The lead times are assumed to be deterministic. A continuous review base-stock policy is used by all facilities. The goal is to operate the inventory control system at the minimum expected long run average cost. The military headquarters responsible for inventory management identified improvement opportunities such as acquiring repair ability and changing the structure of the supply chain from a two-echelon model to a single echelon model. Considering these opportunities, we investigate four different alternative inventory systems, single-echelon and two echelon models with or without repair ability. Our objective is to determine if and under what conditions each alternative results in lower costs.

2 - A Single-echelon (s-1,s) Inventory Model With Discrete Stable Demand Under A Service Constraint

Mauricio Flores, Systems, Instituto Politecnico Nacional, *Oswaldo Morales Matamoros*, *Ricardo Tejeida Padilla*

Normally, the (S-1,S) inventory policies model the demand as a Poisson Process. When demand experiences sporadic or spiky behavior, it would be recommended to use a heavy tail distribution to model it. Under this concern, we develop a single-echelon (S-1,S) inventory policy where demand is discrete stable distribution and the only contraint is service level. By considering demand as a discrete stable distribution, we have the benefit to encompass into the formulas the Poisson distribution when the scale exponent of the discrete stable distribution is one, that is, the present model generalized the previous model that uses Poisson distribution for demand.

3 - Analysis of Planned Inventory and Related Costs from a Decision Making Perspective

Jack Kanet, University of Dayton, *Peter Letmathe*

We provide a classification scheme for planned inventories and for calculating the resulting costs given a production plan. The classification is based on the motives for holding inventory. The scheme is useful as it provides information in making safety stock, capacity planning, and economic batching decisions and provides understanding as to how such decisions are intertwined. Implications are relevant when a firm applies lean management techniques such as setup time reduction or lowering process time variance.

■ WC-26

Wednesday, 14:00 - 15:30, Room E214

Diverse Issues II

Chair: *Svenja Lagershausen*, Seminar für Supply Chain Management und Produktion, Universität zu Köln

1 - Scheduling and control of continuous flows in supply chains with structure dynamics

Dmitry Ivanov, Supply Chain Management, Berlin School of Economics and Law, *Boris Sokolov*

Supply chains (SC) are multi-structural systems. Along with the basic material processes, SCs also include structures of information, energy, topology, etc. The elements of all the structures are interrelated and require their integrated consideration in general and in scheduling and execution control in particular. In addition, those structures are not static, but change due to planned and perturbation-driven factors. Finally, e.g., in information or energy structures, continuous flows exist. The continuous flows may also exist in the main material process structure, e.g., in gas or petrochemical SCs. Although the research on scheduling of discrete flows in SCs has been significantly advanced in recent years, the research on continuous flows and structural integration is rather limited. Based on the previously developed approach to structure dynamics control of SCs, we present in this study an SC scheduling model for continuous flows and exemplify structural interrelations on the integration of material and informational structures. The model is based on a combination of optimal program control and mathematical programming interrelated by Pontryagin's maximum principle. With the results of this study, an explicit incorporation of information and energy flows into SN scheduling and control models becomes possible. This is an important step towards research on embedded and cyber-physical systems in the SCM context.

2 - On the Application of a Multi-Objective Genetic Algorithm to the LORA-Spares Problem

Slawo Wesolkowski, DRDC, *Derek Cranshaw*, *Raman Pall*

Level of repair analysis (LORA) is often defined as the problem of determining whether a component should be repaired or discarded upon its failure, and the location in the repair network to do such work. A related problem is the determination of the optimal number of spares for a given piece of equipment. The most common approaches in the literature on developing a possible spare provisioning decision model are simulation and mathematical programming. Although these two problems (LORA and spare provisioning) are interdependent, they are seldom solved simultaneously due to the complicating nature of the relationships between spare levels and system availability. The need to address LORA and the sparing problems simultaneously has attracted increased attention from the Canadian Department of Defence. In this paper, we propose an approach for the solution of this problem through an application of a multi-objective genetic algorithm (i.e., the Non-dominated Sorting Genetic Algorithm II), where both repair costs (e.g., spare parts, spares transportation, spares storage) and spare parts availability are objectives to be optimized. The approach is to use a Monte Carlo simulation to generate scenarios based on a dataset which includes the expected failures of the equipment and their associated probabilities. The objective functions are computed at each genetic algorithm generation based on the generated scenarios. An example is provided in which non-dominated solutions are identified that can be used for a trade-off analysis.

3 - Distribution of the time between processing starts

Svenja Lagershausen, Department of Supply Chain Management and Production, University of Cologne

We present a method for determining the exact distribution of the time between processing starts of closed queueing networks with phase-type distributed processing times and finite buffer capacities. The distribution is based on the Markov-chain representation of queueing networks and results in a general phase-type distribution.

■ WC-27

Wednesday, 14:00 - 15:30, Room F342

Inventory II

Chair: *Gudrun Kiesmüller*, Institute of Business Administration, Christian-Albrechts-Universität zu Kiel

1 - Hybrid lateral transshipments in multi-item inventory networks

Sandra Rauscher, Management Science, Lancaster University, *Kevin Glazebrook*, *Colin Paterson*, *Thomas Archibald*

Saving costs in inventory systems can often only be accomplished by reducing service levels. Allowing lateral transshipments in multi-location inventory networks permits lower levels of safety stock thereby cutting costs while maintaining or improving service levels. Usually, such movements of stock are either carried out in a reactive manner responding to a stock-out in the system, or preventively to rebalance inventory levels. Recent results show that using a hybrid version of these two approaches can yield further improvements. This lies in the fact that shipment costs in many cases consist of a higher fixed and a lower variable part. The rebalancing of inventory levels can thus be achieved at an often negligible additional cost if a reactive transshipment is made. We extend this idea and implement it in a multi-item setup. Our model describes a multi-location inventory network facing compound, non-homogeneous Poisson demand. Instances of demand have an underlying discrete, multivariate distribution. We derive a quasi-myopic policy by applying a dynamic programming policy improvement step to a no-transshipment policy. Transshipment costs are modelled with a knapsack-like structure to accommodate different types of items. We carry out an extensive simulation study to demonstrate the improvement of hybrid lateral transshipments over existing policies. Further, we assess the effect of modelling multi-item transshipments against operating single item models in parallel.

2 - Supply Chain Models with Preferred Retailer Privy to Supplier's Inventory Information

Hamed Mamani, Dept of Information Systems and Operations Management, University of Washington, *Kamran Moinzadeh*, *Apurva Jain*

We consider a one-supplier/multi-retailer supply chain where there is a retailer with special privileges. This retailer (called privy retailer) has information about supplier inventory conditions. The supplier orders from an outside source after a fixed number of periods. Retailers (facing random demand) place orders at the supplier every period. Unmet demand is backlogged both at the supplier and retailers. Our interest is in analyzing a relatively new feature in supply chain models: availability of supply information to retailer(s) and its impact on the supplier, retailers and the supply chain. Such privileged retailers may exist due to a variety of reasons: long-term relationship with the supplier, retailer market power, or simply because the retailer is a highly profitable customer. Due to access to supply information, privy retailer's inventory policy may change. At times when supply is scarce or is at relatively low levels, such a privy retailer can take advantage of the supply information and act proactively by ordering larger quantities to cover for future periods. We ask how would the retailer's ordering policy change if she has this information and how will the supplier and other retailers react? We first set up a benchmark by considering a centralized setting. The performance of decentralized equilibrium can then be compared to this benchmark. In a two-echelon multi-retailer model exact analysis of both cases, centralized and decentralized, is difficult and therefore, there has not yet been a complete analysis of a supply chain with supply information. Our paper differs from existing literature in that it offers, to the best of our knowledge, the first complete analysis of both cases.

3 - Cost Minimizing Order Schedules for Capacitated Inventory Problems

Florian Kleintje-Ell, Institute of Business Administration, Christian Albrechts Universität zu Kiel, *Gudrun Kiesmüller*

In this paper we study an inventory system of multiple retailers under periodic review and central control. The retailers have to satisfy discrete stochastic demand for a single product, which is backordered, if there is not enough stock available. All retailers can place orders according to a cyclic schedule at a single manufacturing facility with limited capacity. We assume linear holding and backorder costs for the retailers as well as fixed order costs per order, and our aim is the minimization of these costs. We are interested in the optimal order policy for each retailer consisting of an individual order cycle length for a retailer, the allocated capacity for a retailer as well as a modified basestock level. We present a simple approach, based on a deterministic model and compare the solution in a numerical study with an approach, based on an ant colony optimization. We report on the performance of the heuristics and identify parameters, influencing the order schedule and the capacity allocation.

■ WE-26

Wednesday, 17:00 - 18:30, Room E214

Network Design I

Chair: *Cornelia Schoen*, GISMA Business School, Leibniz University Hannover

1 - A Dynamic Model for Facility Location in Closed-Loop Supply Chain Design

Orapadee Joochim, Institut für Produktionswirtschaft, Leibniz Universität Hannover

This paper presents a new mixed-integer linear programming (MILP) model for facility location in the simultaneous design of forward and reverse supply chains. The main contribution of this study is the formulation of a dynamic (i.e., multi-period), multi-echelon, multi-commodity capacitated facility location problem in a strategic planning context. To assess the long-term impact of the problem, our model intends to maximize the net present value (NPV) of expected cash flows for the whole supply chain. Unlike previous works found in the literature, we take into consideration various features of the problem. The proposed model encompasses all key features of strategic decisions regarding the location, capacity allocation, processing-distribution system, supplier selection and supply chain subcontracting. We examine issues related to relocation and capacity expansion under increasing deterministic, dynamic product demands and returns. Numerical results for the issues presented are given through a case study from the generated test data.

2 - Solving the Disassemble-to-order Problem under Yield Model Misspecification

Stephanie Vogelgesang, Faculty of Economics and Management, Otto-von-Guericke University Magdeburg, *Ian M. Langella*, *Karl Inderfurth*

The Disassemble-to-order (DTO) problem deals with the question of how many returned products to disassemble in order to meet a specific demand. A random yield problem concerns itself with how many good quality parts will be harvested from disassembly. Approaches to incorporate random yields into DTO problems usually model randomness in two ways. The first approach, proportional random yields (SP), presumes that the yield rate parameters do not change by increasing or decreasing the number of products to disassemble. Another yield modeling approach, binomial random yields (BI), does not require this assumption but is considerably more complex to analyze. Until now, there has been no attention paid in the literature on which of these two approaches might prevail in practice. Using actual yield data from a car engine remanufacturer, we have tested if one of the modeling approaches is better fitting the disassembly outcome. From the results we can conclude that none of the yield modeling approaches mentioned above can be used exclusively for all parts of the engine to represent the outcome of the disassembly process. Our contribution also aims at exploring the sensitivity of DTO decisions to misspecification of the random yield model. In order to examine the impact of using the wrong modeling approach in decision support, we present a study based on the product structure used in Inderfurth/Langella (OR Spectrum, 2007). For this product structure, the optimal decisions can be obtained both for SP and BI yields. With these decisions on hand, we can calculate the performance loss of a misspecification of the yield model as a relative cost deviation and we are able to indentify cases in which using the wrong yield model has a strong impact on the cost performance.

3 - An Integrated Approach to Green Product and Supply Chain Design

Cornelia Schoen, GISMA Business School, Leibniz University Hannover

In many industries, product design increasingly requires to integrate economic objectives with environmental thinking - driven by raising ecological concerns, regulatory pressures, and the potential to create a marketing edge through sustainable operations. A major challenge of green design is that it must not only embrace a product's key features from a consumer perspective but also all underlying supply chain processes that determine a product's 'greenness'. We present an integrated optimization approach for green product and supply chain design along with applications.

■ WE-27

Wednesday, 17:00 - 18:30, Room F342

Lotsizing

Chair: *Stefan Helber*, Inst. f. Produktionswirtschaft, Leibniz Universität Hannover

1 - Extended Production Policies based on Cyclic Patterns

Philipp Zeise, Lehrstuhl für Quantitative Planung, Universität Siegen

In this paper we consider the production process of a pharmaceutical company. In general, such a production process comprises three stages, namely the production of active pharmaceutical ingredients followed by the production of the final product variants and the packaging process. Essential characteristics of this process are multiple products divided into product families, sequence-dependent setup times, minimum lot sizes, and stochastic demands. The main goal is to reduce work-in-progress and finished product inventories. The production policy used by the company so far bases on a cyclic pattern (sequence of production) determined for each stage independently. Using this sequence each product variant is produced up to its' predetermined inventory replenishment level. We present some ideas how this policy can be extended, e.g. how production can be synchronized over stages in order to reduce total costs per unit of time and planning volatility. Accordingly, several sequencing strategies are proposed. Furthermore, we give first insights yielded by conducting computational experiments based on practical instances.

2 - Analysis of Karush-Kuhn-Tucker conditions for the joint economic lot size problem with asymmetric information

Grigory Pishchulov, Supply Chain Management, TU University Dortmund, *Knut Richter*

Sucky (2006) [A bargaining model with asymmetric information for a single supplier-single buyer problem, European Journal of Operational Research 171, 516-535] has introduced a model that allows a single supplier to proactively design a menu of contracts for offering to a single buyer who has an absolute bargaining power and whose cost parameters are uncertain. Considering the case of two possible cost structures to be assumed for the buyer, the above work identifies six possible menu designs and derives conditions for their optimality using the Lagrangean approach. We however show that the suggested optimality conditions may not necessarily serve as such due to the non-convexity of the problem under consideration - thus proving to serve merely as criteria of local optimality. We then investigate the additional model assumptions that can still ensure the global optimality of a Karush-Kuhn-Tucker solution representing such local optimum. In addition to that, we show that in certain cases also non-eligible solutions may successfully pass the suggested optimality test, and further show how should the respective optimality conditions be properly refined.

3 - Robust capacitated dynamic lot sizing subject to yield uncertainty

Stefan Helber, Inst. f. Produktionswirtschaft, Leibniz Universität Hannover, *Florian Sahling*, *Katja Schimmelpfeng*

We study the problem to determine time-phased production quantities in a single-stage, multi-period and multi-product lot sizing setting. The problem is a generalization of the well-known deterministic Capacitated Lot Sizing Problem (CLSP). While the CLSP does not consider quality imperfections, we assume that the production process is characterized by substantial yield uncertainty described via an interrupted geometric distribution. The idea is that during the production of each single product the process goes "out of control" with a specific probability so that this and all following product units of the particular lot have to be scrapped. In this situation, the lot size has a paramount effect on the average unit production cost and lot sizing becomes immensely important. We present alternative modeling approaches to determine robust production schedules subject to this yield uncertainty. To this end, we approximate the expected end-of-period values of physical inventory and backlog and minimize the expected cost subject to a backlog-oriented Delta Service Level constraint. Our approach leads to robust production plans in the case of yield uncertainty.

■ TA-26

Thursday, 9:00 - 10:00, Room E214

Network Design II

Chair: *Florian Sahling*, Institute of Production Management, Leibniz University Hannover

1 - Robust Strategic Supply Network Design with uncertain Information

Florian Sahling, Institute of Production Management, Leibniz University Hannover, *Michael Hüttemann*, *Ariane Khoramnia*

We present a stochastic version of a three-layer supply network design problem. The configuration of a supply network has to be determined based on demand forecasts for a long planning horizon so that the expected net-present value of the period-based payment flows is minimized and a given service level is met. This leads to a non-linear model formulation which is approximated by a mixed-integer linear model. In the latter model the expected backlog as a function of the production quantity is approximated by piecewise linear functions. A numerical analysis of synthetic problem instances shows that the solution of the linearized model formulation yields a robust and stable supply network configuration in the presence of uncertain and dynamic demand.

2 - A robust Supply Chain Design Problem with modular capacities

Ariane Khoramnia, Institut für Produktionswirtschaft, Leibniz Universität Hannover

We study the problem of where to establish production facilities and how to dimension their capacities in an environment with uncertain demand. In this context, we assume facility resources to be modular and a production facility to be defined by the specific combination of modules. The usage of mobile, modular capacities enables the de-/installation of individual modules at different sites. Furthermore, resources of production sites can even be relocated as a whole. This can be advantageous, for example, in case of a shift in demand. In this way, over-capacity and/or transportation costs can be reduced. As the planning horizon of a supply chain design problem is quite long, decisions have to be made based on demand forecasts. Therefore, an approach to consider modular capacities in a two-layer strategic-tactical supply chain design problem with stochastic demand is introduced. The goal is to find a robust supply chain design so that the expected net-present value is maximized while meeting a given service level. As this model formulation is non-linear, a linearization approach is applied to the non-linear expected backlog function to generate a solvable mixed-integer linear program.

■ TA-27

Thursday, 9:00 - 10:00, Room F342

Contracts

Chair: *Guido Voigt*, Operations Management, Otto-von-Guericke University Magdeburg

1 - Pricing Indirect Behavioral Effects in a Supply Chain: From the Perspective of Contracts as Reference Points

Isik Bicer, Faculty of Business and Economics, University of Lausanne

We consider a supplier-retailer relationship in which a supplier and a retailer negotiate on a contract for the delivery of a single product. The contract specifies the number of firm commitments and options where the supplier reserves a capacity K at t(0) for the retailer's final order that will be given at t(1) > t(0) to be delivered at t(2) > t(1). The retailer who aims to increase his own profit without any concern about the supplier's profitability increases the uncertainty on the supplier's side by changing the cost structure of the contract. Although there are empirical evidences in the literature that the increasing uncertainty on the supplier side also imposes cost burden on the retailer, the current supply chain contracting models do not allow explicitly to price such indirect cost effects. In this research, we integrate "Contracts as Reference Points' theory (Hart and Moore, 2008) into quantity flexible contracts to price the indirect effects of retailer's behavior. Under non-stationary demand and voluntary compliance for the supplier, we show that there is a trade-off for the retailer between decreasing the option cost and increasing the indirect cost.

2 - Contracting under asymmetric holding cost information in a serial supply chain with a nearly profit maximizing buyer

Guido Voigt, Operations Management, Otto-von-Guericke University Magdeburg

Screening contracts (or non-linear "menu of contracts') are frequently used for aligning the incentives in supply chains with private information. In this context, it is assumed that all supply chain parties are strictly (expected) profit maximizing and, therefore, sensible to even arbitrarily small pay-off differences between contract alternatives. However, previous behavioral work on contracting under asymmetric information in supply chains shows that agents (buyers) are not always strictly profit maximizing, but sometimes tend to choose contracts that have only a minor impact on their own performance but a substantially negative impact on the principal's (supplier's) and the overall supply chain's performance. Thus, these studies indicate that the buyers are in fact not strictly but only nearly profit maximizing when making their contract choices. The present work relaxes the assumption of the strictly profit maximizing buyer in a serial supply chain for a lotsizing framework with asymmetrically distributed holding cost information and deterministic end-customer demand. The study provides researchers and managers an approach on how to account for the buyer's insensitivity to arbitrarily small pay-off differences while providing a solution method for the resulting non-linear mathematical program. A numerical study compares the advantages of the "behavioral robust' contract assuming only nearly profit maximizing buyers against the classical screening contract assuming strictly profit maximizing buyers. The results highlight that supply chain performance losses can be substantially reduced under the behavioral robust contract.

■ TC-26

Thursday, 11:30 - 13:00, Room E214

Green Supply Chains

Chair: *Kathrin Fischer*, Institute for Operations Research and Information Systems, Hamburg University of Technology (TUHH)

1 - Evaluating Management Approaches In Green Supply Chain Using Extended Vikor Method

Betül Özkan, Industrial Engineering, Yildiz Technical University, *Nihan çetin Demirel*, *Huseyin Basligil*

The resources used during manufacturing processes are exiguous resources. These used resources and methods affect the human health negatively and damage the environment. These factors cause that the green supply chain becomes more important in recent years. The firms started producing environmentally-conscious products and environmental factors are important at all of the supply chain stages. The management approaches are also very important for firms. The level of green implementations in firms are determined according to management approaches. In this study we evaluate for a medicine firm in Turkey three different management types in green supply chain according to six different main criteria using one of the multi criteria decision making techniques VIKOR. And we determined which management approach is most suitable for the medicine firm.

2 - Business Analytics with AIMMS: optimizing demand & supply allocation of energy efficient systems for buildings

Ovidiu Listes, Paragon Decision Technology

In order to meet the increasing demand for energy efficiency in existing and new buildings, a world leader in insulation materials adopted AIMMS for developing an intelligent decision support tool that could optimize their demand & supply allocation process. The objective is to reduce costs even further while maintaining service levels and minimizing CO2 emissions. We illustrate how AIMMS is able to accommodate the formulation of an efficient allocation model as well as the insightful visualization of the data. We also show how AIMMS allows for fast, flexible experiments and comparison of results, which serve well the business analytics purposes.

3 - Closed-Loop Supply Chain (CLSC) Management: Analysis and classification of existing approaches, and future research prospects

Leena Steinke, Institute for Operations Research and Information Systems, Hamburg University of Technology (TUHH), *Kathrin Fischer*

Product recovery, especially remanufacturing as a higher form of product recovery, is an important topic for manufacturers - in particular for original equipment manufacturers (OEM) - who have to comply with legal requirements. Moreover, they can gain economic advantages by not buying more expensive raw materials or product components, especially as the delivery of these components can be delayed and thus can cause disturbance of the production process. Furthermore, remanufacturing can reduce the energy and work input of the production, decrease the bullwhip effect and/or decrease the inventory variance in a multi-echelon environment of an OEM. Therefore, many papers on the theme of closed-loop supply chain management in an OEM environment have been published during the last decades. The aim of the respective research is to find a strategy which enables the manufacturer to control the hybrid system of manufacturing and remanufacturing and to manage the forward and return flows of products or components as well as the manufacturing/ remanufacturing process, such that returned products serve as a dependable and useful input source in the production process, not only fulfilling legal requirements, but also minimizing the costs of the integrated systems. The systematic survey of the literature on CLSCs presented in this work reviews and classifies the different approaches, e.g. according to their assumptions and modelling approaches, and analyses their contribution to solving the problems caused by adding an additional, uncertain return flow to the supply chain. Moreover, some important further research directions are discussed.

■ TC-27

Thursday, 11:30 - 13:00, Room F342

Supply

Chair: *Rainer Kleber*, Faculty of Economics and Management, Otto-von-Guericke University of Magdeburg

1 - A discrete time approach to analyze the behavior of Milkrun supplied inventories

Justus Arne Schwarz, Chair of Production Management, University of Mannheim

The Milkrun concept is a well-known strategy to distribute or collect goods. Milkrun systems aim to achieve both, low inventory levels and high flexibility. Methods for dimensioning the necessary Milkrun inventories are often based on average values. Especially for high variability of the demand pattern this approach can be misleading. Consequently, a stochastic discrete time model is presented to determine the inventory level for a given service level. The demand pattern is given by discrete distributions of interarrival times and demand size. The developed model extends a general batch building process by an inventory component. The inventory behavior is then modeled by a Markov process. Measures for the system performance are derived from the steady state probabilities. Numerical examples show the characteristic system behavior and quantify the tradeoff between delivery frequency and inventories.

2 - Supply strategies for a fashion retailer

Miriam Kießling, Universität Bayreuth, *Sascha Kurz*, *Jörg Rambau*, *Tobias Kreisel*

We present the Integrated Size and Price Optimization Problem (ISPO) for a fashion retailer with many branches. Branches are supplied by pre-packaged bundles consisting of items in different sizes and quantities — so-called lot-types. Our goal is to find a revenue-maximizing supply strategy. We have developed varying models for size optimization, which differ in the treatment of exogenous influences. Our final model ISPO is a mixed integer linear program, which includes the effect of markdowns for distinct scenarios as recourse for over-supply. To evaluate the applicability of these models we will show results from real world field studies. In a concluding field study we show that the realized revenue based on ISPO solutions is nearly 2 percentage points above that of a one-stage optimization of the distribution ignoring the possibility of optimal pricing

3 - Single vs. dual sourcing: the strategic impact of stock-keeping on supply strategies

Rainer Kleber, Faculty of Economics and Management, Otto-von-Guericke University of Magdeburg, *Karl Inderfurth*, *Peter Kelle*

Supply strategy is getting more important in many industries with an increasing focus on advanced sourcing strategies. In our research we address a procurement problem of a component/material that is used for producing finished goods in a make-to-stock environment under stochastic demand. We consider two sourcing options: the spot market and a capacity reservation contract. The capacity reservation contract is used as an operational risk hedging for high spot market price incidents. Typically, it needs to be fixed for a longer time horizon specifying the price and quantity and pay the reservation price up front. A combined procurement strategy then has to protect against risks of insufficient demand fulfillment and exploit the benefits of forward buying in periods with low spot price levels. After introducing the problem and a basic quantitative model, we evaluate optimal strategies using different combinations of the above two options. In a comprehensive numerical study using a full factorial design we provide answers to the following questions: - What advantage can be drawn from dual sourcing compared to strategies with using (a) the spot market and (b) a long-term contract only? - How does the sourcing strategy react on parameter changes and on capacity for stock-keeping? - How large is the cost penalty of using a simple base stock policy for dual sourcing and which parameters have a large impact on it?

■ TD-26

Thursday, 14:00 - 15:30, Room E214

Transport

Chair: *Joachim R. Daduna*, Hochschule für Wirtschaft und Recht Berlin Berlin

1 - A genetic algorithm for the integrated scheduling of production and transport systems

Jens Hartmann, BIBA - Bremer Institut für Produktion und Logistik GmbH at the University of Bremen, *Thomas Makuschewitz*, *Enzo Frazzon*, *Bernd Scholz-Reiter*

The scheduling of production and transport processes in manufacturing supply chains is currently done separately. Thus, these schedules might lead to a local optimum of an objective pursued by the supply chain. Further improvements of the operational supply chain performance might be achieved by an integrated consideration of operations. The integrated production and transport scheduling problem (PTSP) can be formulated as a mixed-integer program (MIP). The MIP comprises binary optimization variables that represent assignments, e.g. orders to machines or trucks, as well as continuous optimization variables like time and costs. Since it belongs to the class of NP-hard problems, exact solutions are limited to small problem instances. This paper introduces a heuristic approach for the solution of the MIP based on a genetic algorithm that allows solving problem instances of practically relevant size. Here, the problem is split into two subproblems which can be tackled by different solution techniques. The first subproblem deals with the binary variables, which represent the genomes in the genetic algorithm. However, the number of binary variables leads to a very large solution space. Therefore, by using dependencies between binary variables we limit the number of variables that are mutated, whereas the remaining variables are determined in a deterministic way. For a given genome, a configuration of the binary variables, the remaining optimization subproblem is a linear program (LP) which can be solved efficiently in the worst case. Thus, the optimal value of the objective function from the LP represents the value of the fitness function in each iteration of the genetic algorithm. A prototypical implementation is performed for the computational analysis of the heuristic.

2 - Heuristic Strategies for a Multi-Allocation Problem in LTL Logistics

J. Fabian Meier, Institut für Transportlogistik, TU Dortmund, *Uwe Clausen*

We consider a multi-allocation problem with "integral trucks' (i.e. transport costs are not calculated by weight but by the number of trucks used). It consists of two steps: A number of hubs are chosen out of a given set of depots; then the given transport relations are individually assigned to two hubs, one hub or direct transport. Our real world data set consists of 60 depots and 2200 transport relations. An implementation as MIP using CPLEX gave poor results with a gap of about 90%, even for computation times of 12h. The heuristic approach we implemented finds a solution with 50% gap in less than 5 minutes (also using some theoretical observations concerning the best bound); using it to fix the "best hubs', CPLEX allows us to improve this gap to 40%. The idea is as follows: Considering the whole network as collection of n trees sending goods to a chosen depot, we improve the total costs step by step: For that we always take the edge with "most expensive transport' and try to find a new route for it. This process is quite flexible and fast. In our paper we will explain the theoretic ideas, point out different possibilities and connect them to computational results.

3 - Logistics approaches for inner-city deliveries in retail trade - Experiences and opportunities -

Joachim R. Daduna, Hochschule für Wirtschaft und Recht Berlin Berlin

Urban freight transport is a topic which is consistently subject of the (partly also ideologically colored) political discussion. These are basically deliveries in retail trade, as well as construction site transport an transport of waste. Although those are necessary in every city, they are con-fronted with rejection and are often branded as the cause for the known traffic problems in city centers. With respect to deliveries in retail trade, it has been sought for solutions for years within the scopes of city logistics concepts. In the foreground here are three aspects: the cooperative organization of flow of goods with the help of logistical facilities (such as Urban Consolidation Centers or City Terminals), combined with an efficient routing on the basis of terminal and col-lection concepts and also the reduction of pollutant emissions (due to traffic) as well as regula-tory intervention of local public-law authorities. The experiences made worldwide to date are very diverse and the success and failure is strongly dependent on the respective general framework. So far it is not as much focused on the question to what extend the currently incurring deliveries can be avoided or can be organized in another way, without resulting in significant disadvantages for retail trade though. A possible approach is the partial restructuring of warehousing on the basis of cooperation concept in conjunction with a dislocated centralization, especially for smaller and medium-sized enterprises. Different models could be applied here. The main objective is to reduce the inflow of goods which are delivered to the customer at a later point in time as part of service features. Apart from the question whether such concepts are accepted by the affected retail trade, the question of availability of an appropri-ate storage facilities as well as the existence of necessary general conditions has to be born in mind. In addition, the application of efficient IT systems is inevitable for planning as well as for monitoring and control of all required processes.

■ TD-27

Thursday, 14:00 - 15:30, Room F342

Auctions

Chair: *Leena Suhl*, DS&OR Lab, University of Paderborn

1 - A Simple Multi-attribute Yardstick Auction Without Prior Scoring

Kurt Nielsen, Institute of Food and Resource Economics, University of Copenhagen, *Jens Hougaard*, *Athanasios Papakonstantinou*

We analyze a simple multi-attribute procurement auction that postpone the Principal's scoring. We consider the situation where the Principal is uncertain about his own preferences and provides no prior information about the willingness to pay for extreme attribute values. The auction facilitates competition by yardstick prices defined by a convex envelopment of the other bidders' bids. The auction is not incentive compatible, however the yardstick pricing promotes truth-telling in the absent of prior stated preferences (scoring). We analyze to what extent truth-telling is a good bidding strategy. Analytically, the winner as well as inefficient bids (bids where the associated yardstick price is below true cost) have no incentives to deviate from truth-telling ex post. However, efficient bids that did not win the auction may gain by departing from truth-telling. Although no one can influence their own yardstick price which is entirely settled by the other bidders' bids, it is possible to manipulate the neighbors yardstick bids. We show to what extent this is an optimal bidding strategy. By simulation, we investigate the runner up's room for manipulating the auction. Manipulating by bidding above true cost is only feasible for a smaller fraction of the bidders and with few participants the average departure from truth-telling has to be relatively large on average. As the number of participants grow the room for manipulation by smaller departures from truth-telling increases, however so does the risk of a getting a loss. In general, the preliminary results show that the room for manipulation is limited.

2 - A Game-Theoretic Real Option View on Investment Timing and Efficiency in Supply Chains

Andreas Welling, Faculty of Economics and Management, LS Financial Management and Innovation Finance, Otto-von-Guericke University Magdeburg, *Elmar Lukas*

We model a sequential investment bargaining game in a supply chain by means of real options. We show that the supply chain is getting less efficient with every additional chain link and that a first-mover advantage always prevails. Hence, a chain link's share of the supply chain's total generated surplus is increasing with its proximity in the supply chain to the first-mover. While increasing interest rates will reduce the first-mover advantage, we can show that managerial flexibility is strengthening the first-mover advantage by undermining the bargaining power of the remaining chain links

3 - Combinatorial auction for area forwarding based logistics networks

Atilla Yalcin, DS&OR Lab, University of Paderborn, *Leena Suhl*

Outsourcing of logistic processes is a major topic for decision makers in logistic departments. The scope of outsourcing comprises besides short-term, transactional transportation orders even long-term contractual agreements with logistic service providers, also termed as contract logistics. But in case several logistic service providers should be selected for full-truck loads (FTL) and less-than-full truck loads (LTL) in inbound or outbound logistics partioning (or bundling) of areas is required. One possibility to do this is to apply methods from classical facility location planning to determine appropriate areas, and then auction off these areas separately. In addition to this common practice, we explore the following approach: just define smaller, mid-size areas and then do a combinatorial auction. Combinatorial auction is an auction format where bidders can apply for bundles of services (areas). This allows logistic service providers to price preferred areas more precisely and to be more competitive. Another advantage is that most players in the logistic market are small and medium sized companies and this auction format allows them to take part in this auction, which originally motivated this research. But bidding in this auction is more complex since the possibilities for bundles are exponential. Due to cognitive limits of bidders it is expected that each bidder only submits only a few bids. Expecting this behavior this can weaken the advantage of combinatorial auction. Contingent bids can help at this point to express in a comprehensive way a range of bids. We model the bidder's problem of how to find optimal bids and also give a model formulation for the auctioneer winner determination problem. Finally we compare results for different auction formats.

■ FA-26

Friday, 9:00 - 10:00, Room E214

Humanitarian Logistics

Chair: *Kathrin Fischer*, Institute for Operations Research and Information Systems, Hamburg University of Technology (TUHH)

1 - An Analysis of Lateral Transshipment Opportunities for Humanitarian Relief Facility Location in Istanbul

Serhan Duran, Industrial Engineering, Middle East Technical University, *Alp Ertem*, *Serhat Baskaya*

A destructive earthquake is anticipated to occur in Istanbul in the near future. The effects of this earthquake on infrastructure and economy are anticipated to be enormous. Humanitarian relief facilities are planned to locate around Istanbul to execute post-disaster activities and relief operations. The objective of this study is to minimize the average relief response time to serve beneficiaries. A mathematical modeling approach is used to take several decisions such as locations of potential humanitarian relief facilities, the number of opened humanitarian relief facilities, the quantity of relief items hold in the humanitarian relief facilities, the locations humanitarian relief facilities which are allowed to make lateral transshipment and the quantity of lateral transshipment among these facilities.

2 - Decision making in humanitarian logistics — A multi-objective optimization model for allocating relief goods during disaster recovery operations

Beate Rottkemper, Institute for Operations Research and Information Systems, Hamburg University of Technology, *Kathrin Fischer*

Each year, around 400 disasters are reported world-wide and a multitude of people are affected by them. Immediately after a disaster has occurred, media attention is high and hence, there is usually sufficient funding for relief operations. Meanwhile, various long-term aid programmes following sudden-onset disasters are underfunded although the circumstances in the affected regions are far from being normal: Usually, the infrastructure is still in bad shape and disruptions of the relief operations are common. Such disruptions require a fast reaction without abandoning the ongoing relief actions. Furthermore, a trade-off has to be found between minimizing operational costs (as the budget is scarce in this phase) and minimizing the risk of future supply shortages. In this study, a vaccination programme is considered which is disrupted by the outbreak of an epidemic. The routine vaccination programme has to be continued while an emergency vaccination needs to be established in the affected region to prevent a further spread of the epidemic. There are already warehouses established and vaccines in stock for the ongoing programme; these vaccines can now be allocated to the currently affected region, but this should not be done without considering the risk of an epidemic spread into other regions. In this work, a multi-objective mixed integer programming model is developed to provide decision support in such a situation. The model is solved with a weighted-sum method as well as with an epsilon-constraint method, and the results are analysed and compared.

TRAFFIC AND TRANSPORTATION

■ WB-24

Wednesday, 11:30 - 13:00, Room F428

Routing I

Chair: *Karl Nachtigall*, Faculty of Transport and Traffic Sciences, Institut for Logistics and Aviation, Technical University of Dresden

1 - A dynamic pickup-and-delivery approach for relocation operations in bike sharing systems

Viola Ricker, Business Information Systems, University of Braunschweig, *Stephan Meisel*, *Dirk Christian Mattfeld*

In order to reduce traffic congestion and environmental pollution many cities established bike sharing systems as an expansion to their local public transport. In most of the rack-bound bike sharing systems, it is possible to both lend and return bikes spontaneously at an arbitrary station. This leads to imbalances in the spatial distribution of bikes. Counteractions to these imbalances are required for ensuring that a sufficient number of bikes and racks are available in order to satisfy customer demands. The most important countermeasure is relocation of free bikes by means of service vehicles at regular time intervals. However, operating service vehicles tends to be cost-intensive. Thus, the service vehicles must be routed efficiently in order to reduce transportation costs while satisfying customer demands. In this contribution the resulting problem is modelled as a dynamic and stochastic pickup-and-delivery problem with limited service vehicle capacities. We simulate a bike sharing system using real world demand data and derive a relocation policy by repeated solution of pickup-and-delivery problems. The approach is evaluated in comparison to approaches from the literature.

2 - Improved cooperative DVRP algorithm based on vehicle direction determination

Tibor Dulai, Department of Electrical Engineering and Information Systems, University of Pannonia, *Ágnes Stark-Werner*

Dynamic, immediate events have huge role in practical logistic tasks. As computational capabilities have improved, route planning applications begun to take care of immediate events (new orders, break-down of a vehicle, etc. after the fleet of vehicles have started on their routes), and more and more researches were applied in the topic of Dynamic Vehicle Routing Problem (DVRP). Usually the developed algorithms deal with an immediate event after it happens and handles a DVRP problem as a sequence of static VRP problems. We have developed an algorithm, which takes into account that failures may happen during the delivery process and results the solution which has the best answer in case of a transportation failure without decreasing the quality of an usual DVRP solution. Our algorithm is applicable for DVRP problems without time window and needs an arbitrary DVRP solution as its input. The idea is based on that a solution's routes are circles which may be driven in two opposite directions. We choose the directed route set which has averagely the best answer for an immediate event. It is done through supposing vehicle failures in well determined intervals and calculate the extra cost which the nearest vehicle would have in case of its help. The final choice is based on the average of these values. In this paper we improve our basic algorithm by better direction of the helper vehicle after the immediate event happens. The effectiveness of the improvement related to our basic algorithm is analyzed through case studies which were generated arbitrarily and chosen from the Solomon tests, too. Our results may have positive effect for logistic costs of companies and can be applied for any DVRP problem without time window.

3 - Energy-optimized Routing of Electric Vehicles in Urban Delivery Systems

Henning Preis, Faculty of Traffic and Transportation Sciences, Institute for Logistics and Aviation, Technical University of Dresden, *Stefan Frank*, *Karl Nachtigall*

Commercial traffic in urban areas is faced with increasing challanges of ecological compatibility, in particular noise and air pollution. In this context electric driven vehicles seem to offer great opportunities. Along with the technical innovations arises the need of appropriate operating models considering special issues such as energy consumption, range restriction and the use of charging stations. In this paper we present a new model for the well known Vehicle Routing Problem, which adapts most of the needs for operating electric vehicles. This includes an objective function that considers energy consumption depending on driving resistance and loading weight, and a set of additional restrictions to handle the maximum range depending on battery capacity and recharging options. To illustrate the problem a few sets of test instances with different characters are created. Small instances are solved by a non-commercial MIP solver. For solving larger instances the paper introduces an adapted tabu search heuristic which provides reasonable solutions. The resulting sets of vehicle routes are analyzed to expose typical characteristics of energy-based electric vehicle routing. The trade-off in respect of distance-based optimization is examined.

■ WB-25

Wednesday, 11:30 - 13:00, Room F442

Public Transport

Chair: *Leena Suhl*, Int. Graduate School of Dynamic Intelligent Systems, University of Paderborn

1 - Train Timetabling on multiple track and station capacity railways with enhanced upper bound heuristic method

Afshin Oroojlooy Jadid, Industrial Engineering, Sharif University of Technology, *Kourosh Eshghi*

Train scheduling is a significant issue in the railway industry in recent years because it has an important role in railway infrastructure. In this paper, the timetabling problem of a multiple tracked railway network is discussed. More specifically, a general model with specific attention to "Tehran Metro' is presented here in which a set of operational and safety requirements are also considered. The model handles the trains overtaking in a station and innovatively considers the capacity of stations. An objective function is to minimize the total travel time. The problem is NP-hard so the real size problem cannot be solved in acceptable amount of time. In order to reduce the processing time of the problem, first, we represent some heuristic rules to reduce the number of binary variables. These rules are based on parameters such as transfer time between two points, dwell time and safety time of stations. Furthermore, the logical conditions in the problem cause that the impracticable area from solution space is removed. These rules also allow us to reduce the memory and time considerably in compare to the original problem. Comprehensive numerical experiments with different number of trains, stations and capacities are reported to show the performance of the model and its proposed rules. The result shows that the computational time is considerably reduced and the global optimum of the optimization problem is achieved by using the heuristic rules.

2 - Integrated scheduling approaches for minimizing delay propagation in vehicle and crew schedules in public transport

Bastian Amberg, Information Systems, Freie Universitaet Berlin, *Boris Amberg*, *Natalia Kliewer*

This contribution deals with robust vehicle and crew scheduling in public bus transport. As disruptions and - in consequence - delays are unavoidable during execution of vehicle and crew schedules, possible delays should already be considered in the planning phase. Schedules should be created that way that minor disruptions can be absorbed and delay propagation can be controlled. We present integrated scheduling approaches to improve delay-tolerance of both vehicle and crew schedules. In general, the objective is to minimize vehicle and crew costs. Additionally, different indicators are considered for building robust schedules, such as additional buffer times, the number of different crew duties per vehicle, and the expected propagation of delays. The expected propagation of delays is taken into account within and between vehicle blocks and crew duties. As vehicles and crews are scheduled simultaneously the mutual dependencies between vehicles and drivers can be considered to minimize the overall propagation of delays within the transport network. Further, the approaches take advantage of the underlying time-space-network model. The model allows us to compute a flow solution that represents a bundle of feasible, cost efficient vehicle schedules. From the bundle of vehicle schedules we can obtain the one that minimizes the delay propagation best in interaction with the crew schedule. The proposed approaches are tested and compared on real-world instances from public transport companies in Germany. We evaluate computational time of the approaches as well as planned costs and delay propagation of the computed schedules.

3 - A vehicle-crew-scheduling-and-rostering approach for improving driver satisfaction in public bus transport

Lin Xie, DS&OR Lab, University of Paderborn, *Boris Amberg*, *Leena Suhl*

The crew rostering problem (CRP) in public bus transport companies aims at generating a cyclic roster for each group of drivers while management considerations and labor laws have to be satisfied. The rosters are built based on duties that have been computed in the preceding vehicle and crew scheduling stage. During roster generation, preferences of drivers are considered. Optimal rosters are characterized by minimal number of unassigned duties, minimal difference of overtime among all drivers, and maximal satisfaction of drivers. One of the common preferences of drivers is to get similar duties within a working week. Basically, we define similar duties as those duties which contain a large amount of equal (sub-)sequences of service trips. Usually public transport companies face a problem when the vehicle and crew scheduling problems of different days are solved with state-of-the-art optimization methods: as some trips are not serviced every day, cost efficient duties computed for one day may completely differ from duties for another day. To obtain both cost efficient and similar duties, we solve the scheduling problems of different days together. The generated duties are then assigned to drivers in the CRP. The CRP is mostly solved sequentially due to its high complexity, namely firstly the rota scheduling problem, and secondly the duty sequencing problem. However, this method may generate sub-optimal rosters. In order to avoid a sub-optimal solution, this work discusses an integrated CRP by considering the above-mentioned similar duties. We test our approaches on real-world instances and compare the results with regard to computational time and solution similarity.

■ WC-24

Wednesday, 14:00 - 15:30, Room F428

Routing II

Chair: *Julia Rieck*, Operations Research Group, Clausthal University of Technology

1 - A new mathematical model and a variable neighborhood search algorithm for the multi-compartment vehicle routing problem

Tino Henke, Fakultät für Wirtschaftswissenschaft, Otto-von-Guericke Universität Magdeburg, *Gerhard Wäscher*

The capacitated vehicle routing problem and its many variants have been extensively studied over the last decades. In recent years, the research on vehicle routing problems has shifted towards more complex problems. One of these problems is the so-called multi-compartment vehicle routing problem. This problem occurs in several real world applications, as for example in waste collection or product distribution. In this problem, a number of heterogeneous products have to be delivered to (or collected from) several customer locations by a fleet of vehicles. It is necessary, that different products are transported separately from each other because they require different transport conditions (e.g. different temperatures) and/or because they cannot be mixed due to their consistency (e.g. liquid or bulk products). Consequently, it is possible to separate a vehicle's loading area (capacity) into several compartments such that different products can be transported at the same time, which would allow for a reduction of transportation costs. It has to be decided how the available capacity should be divided into compartments and which routes are to be taken in order to serve all customers, such that the total costs of transportation are minimized. For the multi-compartment vehicle routing problem a new optimization model will be proposed, which allows for solving small problem instances to optimality by means of commercial LP solvers. Furthermore, a variable neighborhood search algorithm will be described. The performances of both, the model and the algorithm, have been evaluated in extensive numerical experiments and the corresponding results will be presented.

2 - Adaptive Waiting Strategies for Dynamic Routing of Service Vehicles

Uli Suppa, Carl-Friedrich Gauss Department, University of Braunschweig, *Stephan Meisel*, *Dirk Christian Mattfeld*

An increasing number of business models are relying on service operations that must be implemented by operating a fleet of service vehicles. Example applications include technical repair and maintenance services for end consumers, food home delivery services and emergency field services for mission critical business tools. For each of these cases, the efficiency of service operations often crucially depends on the routing of service vehicles. The routing must guarantee both service reliability and responsiveness while minimizing the operational costs for service provision, i.e., the routing must ensure consistency with service agreements while causing a minimal amount of distance travelled. Waiting strategies have been successfully applied to several dynamic vehicle routing problems in order to minimize distance travelled while satisfying service agreements. In most papers a preselected waiting strategy is applied to a vehicles tour during the working shift regardless of the actual workload. We propose an adaptive waiting strategy, which anticipates future requests as well as adapts to the current states of the vehicles. The adaptive waiting strategy determines vehicle specific waiting strategies, which should be applied during the work shift. The set of possible specific waiting strategies and the size of the fleet of vehicles define the set of candidate solutions that could be implemented. However a complete evaluation of each candidate solution by simulation is prohibitive. Therefore the expected costs for each candidate solution are estimated by a sequential sampling procedure.

3 - Integrated network design and routing: an application in the timber trade industry

Julia Rieck, Operations Research Group, Clausthal University of Technology, *Carsten Ehrenberg*

Most timber-trade companies provide their services using hub-and-spoke networks. Under such networks, economies of scale and scope can be realized by consolidating freight through one or more hubs. Since handling processes at hub locations are especially difficult for large-sized and non-standardized products, the number of intermediate hubs on a shipping path is usually limited to no more than two. Furthermore, routing all freight through a hub is not necessarily appropriate in any situations. Direct transports of products are of considerable importance if vehicles are fully loaded and contain products for only a few destinations. As a rule, timber-trade companies receive periodic orders. Hence, they benefit from stable resources planning as well as pick-up and delivery schedules along fixed vehicle routes. In order to yield an efficient transport network for timber-trade companies three critical design questions have to be taken into account: (a) How many hub facilities are required and where should they be positioned? (b) Should node-to-node links be directly connected or via one or two hubs? (c) Can nodes be combined to form vehicle routes, where every route starts and ends at an assigned hub? The overall network operating costs are composed of fixed costs for establishing hub facilities, and variable costs for handling and transporting goods (directly or on routes). The resulting problem is modeled as a mixed-integer linear model and medium-scale instances are solved using CPLEX. In order to facilitate the solution process, preprocessing information and cutting planes are added during optimization. Test computational runs are conducted on a number of randomly generated instances, duly allowing for control parameters to be able to reproduce real-life situations.

■ WC-25

Wednesday, 14:00 - 15:30, Room F442

Road Traffic

Chair: *Matthias Ehrgott*, Engineering Science, University of Auckland

1 - OR meets Mobility Mining — Dynamically Align Logistics and Traffic Management to Reduce Overall Transportation Costs by higher Quality of Service

Hendrik Stange, Knowledge Discovery, Fraunhofer IAIS, *Thomas Liebig*, *Sebastian Bothe*

Today's mega industrial areas suffer from a significant increase of traffic. In peak hours there is always the fear of a gridlock causing enormous direct and intangible costs. New concepts are required to dynamically align logistic, commuting and private traffic. To this day strong efforts have been made to optimize each subsystem individually. Consequent seamless traffic concepts are still missing and current approaches lack to integrate new sources of high-resolution mobility data. The recently launched Mobility Map Germany as such a database delivers detailed traffic insights for each German street segment and hour of the day and, thus, it enables contemporary concepts for holistic traffic modeling. In this paper we propose an approach for developing dynamic traffic models which takes the local travel behavior into account creating possibilities for optimizing logistics and transportation processes and to reduce general costs of traffic. The goal is to synchronize the multi-modal traffic (logistics, commuter, private, etc.) and to optimize the throughput of the transportation system, to improve its quality of service, to reduce the driver's stress and delays in transport chains. This paper addresses the challenges in designing a dynamic mobility model and in particular investigates possibilities to derive the data required for commuter behavior modeling from big data (such as GSM, GPS, Bluetooth, etc.). We demonstrate the applicability of our novel approach to the industrial region around the city of Wolfsburg (Germany).

2 - Hierarchical system of road networks with inward, outward, and through traffic

Masashi Miyagawa, Regional Social Management, University of Yamanashi

Road network planning involves a hierarchy of network links, ranging from wide high-speed roads to narrow low-speed roads. For efficient road networks, an appropriate hierarchical system must be established. In this paper, we formulate a continuous model for determining the optimal hierarchical system of road networks. The hierarchical system is represented as the proportions of area taken up by roads at each level of the hierarchy. We then obtain the optimal ratio of road areas that minimizes the total travel time. The model explicitly incorporates inward, outward, and through traffic as well as inner traffic to examine how traffic composition affects the optimal ratio of road areas. The result reveals that the optimal ratio of major arterial roads increases with inward, outward and through traffic. Thus, the city that attracts much traffic from other cities requires more major arterial roads than the city where inner traffic is dominant, even though the total traffic volumes are the same. This finding suggests that considering only total traffic volume is insufficient for road network planning.

3 - Multiobjective Network Equilibria and Traffic Assignment

Matthias Ehrgott, Engineering Science, University of Auckland, *Judith Y.T. Wang*

Multi-objective equilibrium models of traffic assignment state that users of road networks travel on routes that are efficient with respect to several objectives, such as travel time and toll. This concept provides a general framework for modelling traffic flow in tolled road networks. We present the concept of time surplus maximisation as a way of handling user preferences. Given a toll, users have a maximum time they are willing to spend for a trip. Time surplus is this maximum time minus actual travel time. A rational user can be assumed to maximise time surplus, leading to the definition of time surplus maximisation bi-objective user equilibrium. We propose to use such models on the lower level of bi-level models for pricing in road networks under multiple upper level objectives such as minimising system travel time and emissions. In such a model a multiobjective optimization problem at the upper level is combined with a multiobjective equilibrium problem at the lower level.

■ WE-24

Wednesday, 17:00 - 18:30, Room F428

Routing III

Chair: *Silvia Schwarze*, Institute of Information Systems, University of Hamburg

1 - Contraction Hierarchies with Turn Restrictions

Curt Nowak, Betriebswirtschaft und Wirtschaftsinformatik, Stiftung Universität Hildesheim, *Felix Hahne*, *Klaus Ambrosi*

For single-pair shortest path problems, Contraction Hierarchies (CH) provide very small query times together with a very low space overhead for the graph. During a preprocessing every node is assigned a distinct rank. Queries are performed using an alternating bidirectional Dijkstra search that only expands edges leading towards higher ranked nodes. In its original version CH do not take turn restrictions (TR) into account. Particularly in urban areas with many TR, this leads to illegal routes whose length may greatly differ from legal ones. Incorporating TR widens the scope of application for CH, e.g. car navigation or precise traffic simulations. One way to consider turn restrictions in CH routing is to switch from a node-based to an edge-based search, implicitly allowing nodes to be settled more than once. Compared to the original CH query this increases the size of the search trees substantially. We present a more space efficient hybrid algorithm combining node-based with on-demand edge-based search. The notion behind this is that nodes may only be settled twice if the encountered path towards them traverses a (possible) turn restriction. In terms of the number of iterations this approach is at least as efficient as the edge-base search. Depending on the number of turn restrictions and the average node degree in the graph our approach outperforms the edge-based search by far.

2 - Cost Allocation in Traveling Salesman Problem with Rolling Horizon

Igor Kozeletskyi, Chair for Logistics and Operations Research, University of Duisburg-Essen, *Alf Kimms*

This paper examines cooperation among salesmen from a game-theoretic perspective in case of the traveling salesman problem with rolling horizon. Rolling horizon planning is modeled using stochastic demands. The goal is to determine a cost allocation for this problem using the Shapley value. The game-theoretic formulation of the problem is provided and structural properties are investigated. To compute the value of the characteristic function of this game, an optimization problem formulated as a stochastic dynamic program is introduced. Due to high computational effort of stochastic dynamic programming and calculation of the Shapley value, a heuristic solution procedure is developed. This procedure combines methods of approximate dynamic programming to find an approximate value of the characteristic function and an estimation algorithm for the Shapley value. The developed computational study tests the computational performance of the solution procedure.

3 - Pricing Strategies for the Site-Dependent Vehicle Routing Problem

Silvia Schwarze, Institute of Information Systems, University of Hamburg

We propose the Vehicle Pricing Game (VPG), a noncooperative n-person game addressing the vehicles' viewpoints within a Vehicle Routing Problem (VRP). Each vehicle acts as a player that demands a price per km for carrying out a tour. Based on these prices, a VRP is solved under the objective of minimizing the total routing costs. The profit of each vehicle is dependent on the length of the assigned tour and on the demanded price and expenses. In particular, we address the question which price a vehicle should choose to maximize the own profit, taking into account that the competing vehicles are facing the same objective and that site-dependencies might be established at the nodes. To answer this question, the interplay of the vehicles is studied within a game-theoretic setting. We present theoretical results on existence and computation of equilibria for particular cases of the VPG. Moreover, we provide results of a numerical study that illustrate how site-dependencies influence the solution of a VPG.

■ WE-25

Wednesday, 17:00 - 18:30, Room F442

Traffic Estimation

Chair: *Thomas Liebig*, Knowledge Discovery, Fraunhofer IAIS

1 - CO2 emission reduction potential of electric vehicle and their impact on the transmission grid in Germany

Patrick Jochem, Chair of Energy Economics (IIP), Karlsruhe Institute of Technology (KIT), *Sonja Babrowski*, *Wolf Fichtner*

Climate change and the necessity to reduce green house gas emissions are widely acknowledged. On the European level, all sectors besides the transport sector (with a share of about 20 %) have already reduced its emissions. In order to reduce CO2 emissions in road passenger transport the European Regulation No 443/2009 for emission performance standards of light duty vehicles was implemented. It is going to be a success in Europe and might lead to a change in vehicle demand towards smaller vehicles. Furthermore, electric vehicles are said to be an efficient technology to reduce greenhouse gases. This hypothesis is mainly connected to three uncertainties. (1) The market penetration is unclear and (2) the specific emissions of vehicles depended on the underlying actual energy mix of electricity generation during the charging process. (3) The additional electricity demand could overcharge the electricity grid — even so this additional demand is marginal concerning the national electricity generation. On the lower grid levels these impacts are analysed elsewhere, in the following we will concentrate on the German high voltage transmission grid. Therefore, we first simulate the individual German road transport sector until 2030 with regard to the annual mileage of the vehicles with a meso-economic multi agent based model developed by Jochem (2009) with an updated integrated vehicle demand model in order to define the market penetration of electric vehicles. Then, we identify the corresponding additional electricity demand over time (load curve) and the corresponding CO2 emissions as well as bottlenecks in the national transmission grid in using the optimizing energy system model PERSEUS-NET (developed by Esser-Frey 2012).

2 - Co-Evolving Travelling Agents Subject to Local Versus Nonlocal Interactions

Olivier Gallay, Mathematical and Computational Sciences, IBM Zurich Research Laboratory, *Max-Olivier Hongler*, *Roger Filliger*

In this work, we study the dynamics of stochastic travelling agents that interact between each other by adapting their speed based on the observed current state of the other agents. Obviously, both the size of the interaction range considered by the agents and the interaction power in itself will ultimately determine the effective interaction strength, and will hence directly influence the global behavior to emerge for the whole agent population. Our goal here is to understand and to exhibit the basic features underlying the formation of robust, self-organized, collective motions. Intuitively, while for weak interactions between the agents, the noisy environment is expected to prevent from the creation of any possible self-organized pattern, it is likely that strong enough interactions will overcome the stochastic noise sources and will ultimately produce an emergent synchronized evolution (i.e. creation of flocks). Our model is based on a discrete two-velocity Boltzmann dynamics, for which a mean-field approach is adopted. This modeling framework enables for a fully analytical discussion of the emerging behavior. Depending on the span and the modulation of the interaction range, we are able to describe a transition from a purely diffusive regime without definite pattern to a flocking evolution represented by a solitary wave traveling with constant velocity. In this latter regime, we explicitly observe the self-organized capability of agents to create, via their mutual interactions, an emergent collective behavior. Beside biology (e.g. bird flocking), our modeling framework finds natural applications in transportation (e.g. car or pedestrian traffic, smart parts logistics) and in human sociology (e.g. diffusion of ideas).

3 - A Case Study on Pedestrian Quantity Estimation

Thomas Liebig, Knowledge Discovery, Fraunhofer IAIS, *Zhao Xu*

Traffic volume estimation is a natural task in street based traffic analysis systems and has important applications, e.g., quality-of-service evaluation, location evaluation or risk analysis. Estimation of pedestrian volumes received latest attention as it offers vast possibilities to extract people's movement motivations and helps to improve and to plan provided infrastructures. Distinguishing from the general large scale traffic volume estimation, pedestrian mobility in closed environments (e.g. train stations) contains the special property that individuals are likely to have homogeneous movement preferences. Thus, trajectory patterns exist and have high impact on the distributions of traffic among the small networks. This work evaluates existing street based approaches (micro simulation, k-Nearest Neighbor, Least Squares Regression and Gaussian Process Regression) for applicability in a closed environment scenario. The experiments on the real world dataset reveal that new approaches taking into account pedestrian movement preferences are required.

■ TA-25

Thursday, 9:00 - 10:00, Room F442

Bike Sharing and Service Regulations

Chair: *Asvin Goel*, MIT-Zaragoza International Logistics Program, Zaragoza Logistics Center

1 - Design of Bike Sharing Stations Anticipating Service Operations

Patrick Vogel, Carl-Friedrich Gauss Department Business Information Systems, Decision Support Group, University of Braunschweig, *Dirk Christian Mattfeld*

In recent years, traditional bike rental services have evolved into innovative bike sharing systems (BSS). At unattended bike stations, pickup and return operations are fully automated, facilitating one-way rental and potentially short rental times. Due to spatio-temporal fluctuation of customer demand, some bike stations tend to run out of bikes in the course of a day, while other bike stations may not be able to offer free bike boxes for bike returns any more. In order to ensure a certain service level, bikes are relocated from rather full to rather empty bike stations by service operators. In contrast to costly relocation operations, we propose to anticipate demand fluctuation as early as within strategic BSS design. Here, sufficient sizing of bike stations as well as intelligent bike allocation may alleviate costs of relocation activities. In particular, we present a mathematical optimization model which determines the optimal trade-off between investment into BSS infrastructure (number of bikes and bike boxes per station) and relocation operations (number, origin and destination of relocated bikes) according to a given service level. To this end, we derive characteristic bike flows by analysis and aggregation of operational ride data. Relocation operations are investigated in terms of different relocation policies deduced from the ride data analysis. Costs of greedy and advanced relocation policies are compared, e.g., nearest neighbor relocation vs. relocation between stations with opposite demand. We present computational experiments considering two years of ride data arising from Vienna's BSS "Citybike Wien'.

2 - The impact of hours of service regulations on transportation costs and accident risks

Asvin Goel, Telematique.eu, *Thibaut Vidal*

In this presentation we analyse and compare different hours of service regulations world wide with respect to their impact on transportation costs and accident risks. Our analysis is based on a powerful metaheuristic approach to optimise vehicle routes considering different hours of service regulations. Computational experiments conducted for hours of service regulations in the United States, Canada, the European Union and Australia demonstrate that European Union rules lead to the highest road safety, while Canadian regulations are the most competitive in terms of economic efficiency. Australian regulations appear to have unnecessarily high accident risk rates with respect to operating costs. The recent rule change in the United States reduces accident risk rates with a moderate increase in operating costs.

■ TC-24

Thursday, 11:30 - 13:00, Room F428

Synchronization in Vehicle Routing I

Chair: *Michael Drexl*, .

1 - Combined flow of goods, vehicles and packaging in logistics networks

Siegfried Jetzke, Logistik und Informationsmanagement, Ostfalia Hochschule für angewandte Wissenschaften

Distributing goods needs different vehicles, packaging and containers. For every node on their path vehicles, containers and supporting equipment must be available on time – simultaneously. For many nodes incoming loads have to be broken up to form new loads: Trucks arrive at a storehouse with many pieces of the same commodity. On their arrival free space, workers and equipment are needed to unload the goods. Some time later some truck leaves the storehouse with a large variety of commodities, a smaller number of each than upon arrival. Up to the time of loading a sufficient quantity of all articles must be available, not only of one. Considering time dependencies needs to view distribution channels as supply nets, rather than supply chains: Transportation times have to be assigned to any edge, service times to nodes. None of these quantities will be known to be exactly. Transportation is influenced by traffic density and service by the productivity possible. In inbound logistics these quantities are not only unknown but also out of our control, they can be kept under control in inhouse logistics. In order to overcome difficulties due to uncertainties we need to introduce some buffer, either in time, in material or additional degrees of freedom in realization, the latter requiring online exchange of information. In this paper we will present a simple example to show how fixing of all times hinders realization. We will discuss a model and the realization for solving the VRP with time windows and merging and demerging loads for inbound logistics together with a new model for simulating the combined flow of goods, containers and vehicles. Due to the better data basis available in inhouse logistics this can be further developed to be used for optimization.

2 - Route Feasibility Testing and Branch-and-Price Algorithms for the Pickup and Delivery Problem with minimum and maximum Ride Times

Timo Gschwind, Johannes Gutenberg University Mainz, *Stefan Irnich*

In the Pickup and Delivery Problem with minimum and maximum Ride Times (PDPRT) user specified transportation requests from origin to destination points have to be served by a homogeneous fleet of vehicles so that the total routing costs are minimal. In addition to pairing, precedence, capacity and time-window constraints, bounds on the minimum and maximum ride-times, i.e. the times between a pickup and its corresponding delivery, are given. This problem is a generalization of the dial-a-ride (DARP) problem where only the maximum ride-times are specified. Considering minimum and maximum ride times in combination with time windows make the feasibility check of a given route a complex task. We devise new feasibility tests with a best worst-case runtime of O(n2). Even more, in column generation approaches for the PDPRT the presence of time windows and both types of ride-time constraints severely complicates the pricing. It is not clear if the handling of all route constraints in the pricing problem pays off compared to ignoring either one or both families of the ride-time constraints during pricing. We present new branch-and-price algorithms that are able to handle all route constraints of the PDPRT and investigate the impact of different pricing problems on a column generation approach.

3 - Branch-and-Cut-and-Price for the Vehicle Routing Problem with Trailers and Transshipments

Michael Drexl, .

In this talk, two MIP formulations for the vehicle routing problem with trailers and transshipments (VRPTT) are presented. The formulations are based on the same network representation of the problem and use the same type of vehicle-class-specific arc flow variables, but different types of continuous resource variables. The formulations are solved by branch-and-cut-and-price algorithms, where several types of cuts are generated dynamically during the solution process, and where the set of variables is enlarged gradually based on reduced cost criteria. The computational properties of the two formulations are compared and discussed. The VRPTT is an interesting problem to study, because it constitutes a unified model for VRPs with multiple synchronization constraints (VRPMSs). These are problems where, in addition to the usual customer covering constraints, a temporal, spatial, and load synchronization between vehicles is required. Such multiple synchronization constraints are relevant, for example, when different types of resources, such as lorries and trailers, are needed to fulfil the given transport requests. Moreover, synchronization is necessary when transshipments between vehicles are allowed. Thus, VRPMSs possess substantial practical relevance and, as will be shown in the talk, their solution poses a considerable challenge.

■ TC-25

Thursday, 11:30 - 13:00, Room F442

Shipping and Railway

Chair: *Dominique Feillet*, CMP Georges Charpak, Ecole des Mines de Saint-Etienne

1 - An extended formulation for allocating classification tracks in hump yards

Florian Dahms, Operations Research, RWTH Aachen, *Markus Bohlin*, *Holger Flier*, *Sara Gestrelius*, *Marco Lübbecke*, *Matus Mihalak*

A major task in railway operations is shunting trains in a hump yard. Freight cars need to be assigned to classification tracks where they can be formed into outgoing trains. Often the objective is to minimize the number of shunting operations like pulling out and rolling in cars to the hump yard. Our model is based on the processes at the Hallsberg hump yard in Sweden. The problem formulation derived from these processes was already shown to be NP-hard by Bohlin et al. Natural compact MIP formulations so far have only yielded very weak linear relaxations and could not be used to efficiently generate optimal solutions for problem instances of reasonable size. We present an extended formulation that produces a very tight linear relaxation and can be efficiently solved via column generation for large problem instances. For several real world instances we are now able to produce optimal solutions. Furthermore we discuss issues like symmetry, branching decisions and problem specific heuristics necessary to improve the solving process.

2 - Liner Shipping Fleet Repositioning with Cargo Flows

Kevin Tierney, IT University of Copenhagen, *Rune Jensen*

Responsible for transporting over 1.3 billion tons of cargo in 2011, liner shipping networks reliably and cheaply connect the world's markets. Vessels are regularly repositioned between services in liner shipping networks to adjust the networks to the world economy and stay competitive. Since repositioning a single vessel can cost hundreds of thousands of US dollars, optimizing the repositioning activities of vessels is an important problem to the liner shipping industry. The Liner Shipping Fleet Repositioning Problem (LSFRP) consists of finding routes that reposition (move) vessels between services in a liner shipping network while respecting the cargo flows of the network. The LSFRP maximizes the profit earned on the subset of the liner shipping network affected by the repositioning, taking into account sailing costs, loading/unloading costs, port fees, and cargo/equipment revenues. Repositioning problems are subject to a number of constraints on how vessels can be moved within the network, such as ensuring that vessels joining a new service have a weekly temporal spacing, i.e. each vessel visits a particular port one week after the previous vessel. Despite its great industrial importance, the LSFRP has received little attention in the literature. We describe the LSFRP in detail and introduce a mathematical model of the LSFRP along with a benchmark suite consisting of real-world data from our industrial collaborator. We solve the mathematical model using CPLEX.

3 - Column generation for the container relocation problem

Elisabeth Zehendner, CMP Georges Charpak, Ecole des Mines de Saint-Etienne, *Dominique Feillet*

Container terminals offer transfer facilities to move containers from vessels to trucks, and vice versa. Within the terminal the container yard serves as a temporary buffer where incoming containers are piled up in stacks. Outgoing containers need to be transported from the yard to a ship or to trucks in predefined sequences. Generally, the retrieval sequence does not match the stacking order within the yard. Since only the topmost container of each stack can be accessed, containers stored above it must be relocated first. A common procedure is to relocate containers within one bay (row of container stacks) since relocations between bays are very time consuming. In order to minimize turnaround times, a move sequence to retrieve containers from the bay in the prescribed order with a minimum number of reshuffles has to be determined. This problem is known as the container relocation problem (CRP) and is known to be NP-hard. We present a column generation approach for this problem. The master problem represents the bay layout over time with two sets of variables. State variables indicate the position of each container in the bay over time. Each movement variable represents a series of movements to retrieve exactly one container and to relocate containers stacked above it. The subproblem uses complete enumeration enhanced with bounding mechanisms to choose movement variables with negative reduced costs. Experiments are conducted for an exact method of the subproblem and for a heuristic variant of the exact method. First results are very promising since both approaches provide very tight lower bounds on the minimum number of relocations.

■ TD-24

Thursday, 14:00 - 15:30, Room F428

Synchronization in Vehicle Routing II

Chair: *Dorota Slawa Mankowska*, Martin-Luther-University Halle-Wittenberg

1 - A multi commodity network flow problem with coordinated arrival times at pairs of nodes

Jörn Schönberger, University of Bremen

The determination of flow through a network is an important planning task in transportation. Typically, it is necessary to determine paths of several assets through a given network in parallel. This is called multi-commodity network flow planning. Often, the underlying application requires coordination among the paths of different commodities (arrival or departure times or locations). Such coordination is called synchronization. We address a multi-commodity network flow problem in which a synchronisation of nodes contained in the determined paths and the arrival times at these "shared nodes' are necessary. A set of N ordered pairs of nodes of a network is given. Each pair represents the demand for transport from the first node in the pair to the second node in the pair. A finite set of vehicles is available to serve this need and n of the N pairs must be served by two or more vehicles. Thus, a multi-commodity network flow problem must be solved to determine exactly one path for each vehicle so that (i) each given pair is contained in at least one path and (ii) at least n pairs are contained in at least two paths and (iii) if a pair is served by several vehicles then their service times must fall into an implicit time window. The here reported research aims at generating parameterizable test instances for a network capacity control problem in road-based freight transportation. We present a mixed-integer linear program for the outlined network flow determination task. Since even small instances of this model turn out to be computationally intractable for mathematical solvers like CPLEX, we configure a genetic search approach to seek for feasible solutions of the proposed model. Results from computational simulation experiments are reported.

2 - Mixed Integer Programming Approaches for a Variant of the Truck and Trailer Routing Problem

Julia Funke, Logistics Department, INFORM GmbH

The formal problem we consider comes from a logistic yard background. Containers are located in a yard and have to be moved at certain times. For these operations a pool of trucks and trailers is available. The tasks should be fulfilled within certain time windows at the least possible cost. We define this problem as an MIP with variable fixation to decrease the size of the problem and solve it with the solver SCIP. We compare three different approaches of fixing variables.

3 - A Vehicle Routing Problem with Synchronization Constraints for Multi-Services at Customers

Dorota Slawa Mankowska, Martin-Luther-University Halle-Wittenberg, *Christian Bierwirth*, *Frank Meisel*

Vehicle Routing Problems (VRPs) are intensively investigated because of their practical importance for various real world applications and because they are difficult to be solved from a computational point of view. We consider a particular type of the VRP, where some customers must be served by more than one vehicle. Such multi-services require that the routes of the involved vehicles are synchronized in time and space. An example can be found in routing of home care staff, where complex services must be performed. This can comprise, for example, handling a heavy patient at the same time or administering medication to a patient before meal. In this talk, we present mixed-integer programming models for such routing problems with synchronization requirements. We propose also a Variable Neighborhood Search procedure for solving large problem instances and show computational results for synchronizing service operations of vehicles.

■ TD-25

Thursday, 14:00 - 15:30, Room F442

Air Transport and Motorail

Chair: *Natalia Kliewer*, Information Systems, Freie Universitaet Berlin

1 - Decision support for capacity planning in motorail transportation

Pascal Lutter, Faculty of Management and Economics, Ruhr University Bochum, *Brigitte Werners*

Loading cars and motorbikes on trains is a challenging task for motorail companies. Several mixed-integer linear programming (MILP) models exist to load containers on trains. Although the general model structure is similar, motorail train loading differs strongly from container loading due to certain technical requirements. In contrast to recent work on auto-carrier loading we consider route specific requirements and physical constraints in more detail and additionally focus on order acceptance in a dynamic environment. Particularly the integration of the booking process distinguishes our approach from previous ones. Orders are placed at different points of time and must be accepted or rejected immediately, so the problem has to be solved repeatedly with varying information. Optimal train utilization can be achieved by the suggested MILP model if vehicle specifications are exactly known. During the booking process decisions have to be made immediately for each arriving booking request. In practice, the frequent use of an optimization model is impossible because of long runtimes and the missing integration in current booking systems. Hence, it is necessary to identify risks and chances in advance to control available capacity. We propose a MILP model which determines maximum weights for all possible vehicle specifications to decide optimally about the acceptance of orders and compare this approach with a simple heuristic method by a simulation study. The proposed models can be solved using standard commercial software as well as open source software. To avoid long runtimes which occur for some instances we also provide a problem specific heuristic solution approach.

2 - Integrating a Simulation Approach for Fare Class Choice with Flexible Substitution Patterns and Fleet Assignment

Frauke Seidel, Institut für Verkehrswirtschaft, Universität Hamburg

To account for individual choice decisions especially regarding buy-up and buy-down behaviour of customers in airline revenue management we aim to provide a simulation based approach with flexible substitution patterns. Thus we are able to incorporate individual decision making behaviour regarding the choice of fare classes. In a next step we extend our approach to integrate the described simulation model in a general optimization model of fleet assignment. Hence, we are able to use the improvements in demand modelling with dependent demand structures to enhance the results of an integrated approach of fleet assignment and revenue management.

3 - Empirical and Mechanistic Models for Flight Delay Risk Distributions

Lucian Ionescu, Information Systems, Freie Universität Berlin, *Claus Gwiggner*, *Natalia Kliewer*

In the field of robust flight optimization, disruption and delay propagation play a central role. Recently, huge amounts of data became available for analysis of these delays. For example, empirical distribution functions can be estimated and used as input for scheduling systems. But for a better understanding of the underlying mechanisms, distribution models with explicit dependencies and interpretable parameters are more desirable. In this paper we present new patterns in flight delay data and an initial model of the underlying physical processes.

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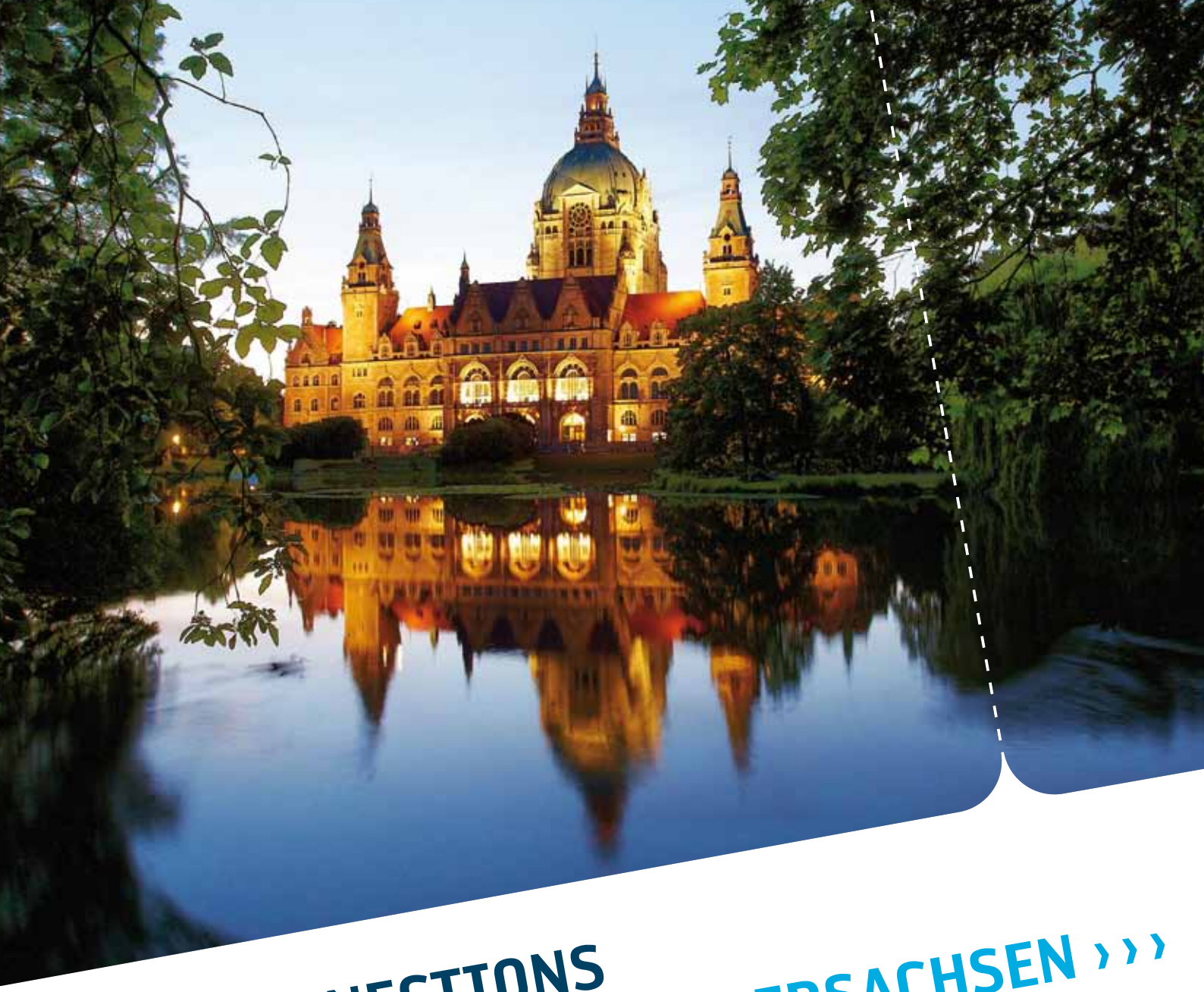

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