EURO
The Association of European
Operational Research Societies

POLITECHNIKA POZNAŃSKA
POZNAN UNIVERSITY OF TECHNOLOGY

EURO 2016
POZNAŃ
3-6
07 2016

CONFERENCE HANDBOOK

28th European Conference on Operational Research

EURO 2016 POZNAŃ 3-6 07 2016

CONFERENCE VENUE

Poznań International Fair
Railway station
Old Market
Poznan University od Technology

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28th European Conference on Operational Research	
Poznan University of Technology, Poznań, Poland	
July 3-6, 2016	

Contact information

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Conference handbook

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	Sarah Fores (EURO Manager)
	Bernard Fortz (EURO Webmaster)

EURO-k conferences

The EURO-k Conferences are intended to be forums for communication and cooperation among European Operational Researchers. Being broadly oriented, they are intended to be international meetings of Operational Researchers who are active in all the diverse special areas of Operational Research and to the free exchange of knowledge, experience, new ideas and promising results relating to the research and practice of OR. In the 40-year history of the EURO-k series, the conferences have been held in 18 different countries. In 2016 - for this first time - it is organised in Poland.

EURO Conference History

k	Year	City	Country	k	Year	City	Country
1	1975	Brussels	Belgium	16	1998	Brussels	Belgium
2	1976	Stockholm	Sweden	17	2000	Budapest	Hungary
3	1979	Amsterdam	The Netherlands	18	2001	Rotterdam	The Netherlands
4	1980	Cambridge	United Kingdom	19	2003	Istanbul	Turkey
5	1982	Lausanne	Switzerland	20	2004	Rhodes	Greece
6	1983	Vienna	Austria	21	2006	Reykjavik	Iceland
7	1985	Bologna	Italy	22	2007	Prague	Czech Republic
8	1986	Lisbon	Portugal	23	2009	Bonn	Germany
9	1988	Paris	France	24	2010	Lisbon	Portugal
10	1989	Belgrade	Yugoslavia	25	2012	Vilnius	Lithuania
11	1991	Aachen	Germany	26	2013	Rome	Italy
12	1992	Helsinki	Finland	27	2015	Glasgow	United Kingdom
13	1994	Glasgow	United Kingdom	**28**	**2016**	**Poznań**	**Poland**
14	1995	Jerusalem	Israel	29	2018	Valencia	Spain
15	1997	Barcelona	Spain				

EURO 2016 - 28th European Conference on Operational Research

EURO 2016 is the premier European conference for Operational Research and Management Science organized by EURO – the European Association of Operational Research Societies and the Polish Operational and Systems Research Society at Poznan University of Technology.

Poznan University of Technology - being one of the leading European centres in decision analysis, optimization, project management, and scheduling - is a perfect place to share cutting edge ideas from the OR/MS community. The main conference venue is the university campus at the riverside, located close to the historical centre of Poznań.

The Program and Organizing Committees, chaired by Daniele Vigo and Joanna Józefowska, respectively, have prepared a high quality scientific program and an exciting social program.

All conference attendees will have an excellent opportunity to explore Poznań. The city offers a wide range of historical and leisure spots to visit, including the renaissance Old Market Square, the enchantingly located Cathedral, former Imperial Castle, Malta lake, and a set of rearranged post-industrial venues.

▶ WELCOME

Elena Fernández

President of EURO

Department of Statistics and Operations Research
Universitat Politecnica de Catalunya-BcnTech

e-mail: **e.fernandez@upc.edu**

Welcome to the 28th European Conference on Operational Research!

EURO – The Association of European Operational Research Societies was created in 1975 in conjunction with the first EURO conference, which took place in Brussels.

Since its creation EURO has voyaged a long way favoring collaboration between its member societies, encouraging the activities of its working groups, supporting publications, and trying to develop appropriate instruments towards its goal of promoting Operational Research. EURO conferences are indeed among the most important such instruments. They provide opportunities for researchers and practitioners to get together, exchange ideas and discuss current developments in, and advances of, our profession. The EURO XXVIII Conference in Poznań offers an excellent setting for the above and perfectly illustrates the increasing interest that our conferences raise in our community.

All this would not have been possible without the great effort of a large team of dedicated people. The Programme Committee, chaired by Daniele Vigo, and the Organizing Committee, chaired by Joanna Józefowska, have worked hard in order to offer all of us an outstanding conference. The rich scientific programme proposed by the Programme Committee includes a wide range of areas and covers numerous topics both from the methodological and the application point of view. The exciting social programme designed by the Organizing Committee offers a great environment for discussion with old and new friends in the most pleasant atmosphere.

In the name of EURO, I would like to sincerely thank the Programme and Organizing Committee Chairs, as well as their teams for their generous efforts in making this meeting such a big success. My gratitude also goes to the numerous stream organizers who have provided their support in designing the programme. I finally want to thank you all for participating in the EURO XXVIII conference and so contributing to the progress of our wide EURO community.

I wish all of you a productive conference and a very pleasant stay in Poznań.

Elena Fernández
President of EURO

► WELCOME

Daniele Vigo

Chair of the EURO 2016 Programme Committee

Department of Electrical, Electronic and Information Engineering
University of Bologna

e-mail: **daniele.vigo@unibo.it**

Joanna Józefowska

Chair of the EURO 2016 Organising Committee

Institute of Computing Science, Faculty of Computing
Poznan University of Technology

e-mail: **joanna.jozefowska@cs.put.poznan.pl**

Dear EURO Conference Participants,

We are pleased to warmly welcome you to the XXVIII EURO Conference, which this year is held in Poznan – the cradle of Poland in the year of the 1050th anniversary of Poland's baptism.

The start of EURO conferences dates back in 1975, when the first meeting took place in Brussels. Since then, 27 conferences were organized in many of the largest European towns and cities and attracted researchers not only from Europe but in large numbers from all continents, making it one of the most important and largest scientific events for the OR community.

This year, for the first time the EURO Conference has come to Poland and it is organized at the Poznan University of Technology, thanks to the reputation of its large OR group successfully led for more than 40 years by Jan Węglarz.

During the years the EURO conference has become a complex and rich scientific event with a large participation and the Poznan conference is not an exception. Thanks to the enthusiastic and competent work of a large number of persons who served as Stream and Session organizers, we received more than 2000 abstracts, more than one third of which are from outside Europe.

We are grateful to the prestigious plenary speakers and, in particular, to Robert Aumann, the 2005 Nobel Memorial Prize laureate in Economic Sciences, for having accepted the invitation to stay with us over the next three days. We are also extremely happy to welcome to Poznan the 11 esteemed keynote and tutorial speakers who will illustrate the state of the art in a wide range of OR fields. Other important events are represented by the workshops, the EURO prize sessions and by the more than 450 sessions representing the scientific presentations of the delegates.

Also this year the *Making an Impact* (MAI) initiative, launched last year in Glasgow, will be present at the EURO conference with several dedicated activities and workshops as well as links to practice-based activities in other streams. Visit the MAI stand in Building CW, or the relevant section of the EURO2016 website, or look at the special *MAI timetable* in your conference pack, to find out more about the activities aimed at supporting OR practice and bringing academics and practitioners together to find mutual inspiration and start fruitful collaborations.

We wish for you to spend the next days attending inspiring presentations, engaging in fruitful discussions, refreshing old and establishing new contacts with colleagues and friends, and discovering the beautiful town of Poznan.

Daniele Vigo
EURO 2016 PC Chair

Joanna Józefowska
EURO 2016 OC Chair

► COMMITTEES

Programme Committee

Daniele Vigo
Chair of the EURO 2016 Programme Committee
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ESSEC Business School, France

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Dolores Romero Morales
Copenhagen Business School, Denmark

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London School of Economics, United Kingdom

Gerhard-Wilhelm Weber
Middle East Technical University, Turkey

Ekaterina Kostina
University of Heidelberg, Germany

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Chair of the EURO 2016 Organising Committee
Poznan University of Technology, Poland

Jan Owsiński
General Secretary of the Polish Operational and Systems Research Society

Jacek Błażewicz
Poznan University of Technology, Poland

Grzegorz Pawlak
Poznan University of Technology, Poland

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EURO Vice President I (2015)
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Maciej Stroiński
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Janusz Kacprzyk
President of the Polish Operational and Systems Research Society

Jan Węglarz
Poznan University of Technology, Poland

Miłosz Kadziński
Poznan University of Technology, Poland

Daniele Vigo
Chair of the EURO 2016 Programme Committee
University of Bologna, Italy

► ORGANISATION SUPPORT

Poznan University of Technology
Politechnika Poznańska

pl. Marii Skłodowskiej-Curie 5
60-965 Poznań, Poland

established: 1919

website: www.put.poznan.pl/

rector: Prof. Tomasz Łodygowski

Poznan University of Technology (PUT) is one of the leading technical universities in Poland. With its **21 thousand students** and **12 hundred academic staff** it has become one of the most recognized landmarks of Western Poland, where education is perfectly combined with industry.

PUT grew out of the Higher State School of Mechanical Engineering which **was established in 1919**. In the first few decades, it was oriented toward mechanical, electrical, and civil engineering. Currently, ten PUT's faculties offer **study programs** conducted both in Polish and English in **27 fields** ranging from architectural design through computer science, telecommunications, and transportation to technical physics and chemical technology.

PUT has been given a very high position in the national university rankings. Over the years, the university has successfully developed **relationships with all aspects of business**, management, and new technology communities. Their encouragement supported by the advice of more than a thousand SMEs help us to adjust our educational programs. In this way, PUT's graduates can meet the high requirements of the international markets.

Although PUT has world-class achievements in chemical technologies, mechatronics, engineering, and production systems, it is very well known for its **Operations Research and Management Science group**. The group was set up around 40 years ago, and is currently established within the Faculty of Computing. It consists of about 60 researchers with its three pillars - EURO Gold Medal winners: Jacek Błażewicz, Roman Słowiński, and Jan Węglarz. The main interests of the group members is best shown by the focus of the EURO Working Groups (EWGs) they are most actively involved. These include EWGs on Multiple Criteria Decision Aiding, Combinatorial Optimization, Transportation and Project Management and Scheduling.

EURO - The Association of European Operational Research Societies

member societies: 31

established: 1975

website: www.euro-online.org

president: Prof. Elena Fernández

EURO is the **Association of European Operational Research Societies**. It is a non-profit organisation, **founded in 1975** and domiciled in Switzerland. Its objective is to **promote Operational Research throughout Europe**. EURO is a regional grouping within the International Federation of Operational Research Societies (IFORS) and full membership is restricted to national societies that are members of IFORS.

EURO is regulated by a Council consisting of representatives/alternates of all its members and an Executive Committee, which constitutes its board of directors. In addition the Executive Committee and Council select an IFORS Vice-President to liaise with IFORS. EURO is supported by additional officers who have specific responsibilities and administrative roles.

The aims of EURO are the advancement of knowledge, interest and education in operational research by the exchange of information, the holding of meetings and conferences, the publication of books, papers, and journals, the awarding of prizes, and the promotion of early stage talents. Full details of EURO activities can be found at https://www.euro-online.org/.

Polish Operational and Systems Research Society
Polskie Towarzystwo Badań Operacyjnych i Systemowych

Newelska 6
01-447 Warszawa, Poland

website: www.ptbois.org.pl

established: 1986

president: Prof. Janusz Kacprzyk

Polish Operational and System Research Society (POSRR) was **established in 1986** as an initiative of the research community active in the two closely related domains, aiming at a more effective promotion of the two domains and activation of a broader circle of specialists, especially those involved in practical work. The Society functions on the basis of a legal registration, through its statutory bodies.

The Society conducts the following kinds of activities:
- **Organisation of cyclical national conferences (BOS)** of the research and application communities from operational and system research as well as co-organisation of international and specialist conference in the subject.
- **Publications**, containing materials originating either from the BOS conferences or from other forms of activity.
- Own research, including that conducted in collaboration with other institutions. Research is usually done through **project teams** established by the Society for particular purposes. Through its broad contacts POSRR is capable of carrying out valuable work, of both fundamental and of applied nature in a variety of specific domains.
- Demonstrating to the wider community the benefits that Operational Research can bring to the society.

More details about the activities of POSRR can be found at http://www.ptbois.org.pl/.

Poznań Supercomputing and Networking Center (PSNC)
Poznańskie Centrum Superkomputerowo-Sieciowe (PCSS)

ul. Jana Pawła II 10
61-139 Poznań
tel: (+48 61) 858-20-01
fax: (+48 61) 852-59-54

e-mail: office@man.poznan.pl
websites:
pcss.pl
conference4me.psnc.pl/en/

Poznań Supercomputing and Networking Center (PSNC), affiliated to the Institute of Bioorganic Chemistry of the Polish Academy of Sciences, was founded in 1993 to build and develop computer infrastructure for science and education in Poznań and in Poland. This infrastructure includes metropolitan network POZMAN, High Performance Computing (HPC) Center, as well as the national broadband network PIONIER, providing the Internet and network services on international, domestic and local levels. With the development of the computer infrastructure, PSNC has been managing research and development within the field of new generation computer networks, high performance – parallel and distributed – computations and archive systems, cloud computing and grid technologies. PSNC is working also on the themes of green ICT, future Internet technologies & ideas, network safety, innovative applications, web portals, as well as creating, storing and managing digital content. Since PSNC is a public entity, within its sphere of interests is the development of solutions for e-government, education, medicine, new media & communications.

At EURO 2016, PSNC supports the Organizing Committee in conducting online transmission of some special sessions during the conference as well as preparation of the Conference App.

Poznań International Fair Ltd.

Międzynarodowe Targi Poznańskie (MTP)

Głogowska 14
60-734 Poznań, Poland
website: www.mtp.pl
www.pcc.mtp.pl

founded: 1921
president: Przemysław Trawa
representatives: Sabrina Żymierska
Anna Paczos

Poznań International Fair (MTP) is a **leader of the Polish exhibition industry** and the first organizer of exhibition events and fair in Central and Eastern Europe. MTP, consisting of over 70 meeting rooms, Congress Hall for up to 2000 participants and 16 exhibition halls, offers modern and versatile interiors, open space and plenty of natural light. The breakout rooms, equipped with the latest technologies and a modular system of sliding walls, allow for the organization of diverse range of events - from small business meetings for twelve people to congresses for more than twelve thousands participants.

Professional and experienced MTP team offers comprehensive organization of every event, incl. rental of the conference rooms, lighting design and sound system, catering, running the congress office, transport and accommodation. Also organizing the press conferences or the press centre, preparing all promotional materials or artistic setting are in wide range of MTP ability.

At EURO 2016, MTP are the Professional Conference Organising Company chosen by the conference Organising Committee to support the organisation and the successful running of the conference.

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▶ MAP OF CAMPUS

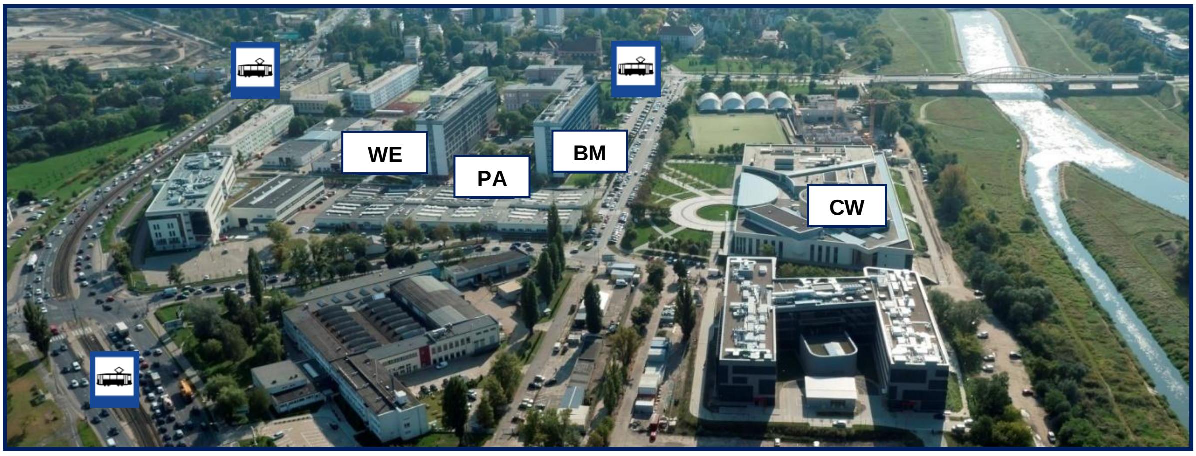
Conference Venue

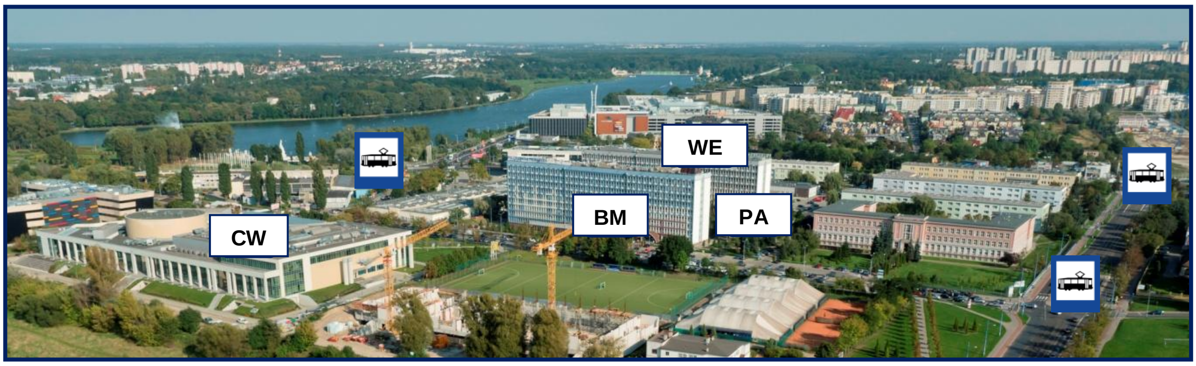
The conference will be organized at **Poznan University of Technology, Warta (Piotrowo) Campus** which is beautifully located on the riverside**,** next to a recreational area of Malta lake**,** and within a close and easy reach of the city centre**.**

The main EURO 2016 conference venue is a modern **Lecture Centre** (Centrum Wykładowe; **CW**). It has been constructed in the last 10 years in such a way that from its three passages you can see the historical symbols of Poznań: City Hall, Cathedral, and Bernardine Church.

Another three modernist buildings from the 70s (**BM, PA, and WE**) are the symbols of the campus. These have been recently renovated, normally accommodating the Faculties of Mechanical and Electrical Engineering. BM and WE are the tall buildings (BM has a characteristic large timer on its top), whereas PA is a passage between BM and WE.

Bird's Eye-View on the Conference Venue





▶ MAP OF CAMPUS

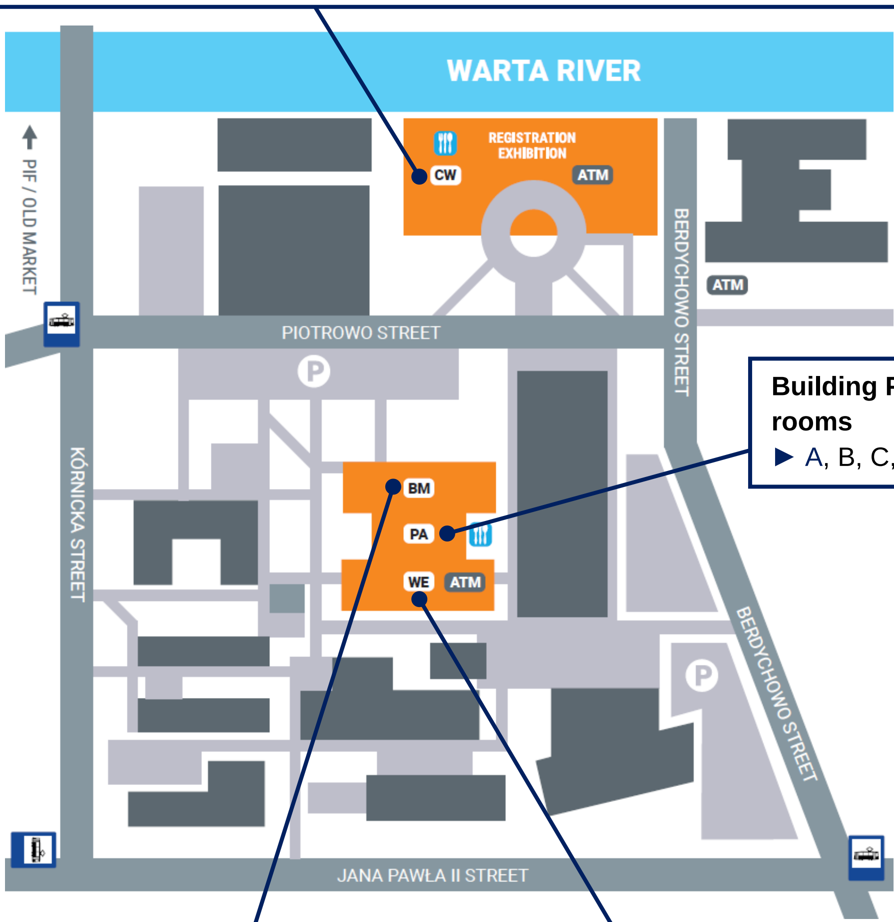
Lecture Rooms

Technical sessions will be held in four building on campus:

- ▶ **CW**: **C**entrum **W**ykładowe / Lecture Centre
- ▶ **BM**: **B**udowa **M**aszyn / Mechanical Engineering
- ▶ **WE**: **W**ydział **E**lektryczny / Faculty of Electrical Engineering
- ▶ **PA**: **Pa**saż (Łącznik) / Passage

The room numbers indicate the building, floor and room number.

Building CW: rooms
- ▶ **ground floor**: AULA, 1, 2, 3, 4, 6, 021, 022, 023, 024, 025, 027, 028, 029, 0210
- ▶ **1st floor**: 7, 8, 9, 12, 13, 121, 122, 123, 124, 125, 126, 127, 128, Lobby



Building PA, rooms
- ▶ A, B, C, D

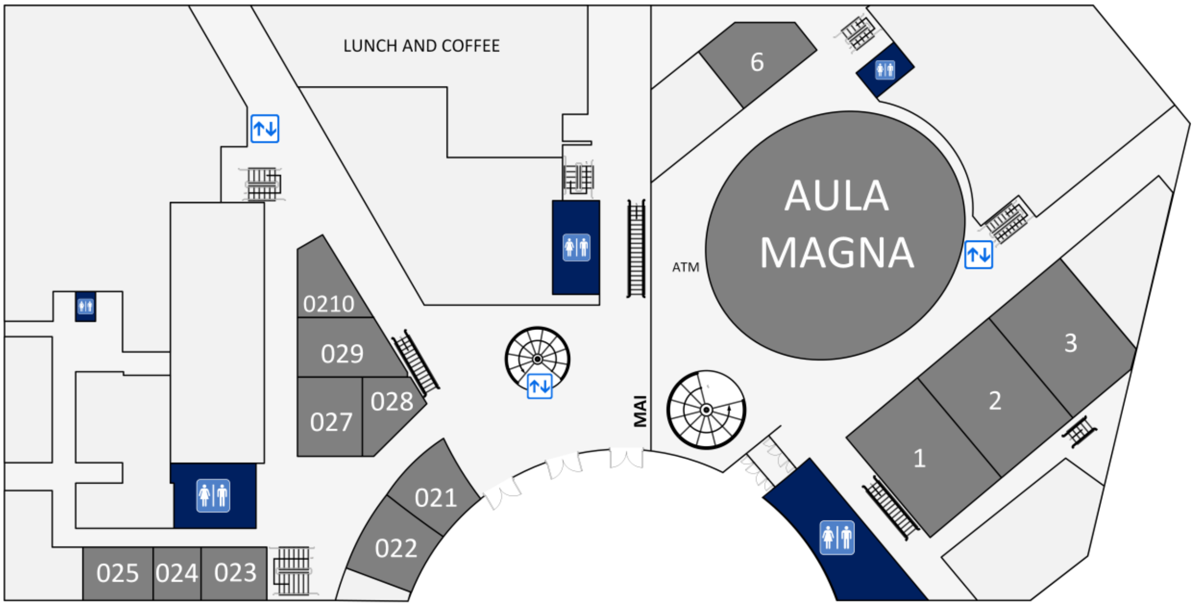
Building BM: rooms
- ▶ **ground floor**: 7, 17, 18, 19, 20
- ▶ **1st floor**: 109D, 109M, 110, 111, 112, 113, 116, 119
- ▶ **2nd floor**: 212

Building WE: rooms
- ▶ **ground floor**: 18
- ▶ **1st floor**: 107, 108, 115, 116, 119, 120
- ▶ **2nd floor**: 209

▶ MAPS OF MEETING ROOMS

Floor Plans for Building CW

Building CW, ground floor



Room	Seats
021	76
022	54
023	48

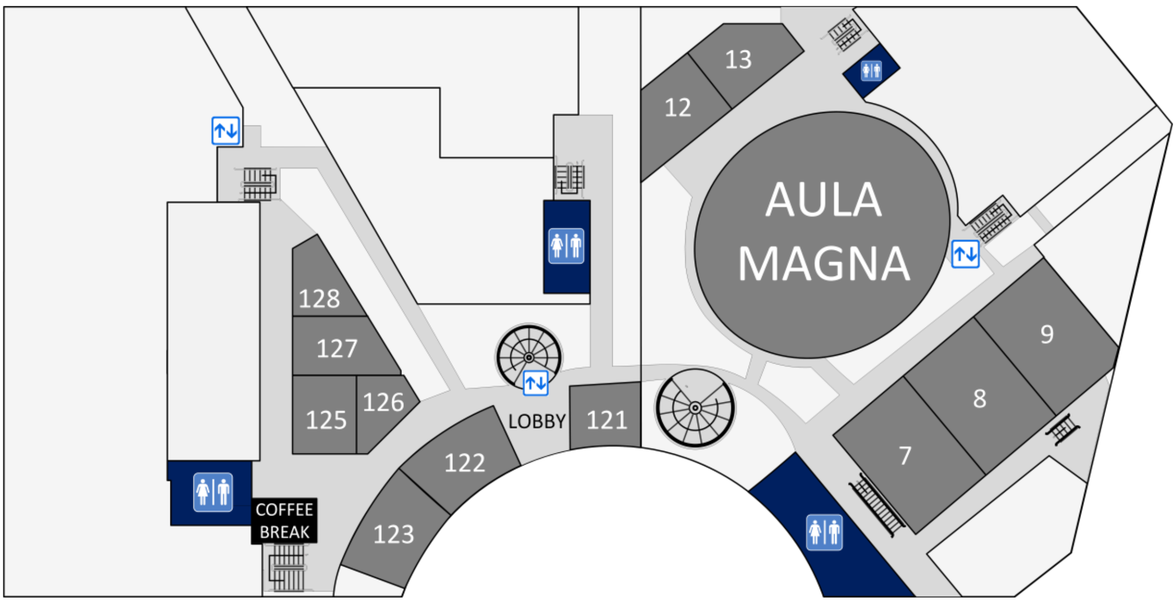
Room	Seats
025	55
027	64
028	33

Room	Seats
029	81
0210	46

Room	Seats
AULA	665
1	200
2	200

Room	Seats
3	200
6	59

Building CW, 1st floor



Room	Seats
121	40
122	96
123	80

Room	Seats
125	60
126	30

Room	Seats
127	60
128	40

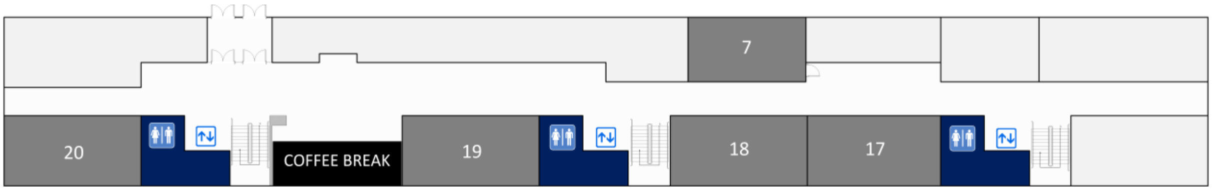
Room	Seats
7	146
8	146
9	146

Room	Seats
12	72
13	84

▶ MAPS OF MEETING ROOMS

Floor Plans for Buildings BM and PA

Building BM, ground floor



Room	Seats
7	40

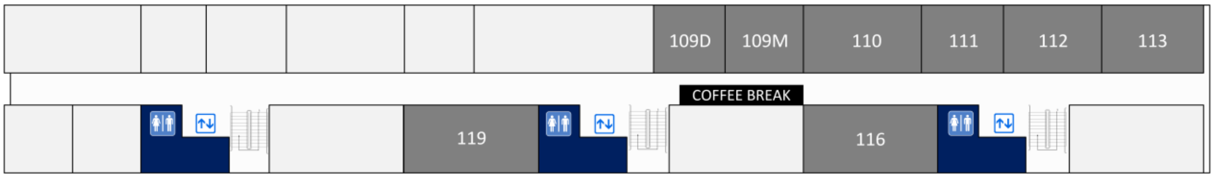
Room	Seats
17	60

Room	Seats
18	60

Room	Seats
19	60

Room	Seats
20	60

Building BM, 1st floor



Room	Seats
109D	30
113	40

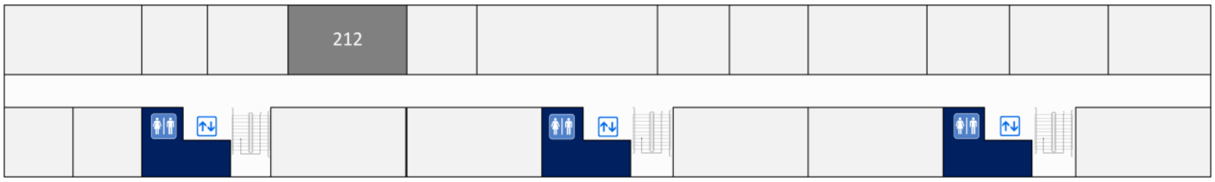
Room	Seats
109M	24
116	60

Room	Seats
110	66
119	60

Room	Seats
111	35

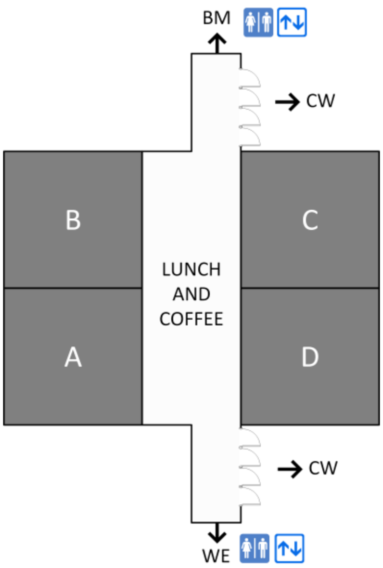
Room	Seats
112	16

Building BM, 2nd floor



Room	Seats
212	40

Building PA

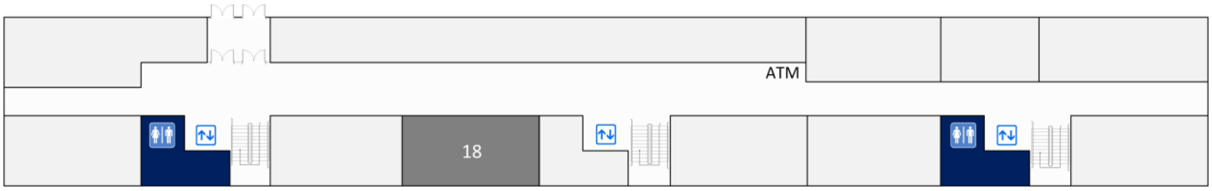


Room	Seats
A	155
B	222
C	120
D	126

▶ MAPS OF MEETING ROOMS

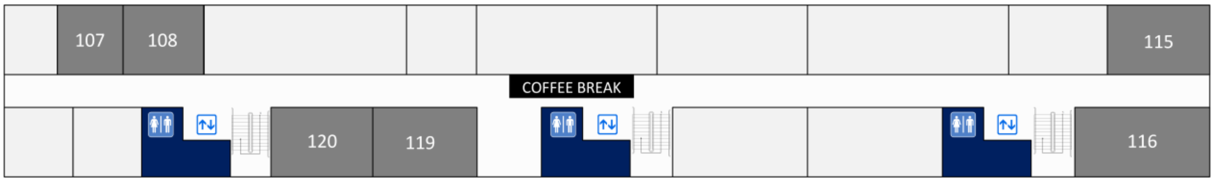
Floor Plans for Building WE

Building WE, ground floor



Room	Seats
18	30

Building WE, 1st floor



Room	Seats
107	42
120	60

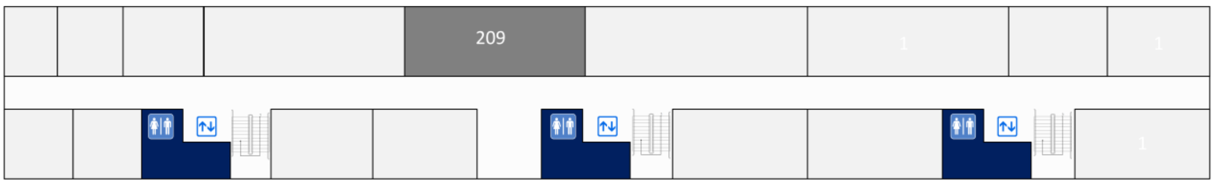
Room	Seats
108	42

Room	Seats
115	36

Room	Seats
116	60

Room	Seats
119	60

Building WE, 2nd floor



Room	Seats
209	90

REGISTRATION DESKS

The registration desks will be located on the ground floor of Building CW. We recommend picking up your registration material as soon as you arrive on Sunday to avoid queues on Monday morning.

Opening Hours of the Registration desk:

► **Sunday 12:00 - 20:00** **Monday 07:30 - 18:00** **Tuesday 07:30 - 16:00** **Wednesday 07:30 - 15:00**

REGISTRATION

Registration is required for all participants and exhibitors. Registered participants and exhibitors will receive a badge giving them access to the conference venue as well as participant's materials. Participants and exhibitors are requested to wear their badge visibly at all times.

The registration fee for a full delegate covers the following:

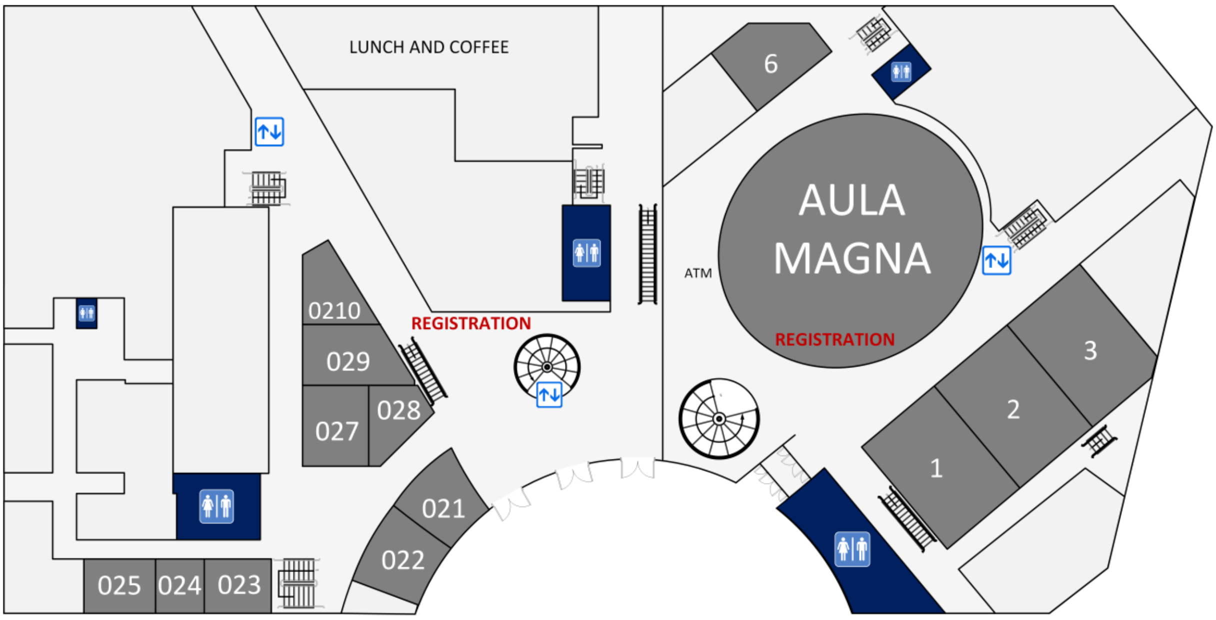
- Admission to all sessions and the exhibition
- Conference materials (in appropriate format)
- Tea, coffee and lunches throughout the conference
- Admission to the Welcome Reception on July 3, 2016 at Poznan University of Technology
- Voucher for Snack & Beer at Old Market Square on July 4, 2016
- Admission to the Farewell Party on July 6, 2016 at Poznan University of Technology
- Badge serving as a 4-day ticket (valid from Sunday to Wednesday) for public transport (tram, bus) in Poznań

The registration fee for an accompanying person covers the same except the admission to sessions and conference materials.

Please note that the conference gala dinner is not included in the registration fee.

LOCATION OF THE REGISTRATION DESKS

Building CW, ground floor Address: Piotrowo 2, 60-965 Poznań



▶ LUNCHES AND COFFEE BREAKS

LUNCHES

Lunch will be distributed in the conference buildings:

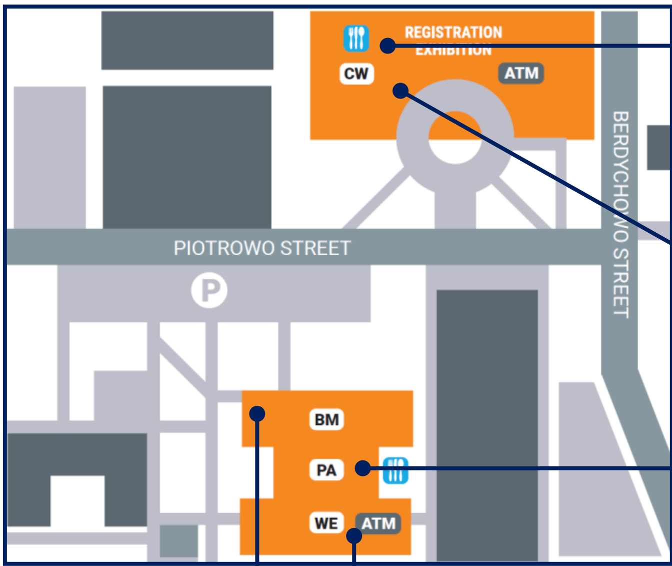
▶ **from Monday (July 4) to Wednesday (July 6), from 12:00 to 14:15**

You will get the lunch coupons (one per each day) with your badge.

LOCATION OF LUNCH HUBS

Building CW, ground floor - for conference participants in Building CW

Building PA (accessible from outside as well as from the basements of Buildings BM and WE) - for conference participants in Buildings BM, WE, and PA



LUNCH HUB AND COFFEE BREAK
IN BUILDING CW
ROOMS 051 and 053 (ground floor)
lunch for conference participants in Building CW

COFFEE BREAK IN BUILDING CW
NEXT TO ROOM 123 (1st floor)
for conference participants in Building CW

LUNCH HUB AND COFFEE BREAK
IN BUILDING PA
lunch for conference participants in Buildings BM, PA, and WE
If your session in scheduled in Building BM or WE, go to the central part of its basement (level -1) which links to Building PA

COFFEE BREAK
IN BUILDING BM
ground floor
and 1st floor
for conference participants in Building BM

COFFEE BREAK
IN BUILDING WE
NEXT TO ROOM 119
(1st floor)
for conference participants in Building WE

COFFEE BREAK

Coffee, tea, and cake will be distributed in the conference buildings:

▶ **from Monday (July 4) to Wednesday (July 6), from 10:00 to 10:30**

▶ **on Monday (July 4), from 16:00 to 16:30,** and **on Wednesday (July 6), from 15:30 to 16:00**

LOCATION OF COFFEE BREAKS

Main lunch hubs: Building CW, ground floor (rooms 051 and 053) and **Building PA**

Building CW, 1st floor, next to room 123

Building BM, ground floor, opposite the main entrance (next to room 19), and 1st floor

Building WE, 1st floor, next to room 119

EURO 2016 Schedule at a Glance

Sunday, July 3	Monday - Wednesday	Monday, July 4	Tuesday, July 5	Wednesday, July 6
	Morning A	MA 08:30-10:00 Parallel Sessions	TA 08:30-10:00 Parallel Sessions	WA 08:30-10:00 Parallel Sessions
	Refreshment Break	10:00-10:30	10:00-10:30	10:00-10:30
Registration Open 12:00 - 20:00 **Exhibition Open 12:00 - 20:00**	**Morning B**	MB 10:30-12:00 Parallel Sessions	TB 10:30-12:00 Parallel Sessions	WB 10:30-12:00 Parallel Sessions
	Lunch 12:00 -14:15	12:00-12:30	12:00-12:30	12:00-12:30
	Midday C	MC 12:30-14:00 Parallel Sessions	TC 12:30-14:00 Parallel Sessions	WC 12:30-14:00 Parallel Sessions
		14:00-14:30	14:00-14:30	14:00-14:30
	Afternoon D	MD 14:30-16:00 Parallel Sessions	TD 14:30-16:00 Parallel Sessions	WD 14:30-15:30 **Plenary**
	Refreshment Break	16:00-16:30	-	15:30-16:00
SE 16:30-18:00 **Opening Session**	**Afternoon E**	ME 16:30-17:30 **Plenary**	TE 17:30-18:30 **Plenary**	WE 16:00-17:45 **Closing Session**
Welcome Reception	Evening	Snack & Beer Old Market Square	Conference Dinner	Farewell Party

Awards and Special Presentations Schedule

	Sunday, July 3	Monday, July 4	Tuesday, July 5	Wednesday, July 6
Morning A		MA 08:30-10:00 **ROADEF/EURO** (CW, 123)	TA 08:30-10:00 **ROADEF/EURO** (CW, 123)	WA 08:30-10:00
Morning B		MB 10:30-12:00 **EJOR** (CW, 1) **Memorial session** (CW, 123)	TB 10:30-12:00 **EDDA** (CW, 123)	WB 10:30-12:00
Midday C		MC 12:30-14:00 **EEPA 1** (CW, 123) **EthOR** (CW, 1)	TC 12:30-14:00	WC 12:30-14:00
Afternoon D		MD 14:30-16:00 **EEPA 2** (CW, 123)	TD 14:30-16:00 **MAI Roundtable** (CW, 123)	WD 14:30-15:30
Afternoon E	SE 16:30-18:00 **Opening Session** **EGM, EDSM**	ME 16:30-17:30	TE 17:30-18:30	WE 16:00-17:45 **Closing Session**

Invited Speakers Schedule (Building CW, Aula)

	Sunday, July 3	Monday, July 4	Tuesday, July 5	Wednesday, July 6
Morning A		MA 08:30-10:00 **Marielle Christiansen**	TA 08:30-10:00 **José Fernando Oliveira**	WA 08:30-10:00 **Marc Pirlot**
Morning B		MB 10:30-12:00 **Mauricio Resende**	MB 10:30-12:00 **Gerrit Timmer**	WB 10:30-12:00 **Stephen J. Wright**
Midday C		MC 12:30-14:00 **Alexander Shapiro**	TB 12:30-14:00 **Emma Hart**	WB 12:30-14:00 **Giovanni Rinaldi**
Afternoon D		MD 14:30-16:00 **Hans Georg Bock**	TD 14:30-16:00 **Pablo Moscato**	WD 14:30-15:30 plenary **Rolf Möhring**
Afternoon E	SE 16:30-18:00 **Opening Session**	ME 16:30-17:30 plenary **Dimitris Bertsimas**	TE 17:30-18:30, plenary **Robert Aumann** Poznań International Fair Earth Hall (Sala Ziemi)	WE 16:00-17:45 **Closing Session**

► OPENING AND CLOSING

Opening Session

► **Sunday, July 3, 2016: 16:30 - 18:00** **Building CW, Aula**

Chair: **Daniele Vigo,** Chair of the EURO 2016 Programme Committee

► Welcome addresses

Daniele Vigo, Chair of the EURO 2016 Programme Committee
Elena Fernández, President of EURO
Tomasz Łodygowski, Rector of Poznan University of Technology
Representative of Poznań's government

► EURO Gold Medal

Announcement of the EURO Gold Medal 2016 Laureate(s)
Presentation(s) by the EURO Gold Medal Laureate(s)

► EURO Distinguished Service Medal

Announcement of the EURO Distinguished Service Medal Award
Acceptance by the EURO Distinguished Service Medal Laureate

► Latest information and special remarks

Daniele Vigo, Chair of the EURO 2016 Programme Committee
Joanna Józefowska, Chair of the EURO 2016 Organising Committee

► Opening session will be followed by the Welcome Reception

Closing Session

► **Wednesday, July 6, 2016: 16:00 - 17:45** **Building CW, Aula**

Chair: **Joanna Józefowska,** Chair of the EURO 2016 Organising Committee

► Welcome addresses

Joanna Józefowska, Chair of the EURO 2016 Organising Committee

► Announcement of EURO Awards

EURO Award for the Best EJOR Papers (EABEP 2016)
EURO Doctoral Dissertation Award (EDDA 2016)
EURO Excellence in Practice Award (EEPA 2016)
ROADEF/EURO Challenge 2016

► Calls for Participation in Future Activities

IFORS 2017 - Québec, Canada
EURO 2018 - Valencia, Spain

► Special Issues after EURO 2016

Daniele Vigo, Chair of the EURO 2016 Programme Committee

► Farewell addresses

Daniele Vigo, Chair of the EURO 2016 Programme Committee
Albert Wagelmans, EURO Vice-President 1
Joanna Józefowska, Chair of the EURO 2016 Organising Committee

► Closing session will be followed by the Farewell Party

► SESSION GUIDELINES

Guidelines for Speakers

The location of your session is shown in the **Technical Programme** section of the Conference Handbook. You can also find it in the online programme at the **conference website**.

There are typically 4 talks in each session of 90 minutes. This gives **20 minutes for each speaker** including questions, and 2-3 minutes for switching speaker.

Time your presentation to fit within 15-18 minutes, leaving time for audience questions. Limit your presentation to key issues with a brief summary. Clearly state which problem you are solving, and why it is relevant.

Arrive at your session **at least 10 minutes before its scheduled start** to check in with the session chair, and to set up your presentation and test connection with the projector.

Bring **a copy** of your presentation on a **USB stick** to enable easy transfer to the computer being used for the presentation. All presentations in a session should be loaded on one computer/laptop to make handovers smoother.

If sessions do not have 4 talks the schedules talks should stick to the 20 minutes slots to allow delegates to transfer from other session if they wish. The unused slots can be used for general discussion.

If a speaker does not show up, the original time schedule should be adhered to rather than sliding every talk forward. This allows for effective session jumping.

If the scheduled chairman does not show up, the first speaker should take over the responsibility of chairing the session.

Guidelines for Session Chairs

The role of the chair is to **ensure the smooth execution** of the session.

Ensure that the session begins and ends on time. Each session lasts 90 minutes with equal time allotted for each presentation in the session. Typically, the time per presentation should be 20 minutes, except where there are 5 talks in a session. This allows for 2-3 minutes for the changeover of the speaker.

Contact the speakers before the session, to verify who will present and to pre-empt any technical problems. **Ensure that all presentation in a session are loaded on one computer**/laptop.

Introduce each presentation (just the title of the paper and the name of the presenting author).

Ensure that **presentations are made in the order shown in the programme**. This allows for session jumping. If a speaker cancels or does not attend, the original time schedule should be adhered to rather than sliding every talk forward.

Express visually to the speaker how many minutes (5, 1) are left, using either your hands or prepared cards.

At the end of each presentation ask for questions and thank the speaker.

Audio/Visual Equipment

All lecture rooms in EURO 2016 are equipped with a computer projector having a VGA connection.

All lecture rooms in Buildings CW and PA are equipped with a computer. The computers contain up-to-date software for the main presentation formats (PowerPoint, PDF) and have USB connections for memory cards.

If your talk is scheduled in Building BM or WE, bring your own laptop, or pre-arrange with other speakers in your session that at least one you brings a laptop from which you can project the talks.

Bring a power adaptor with you. We recommend that you do not attempt to run your presentation off the laptop battery. If your laptop is not compatible with EU-standard plug, please bring an electrical adaptor.

If you use an Apple product, you will probably need the appropriate adaptor for the external video output (VGA standard).

▶ **Programme overview as for June 28, 2016.**

	July 3	Monday, July 4, 2016					Tuesday, July 5, 2016					Wednesday, July 6, 2016				
	16:30-18:00	8:30-10:00	10:30-12:00	12:30-14:00	14:30-16:00	16:30-17:30	8:30-10:00	10:30-12:00	12:30-14:00	14:30-16:00	17:30-18:30	8:30-10:00	10:30-12:00	12:30-14:00	14:30-15:30	16:00-17:45
Stream	**SA**	**MA**	**MB**	**MC**	**MD**	**ME**	**TA**	**TB**	**TC**	**TD**	**TE**	**WA**	**WB**	**WC**	**WD**	**WE**
Opening session	CW AUL															
Closing session																CW AUL
Plenary talk Robert Aumann											PIF EH					
Plenary talk Dimitris Bertsimas						CW AUL										
Plenary talk Rolf Möhring															CW AUL	
Keynote talk Marielle Christiansen		CW AUL														
Keynote talk Mauricio Resende			CW AUL													
Keynote talk Alexander Shapiro				CW AUL												
Keynote talk Hans Georg Bock					CW AUL											
Keynote talk - José Fernando Oliveira							CW AUL									
Keynote talk Gerrit Timmer								CW AUL								
Keynote talk Emma Hart									CW AUL							
Keynote talk Pablo Moscato										CW AUL						
Keynote talk Marc Pirlot												CW AUL				
Keynote talk Stephen J. Wright													CW AUL			
Keynote talk Giovanni Rinaldi														CW AUL		
EURO Awards		CW 123		CW 123	CW 123		CW 123	CW 123								
EURO Journals			CW 1													

▶ PROGRAMME OVERVIEW

	July 3	Monday, July 4, 2016					Tuesday, July 5, 2016					Wednesday, July 6, 2016				
	16:30-18:00	8:30-10:00	10:30-12:00	12:30-14:00	14:30-16:00	16:30-17:30	8:30-10:00	10:30-12:00	12:30-14:00	14:30-16:00	17:30-18:30	8:30-10:00	10:30-12:00	12:30-14:00	14:30-15:30	16:00-17:45
Stream	**SA**	**MA**	**MB**	**MC**	**MD**	**ME**	**TA**	**TB**	**TC**	**TD**	**TE**	**WA**	**WB**	**WC**	**WD**	**WE**
Area: Analytics, Data Science and Data Mining																
Business Analytics and Intell. Optimizat.							BM 109D	BM 109D	BM 109D	BM 109D		BM 109D	BM 109D	BM 109D		
Computational Statistics		BM 113	BM 113	BM 113	BM 113		BM 113	BM 113	BM 113							
Data Science in Optimisation								BM 20								
Information and Intelligent Systems								BM 18	BM 18	BM 18		BM 18	BM 18			
Area: Artificial Intelligence, Fuzzy Systems and Computing																
Computing												CW 023	CW 023	CW 023		
Fuzzy Optimization - Syst., Net. and Appl.		CW 127	CW 127													
Probabilistic Models												CW 127	CW 127			
Area: Continuous Optimization																
Convex Optimization		PA B	PA B	PA B	PA B		PA B	PA B	PA B	PA B		PA B	PA B			
Convex Optimization														PA D		
Convex, Semi-Infin. and Semidef. Optim.			PA C	PA C												
Global Optimization					PA C		PA C									
Mathematical Programming		PA D	PA D	PA D	PA D											
Nonsmooth Optimization									PA D	PA D		PA D				
Vector and Set-Valued Optimization								PA C	PA C	PA C		PA C				
Area: Control Theory and System Dynamics																
Dynamic Programming					BM 20		BM 20									
Dynamical Models in Sustainable Devel.		BM 109D	BM 109D	BM 109D	BM 109D											
Dynamical Syst. and Mat. Model. in OR		BM 20	BM 20	BM 20												
Optimal Control Applications													BM 110	BM 110		
Rec. Adv. in Dynam. of Variat. Inequal ...							BM 110	BM 110								
Syst. Dynam. Model. and Simulation		BM 110	BM 110	BM 110	BM 110											
Area: Decision Analysis, Decision Support Systems, DEA and Performance Measurement																
DEA and Perf. Measurement									WE 18	WE 18		WE 18	WE 18	WE 18		
Decision Support Systems								WE 107	WE 107	WE 107						
OR in Clinical Decision Support													WE 209	WE 209		
Spatial Risk Analysis									CW 123							

► PROGRAMME OVERVIEW

	July 3	Monday, July 4, 2016					Tuesday, July 5, 2016					Wednesday, July 6, 2016				
	16:30-18:00	8:30-10:00	10:30-12:00	12:30-14:00	14:30-16:00	16:30-17:30	8:30-10:00	10:30-12:00	12:30-14:00	14:30-16:00	17:30-18:30	8:30-10:00	10:30-12:00	12:30-14:00	14:30-15:30	16:00-17:45
Stream	**SA**	**MA**	**MB**	**MC**	**MD**	**ME**	**TA**	**TB**	**TC**	**TD**	**TE**	**WA**	**WB**	**WC**	**WD**	**WE**
Area: Discrete Optimization, Mixed Integer Linear and Nonlinear Programming																
Combinatorial Optimization 1		CW 027	CW 027	CW 027	CW 027		CW 027	CW 027	CW 027	CW 027		CW 027	CW 027	CW 027		
Combinatorial Optimization 2										CW 029		CW 029	CW 029	CW 029		
Discrete and Global Optimization				CW 127	CW 127		CW 127	CW 127	CW 127							
Discrete Optimization under Uncertainty		CW 128	CW 128	CW 128												
Mixed-Integer Linear and Nonlin. Program.			CW 125	CW 125	CW 125		CW 125	CW 125	CW 125							
Area: Emerging Applications of OR																
Algorithms and Comp. Optimization												CW 7	CW 7	CW 7		
Custom. Based Serv. and Knowledge...												CW 9				
Emerging Appl. in Portfolio Selection...										CW 12		CW 12				
Env. Sustainability in Supply Chains										CW 6		CW 6	CW 6			
Op.Res. and Comb. Opt. in Web Engin.				CW 6	CW 6											
OR and the Arts		CW 12														
OR in Quality Management		CW 6														
OR Methods in Cons. Behav. Research													CW 12			
Recent Dev. on Opt. and Res. on GT							CW 6	CW 6	CW 6							
Area: Energy, Environment, Natural Resources and Climate																
Biomass-Based Supply Chains		WE 107														
Energy/Environment and Climate									WE 116	WE 116		WE 116	WE 116	WE 116		
Long Term Planning in Ene., Env. and Cli.								WE 120	WE 120	WE 120		WE 120				
Optimization in Ren. Energy Systems					WE 18		WE 18	WE 18								
OR in Agriculture, Forestry and Fish.										WE 209		WE 209				
Stochastic Models in Ren. Gen. Electricity		WE 18	WE 18	WE 18												
Area: Financial Modeling, Risk Management and Managerial Accounting																
Computational Methods in Finance												WE 108	WE 108	WE 108		
Dec. Mak. Modeling and Risk Ass. in Fin.					WE 116		WE 116	WE 116								
Financial and Comm. Modeling			WE 107	WE 107												
Financial Eng. and Optimization		WE 108	WE 108	WE 108	WE 108											
Financial Mathematics and OR		WE 209	WE 209	WE 209	WE 209		WE 209	WE 209	WE 209							
Long Term Financial Decisions				WE 116												
Numerical and Sim. Methods in Finance								WE 115								
Op. Res. in Financial and Man. Accounting													WE 120	WE 120		
Simulation in Man. Acc. and Man. Contr.			WE 116													

	July 3	Monday, July 4, 2016					Tuesday, July 5, 2016					Wednesday, July 6, 2016				
	16:30-18:00	8:30-10:00	10:30-12:00	12:30-14:00	14:30-16:00	16:30-17:30	8:30-10:00	10:30-12:00	12:30-14:00	14:30-16:00	17:30-18:30	8:30-10:00	10:30-12:00	12:30-14:00	14:30-15:30	16:00-17:45
Stream	**SA**	**MA**	**MB**	**MC**	**MD**	**ME**	**TA**	**TB**	**TC**	**TD**	**TE**	**WA**	**WB**	**WC**	**WD**	**WE**
Area: Game Theory and Mathematical Economics																
Dynamic Models in Game Theory							WE 120									
Game Theory and Operations Manag.									WE 108	WE 108						
Game Theory, Solutions and Str.		WE 120	WE 120	WE 120	WE 120											
Math. Models in Macro- and Microec.							WE 108	WE 108								
Risk, Uncertainty, and Decision							CW 2						WE 107			
Area: Graphs and Networks																
Graph Searching									CW 021	CW 021		CW 021				
Graphs and Networks		CW 028	CW 028	CW 028	CW 028		CW 028	CW 028								
Optimization of Gas Networks			CW 126				CW 126	CW 126	CW 126	CW 126						
Telecommunications and Network Optim.					CW 021		CW 021	CW 021								
Area: Metaheuristics																
Metaheuristics								PA A	PA A	PA A		PA A	PA A			
Area: Multiple Criteria Decision Making and Optimization																
Analytic Hierarchy Process / ANP							CW 1	CW 1	CW 1	CW 1		CW 1	CW 1	CW 1		
Evolutionary Multiobj. Optimization		CW 7	CW 7	CW 7												
Multiobjective Optimization		CW 8	CW 8	CW 8	CW 8		CW 8	CW 8	CW 8	CW 8		CW 8				
Multiple Criteria Decision Aiding 1		CW 2	CW 2	CW 2	CW 2			CW 2	CW 2	CW 2		CW 2	CW 2	CW 2		
Multiple Criteria Decision Aiding 2		CW 9	CW 9	CW 9	CW 9											
Multiple Criteria Decision Analysis		CW 13	CW 13	CW 13	CW 13											
Preference Learning							CW 13	CW 13	CW 13	CW 13		CW 13	CW 13			
Rough Sets in Decision								CW 7	CW 7	CW 7						
Area: OR Education																
Initiatives for OR Education		PA A	PA A	PA A	PA A											
Teaching OR/MS										CW 9						
Area: OR for Developing Countries and Humanitarian Applications																
Humanitarian Operations								BM 111	BM 111	BM 111			BM 111	BM 111		
Optimization for Sustainable Devel.		BM 109M	BM 109M													
OR for Development and Dev. Countries													BM 20	BM 20		
OR for Sustainable Development		BM 18														

▶ PROGRAMME OVERVIEW

	July 3	Monday, July 4, 2016					Tuesday, July 5, 2016					Wednesday, July 6, 2016				
	16:30-18:00	8:30-10:00	10:30-12:00	12:30-14:00	14:30-16:00	16:30-17:30	8:30-10:00	10:30-12:00	12:30-14:00	14:30-16:00	17:30-18:30	8:30-10:00	10:30-12:00	12:30-14:00	14:30-15:30	16:00-17:45
Stream	**SA**	**MA**	**MB**	**MC**	**MD**	**ME**	**TA**	**TB**	**TC**	**TD**	**TE**	**WA**	**WB**	**WC**	**WD**	**WE**
Area: OR History and OR Ethics																
How OR found its way into Universities								CW 022	CW 022							
Memorial Session			CW 123													
OR and Ethics		CW 1		CW 1	CW 1											
Area: OR in Health, Life Sciences and Sports																
Comp. Biol., Bioinf. and Medicine 1		BM 17	BM 17	BM 17	BM 17		BM 17	BM 17	BM 17	BM 17		BM 17	BM 17	BM 17		
Comp. Biol., Bioinf. and Medicine 2														BM 19		
Health Care Emergency Man.		BM 7	BM 7													
Health Care Management					BM 109M		BM 109M	BM 109M								
Methodology of Societal Complexity													CW 025	CW 025		
Op. Res. for Health and Social Care									BM 110	BM 110						
OR in Sports		BM 111	BM 111	BM 111	BM 111		BM 111									
Scheduling in Healthcare			BM 18	BM 18	BM 18		BM 18									
Area: OR in Industry and Software for OR																
Engineering Optimization				CW 126	CW 126											
IBM Research Applications								CW 9	CW 9							
Mathematical Program. Software					CW 12		CW 12	CW 12	CW 12							
Operations/Marketing Interface														CW 13		
OR and Real Implementation													CW 9	CW 9		
OR Applications in Industry			CW 12	CW 12												
Area: Practice of OR (Making an Impact) (see also **www.euro2016.poznan.pl/making-an-impact/** for additional activities)																
Case Studies in OR									BM 20	BM 20		BM 20				
Defence and Security		BM 119	BM 119	BM 119	BM 119											
Workshops and roundtable		CW 122			CW 122		CW 9		CW 122	CW 123		WE 107	CW 122	CW 122		
Mentoring					CW 024				CW 024				CW 024			
Area: Production Management and Supply Chain Management																
Cutting and Packing										CW 022		CW 022	CW 022	CW 022		
Demand and Supply Man. in Retail ...							CW 0210	CW 0210	CW 0210	CW 0210		CW 0210	CW 0210			
Lot Sizing, Lot Sch. and Prod. Planning		CW 021	CW 021	CW 021												
Production and Oper. Management		CW 023	CW 023	CW 023	CW 023		CW 023	CW 023	CW 023	CW 023						
Supply Chain Management												CW 126	CW 126	CW 126		
Sustainable Supply Chains		CW 029	CW 029													

▶ PROGRAMME OVERVIEW

	July 3	Monday, July 4, 2016					Tuesday, July 5, 2016					Wednesday, July 6, 2016				
	16:30-18:00	8:30-10:00	10:30-12:00	12:30-14:00	14:30-16:00	16:30-17:30	8:30-10:00	10:30-12:00	12:30-14:00	14:30-16:00	17:30-18:30	8:30-10:00	10:30-12:00	12:30-14:00	14:30-15:30	16:00-17:45
Stream	**SA**	**MA**	**MB**	**MC**	**MD**	**ME**	**TA**	**TB**	**TC**	**TD**	**TE**	**WA**	**WB**	**WC**	**WD**	**WE**
Area: Revenue Management																
Advances in Revenue Managem.					WE 107		WE 107									
Area: Routing, Location, Logistics and Transportation																
Green Logistics									CW 028	CW 028		CW 028	CW 028	CW 028		
Healthcare Logistics					CW 128		CW 128	CW 128	CW 128	CW 128		CW 128	CW 128	CW 128		
Location		CW 022	CW 022	CW 022	CW 022		CW 022									
Maritime Transportation										CW 125		CW 125	CW 125	CW 125		
Public Transportation		CW 025	CW 025	CW 025	CW 025		CW 025	CW 025	CW 025	CW 025		CW 025				
Transportation		CW 0210	CW 0210	CW 0210												
Transportation and Logistics													CW 021	CW 021		
Vehicle Routing and Logistics Optim. 1		CW 3	CW 3	CW 3	CW 3		CW 3	CW 3	CW 3	CW 3		CW 3	CW 3	CW 3		
Vehicle Routing and Logistics Optim. 2				CW 029	CW 029		CW 029	CW 029	CW 029							
Area: Scheduling, Timetabling and Project Management																
Project Management and Scheduling							BM 119	BM 119	BM 119	BM 119		BM 119	BM 119	BM 119		
Scheduling Theory and Applications												BM 116	BM 116	BM 116		
Scheduling with Resource Constr.										BM 109M		BM 109M	BM 109M	BM 109M		
Scheduling, Sequen., and Applications										BM 113		BM 113	BM 113	BM 113		
Supply Chain Sched. and Logistics		BM 116	BM 116	BM 116	BM 116		BM 116	BM 116	BM 116	BM 116						
Timetabling												BM 7	BM 7	BM 7		
Area: Simulation, Stochastic and Robust Optimization																
Robust Optimization									WE 115	WE 115		WE 115	WE 115	WE 115		
Stoch. Modeling and Simulation in Eng...		WE 115	WE 115	WE 115	WE 115		WE 115									
Area: Soft OR, Problem Structuring Methods and Behavioural OR																
Behavioural Oper. Research		BM 19	BM 19	BM 19	BM 19		BM 19	BM 19	BM 19	BM 19		BM 19	BM 19			
Soft OR and Problem Structuring Methods								BM 7	BM 7	BM 7						

► CONFERENCE APP & WiFi

Conference App

The Conference4me smartphone app provides you with the most comfortable tool for planning your participation in EURO 2016. Browse the complete programme directly from your phone or tablet and create your very own agenda on the fly. The app is available for Android, iOS, Windows Phone and Kindle Fire devices. To download mobile app, please visit

http://conference4me.eu/download

or type 'conference4me' in Google Play, iTunes App Store, Windows Phone Store or Amazon Appstore, or scan the below image with your mobile phone (QR-Code reader required). More information can be found here http://conference4me.eu/download

My Program in the EURO online system

In addition to the conference app, the full programme and specific time slots in the schedule are browse-able online at:

https://www.euro-online.org/conf/euro28/program

On different places on the site, you have the possibility to add sessions to your own personalised programme. You can always access it through the **My Program** link in the left menu. Note that this feature is only available if you are logged in to EURO. You can also export your personal programme as a calendar.

WiFi

WiFi access is available across the campus free of charge.

The following networks are available:

► eduroam

An international WiFi confederation - if you are visiting from an institution that participates in the eduroam scheme, you can connect to the "eduroam" SSID to gain basic Internet connectivity.

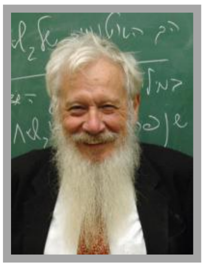
Your device will require to be configured in advance before you arrive. To log in you should use the credentials supplied by your home institution.

► PUT-events-WiFi

To log in use a unique user account and password provided with your badge.

▶ INVITED SPEAKERS SCHEDULE

	Sunday, July 3	Monday, July 4	Tuesday, July 5	Wednesday, July 6
Morning A		▶ MA 08:30-10:00 **Marielle Christiansen** NTNU, Norway *Optimization of Maritime Transportation* ▶ Building CW, Aula	▶ TA 08:30-10:00 **José Fernando Oliveira** FEUP, Portugal *Waste Minimization: the Contribution of Cutting and Packing Problems for a More Competitive and Environmentally Friendly Industry* ▶ Building CW, Aula	▶ WA 08:30-10:00 **Marc Pirlot** Un. Mons, Belgium *Preference Elicitation and Learning in a Multiple Criteria Decision Analysis Perspective: Specificities and Fertilization through Inter-disciplinary Dialogue* ▶ Building CW, Aula
Morning B		▶ MB 10:30-12:00 **Mauricio Resende** Amazon Inc, USA *Logistics Optimization at Amazon: Big data & Operational Research in Action* ▶ Building CW, Aula	▶ TB 10:30-12:00 **Gerrit Timmer** ORTEC and Free University Amsterdam *Making an Impact with OR; Lessons Learned from 35 Years of Experience in Applying OR* ▶ Building CW, Aula	▶ WB 10:30-12:00 **Stephen J. Wright** University of Wisconsin-Madison, USA *Optimization in Data Analysis* ▶ Building CW, Aula
Midday C		▶ MC 12:30-14:00 **Alexander Shapiro** Georgia Tech, USA Risk Averse and Distributionally Robust Multistage Stochastic Optimization ▶ Building CW, Aula	▶ TC 12:30-14:00 **Emma Hart** Edinburgh Napier Un., UK Lifelong Learning in Optimization ▶ Building CW, Aula	▶ WC 12:30-14:00 **Giovanni Rinaldi** IASI, Italy Maximum Weight Cuts in Graphs and Extensions ▶ Building CW, Aula
Afternoon D		▶ MD 14:30-16:00 **Hans Georg Bock** Un. Heidelberg, Germany *Mixed-Integer Optimal Control - Theory, Numerical Solution and Nonlinear Model Predictive Control* ▶ Building CW, Aula	▶ TD 14:30-16:00 **Pablo Moscato** Un. Newcastle, Australia *Information-based Medicine and Combinatorial Optimization: Opportunities and Challenges* ▶ Building CW, Aula	▶ WD 14:30-15:30, plenary **Rolf Möhring** Beijing Institute for Scientific and Engineering Computing *Optimizing the Kiel Canal - Integrating Dynamic Network Flows and Scheduling* ▶ Building CW, Aula
Afternoon E	▶ SE 16:30-18:00 **Opening Session** ▶ Building CW, Aula	▶ ME 16:30-17:30, plenary **Dimitris Bertsimas** Massachusetts Institute of Technology *Machine Learning and Statistics via a Modern Optimization Lens* ▶ Building CW, Aula	▶ TE 17:30-18:30, plenary **Robert Aumann** Hebrew University of Jerusalem *Why Optimize? An Evolutionary Perspective* ▶ **Poznań International Fair, Earth Hall**	▶ WE 16:00-17:45 **Closing Session** ▶ Building CW, Aula



Robert Aumann

Hebrew University of Jerusalem, Israel

2005 Nobel Memorial Prize in Economic Sciences

Why Optimize? An Evolutionary Perspective

► Tuesday, July 5, 2016, 17:30 - 18:30 *Poznań International Fair, Earth Hall*

Biography

Robert Aumann was born in Frankfurt am Main, Germany, in 1930, to a well-to-do orthodox Jewish family. He emigrated to the United States with his family in 1938, settling in New York. In the process, his parents lost everything, but nevertheless gave their two children an excellent Jewish and general education. Aumann attended Yeshiva elementary and high schools, got a bachelor's degree from the City College of New York in 1950, and a Ph.D. in mathematics from MIT in 1955.

He joined the mathematics department at the Hebrew University of Jerusalem in 1956, and has been there ever since. In 1990, he was among the founders of the **Center for Rationality at the Hebrew University**, an interdisciplinary research center, centered on Game Theory, with members from over a dozen different departments, including Business, Economics, Psychology, Computer Science, Law, Mathematics, Ecology, Philosophy, and others.

Robert Aumann is the author of over ninety scientific papers and six books, and has held visiting positions at Princeton, Yale, Berkeley, Louvain, Stanford, Stony Brook, and NYU. He is a member of the American Academy of Arts and Sciences, the National Academy of Sciences (USA), the British Academy, and the Israel Academy of Sciences; holds honorary doctorates from the Universities of Chicago, Bonn, Louvain, City University of New York, and Bar Ilan University; and has received numerous prizes, including the **Nobel Memorial Prize in Economic Sciences for 2005**.

Why Optimize? An Evolutionary Perspective

By the doctrine of "Survival of the Fittest", evolutionary pressures indirectly lead to optimal functioning of vital processes like nourishment and reproduction. Conscious, purposeful optimization does so directly, indeed more efficiently. The lecture conveyed during EURO 2016 will suggest that the poorly understood phenomenon of consciousness has evolved for precisely that reason - to enable efficient optimization of life processes.

Reminder

The central plenary lecture by Robert Aumann takes place **outside the main conference venue,** in the beautiful **Earth Hall at Poznań International Fair** (Głogowska 10).

How to reach Poznań International Fair from EURO 2016 venue?

Take a tram! There are two routes you may follow.

Go to **Politechnika stop**, take a tram (**line 5 or 13**), **heading to Bałtyk**. The tram will pass close to the Old Market Square, a symbol of Poznań's modernim - Okrąglak (The Round House), Kaiser's Castle, and June 1956 Events Monument. After about 12 minutes in a tram you will be there at Bałtyk, next to Poznań International Fair (Międzynarodowe Targi Poznańskie). Just take a short walk to the main entrance of PIF.

Remark: Please consult this option with the *JakDojade* application as this route is frequently changed, being under renovation.

Alternatively, have a short walk to **Serafitek stop**, take a tram (**line 6 or 18**), **heading to Most Dworcowy**. After about 9 minutes in a tram you will be at the entrance of Poznań International Fair.

Dimitris Bertsimas

Sloan School of Management; Operations Research Center
Massachusetts Institute of Technology, Cambridge, USA

Machine Learning and Statistics via a Modern Optimization Lens

▶ **Monday, July 4, 2016, 16:30 - 17:30** *Building CW, Aula*

Biography

Dimitris Bertsimas is currently the **Boeing Professor of Operations Research** and the co-director of the Operations Research Center at the Massachusetts Institute of Technology. He has received a BS in Electrical Engineering and Computer Science at the National Technical University of Athens, Greece in 1985, a MS in Operations Research at MIT in 1987, and a Ph.D in Applied Mathematics and Operations Research at MIT in 1988. Since 1988, he has been with the MIT faculty. Since the 1990s he has started several successful companies in the areas of financial services, asset management, health care, publishing, analytics and aviation.

His research interests include analytics, optimization and their applications in a variety of industries. He has co-authored more than 170 scientific papers and four textbooks, including the book "The Analytics Edge" published in 2016. He is former area editor in Operations Research in Financial Engineering and in Management Science in Optimization. He has supervised 57 doctoral students and he is currently supervising 16 others.

He is a member of the US National Academy of Engineering, and an INFORMS fellow. He has received **several research awards** including the Philip Morse lectureship award (2013), the William Peirskalla award for best paper in health care (2013), the best paper award in Transportation Science (2013), the Farkas prize (2008), the Erlang prize (1996), the SIAM prize in optimization (1996), the Bodossaki prize (1998), and the Presidential Young Investigator award (1991-1996).

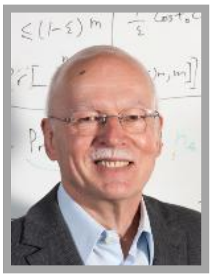
Machine Learning and Statistics via a Modern Optimization Lens

The field of Statistics has historically been linked with Probability Theory. However, some of the central problems of classification, regression and estimation can naturally be written as optimization problems. While continuous optimization approaches has had a significant impact in Statistics, mixed integer optimization (MIO) has played a very limited role, primarily based on the belief that MIO models are computationally intractable. The period 1991-2015 has witnessed a) algorithmic advances in mixed integer optimization (MIO), which coupled with hardware improvements have resulted in an astonishing 450 billion factor speedup in solving MIO problems, b) significant advances in our ability to model and solve very high dimensional robust and convex optimization models.

We demonstrate that modern convex, robust and especially mixed integer optimization methods, when applied to a variety of classical Machine Learning (ML)/Statistics (S) problems can lead to certifiable optimal solutions for large scale instances that have often significantly improved out of sample accuracy compared to heuristic methods used in ML/S. Specifically, we report results on:

1. The classical variable selection problem in regression currently solved by Lasso heuristically.
2. We show that robustness and not sparsity is the major reason of the success of Lasso in contrast to widely held beliefs in ML/S.
3. A systematic approach to design linear and logistic regression models based on MIO.
4. Optimal trees for classification solved by CART heuristically.
5. Robust classification including robust Logistic regression, robust optimal trees and robust support vector machines.
6. Sparse matrix estimation problems: Principal Component Analysis, Factor Analysis and Covariance matrix estimation.

In all cases we demonstrate that optimal solutions to large scale instances a) can be found in seconds, b) can be certified to be optimal in minutes and c) outperform classical approaches. Most importantly, this body of work suggests that linking ML/S to modern optimization will lead to significant advantages.



Rolf Möhring

Beijing Institute for Scientific and Engineering Computing, Beijing, China
Berlin University of Technology, Berlin, Germany

Optimizing the Kiel Canal
Integrating Dynamic Network Flows and Scheduling

▶ **Wednesday, July 6, 2016, 14:30 - 15:3** *Building CW, Aula*

Biography

Rolf Möhring obtained his M.S. (1973) and P.h.D (1975) in Mathematics at the RWTH Aachen and is since 1987 **Professor for Applied Mathematics and Computer Science** at Berlin University of Technology, where he heads the research group "Combinatorial Optimization and Graph Algorithms" (COGA). He has held earlier positions as associate and assistant professor at the University of Bonn, the University of Hildesheim, and the RWTH Aachen. His research interests center around graph algorithms, combinatorial optimization, scheduling, logistics, and industrial applications. Part of his research has been done in DFG Research Center Matheon, where he was Scientist in Charge of Application Area "Logistics, traffic, and telecommunication networks".

He has been chair of the German Operations Research Society and the Mathematical Programming Society and has been awarded the **Scientific Award of the German Operations Research Society** and the **EURO Gold Medal of the European Association of Operational Research Societies**. Since 2014 he is a honorary professor at the Beijing University of Technology.

Optimizing the Kiel Canal - Integrating Dynamic Network Flows and Scheduling

We introduce, discuss, and solve a hard practical optimization problem that deals with routing bidirectional traffic on the Kiel Canal, which is the world's busiest artificial waterway with more passages than the Panama and Suez Canal together. The problem arises from scarce resources (locations) at which large ships can only pass each other in opposing directions.

The lecture will illustrate recent developments in this direction on the example of the Kiel Canal problem, which was a project with the German Federal Waterways and Shipping Administration. Here certain ships must wait in sidings to let opposing traffic pass. This requires to decide on who should wait for whom (scheduling), in which siding to wait (packing) and when and how far to steer a ship between sidings (routing), and all this for online arriving ships at both sides of the canal.

This is a prototype problem for traffic management and routing in logistic systems. One wants to utilize the available street or logistic network in such a way that the network "load" is minimized or the "throughput" is maximized. The aspects of "time" and "congestion" play a crucial role in these problems and require new techniques that need to integrate dynamic network flows and scheduling.

The combination of routing and scheduling (without the packing) leads to a new class of scheduling problems dealing with scheduling bidirected traffic on a path, and we will address recent complexity and approximation results for this class.

For the full problem, we need a feasible assignment of parking slots within sidings over time that is consistent with the scheduling decisions between the sidings and the routing. To that end, we used a routing algorithm that we had developed earlier for routing automated guided vehicles in a container terminals (cooperation with HHLA). We will explain details of this algorithm and show how to combine it with a rolling horizon technique for the scheduling and packing decisions in the canal. This provides a unified view of routing and scheduling that blends simultaneous (global) and sequential (local) solution approaches to allocate scarce network resources to a stream of online arriving vehicles in a collision-free manner.

Computational experiments on real traffic data with results obtained by human expert planners show that our combinatorial algorithm improves upon manual planning by 25%. It was subsequently used to identify bottlenecks in the canal and to make suggestions for enlarging the capacity of critical sections of the canal to make it suitable for future traffic demands.

Marielle Christiansen

Department of Industrial Economics and Technology Management
Norwegian University of Science and Technology (NTNU), Trondheim, Norway

Optimization of Maritime Transportation

► **Monday, July 4, 2016, 08:30 - 10:00** *Building CW, Aula*

Abstract: In this tutorial, we will give a short introduction to the shipping industry and an overview of some OR-focused planning problems within maritime transportation. Examples from several real ship routing and scheduling cases, elements of models and solution methods will be given. Finally, we present some trends regarding future developments and use of OR-based decision support systems for ship routing and scheduling.

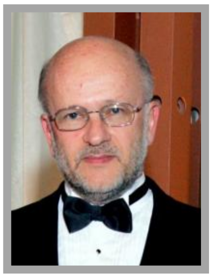
Mauricio Resende

Mathematical Optimization and Planning
Amazon Inc, USA

Logistics Optimization at Amazon
Big Data & Operational Research in Action

► **Monday, July 4, 2016, 10:30 - 12:00** *Building CW, Aula*

Abstract: We consider optimization problems at Amazon Logistics. Amazon.com is the world's largest e-commerce company, selling millions of units of merchandise worldwide on a typical day. To achieve this complex operation requires the solution of many classical operational research problems. Furthermore, many of these problems are NP-hard, stochastic, and inter-related, contributing to make Amazon Logistics a stimulating environment for research in optimization and algorithms.



Alexander Shapiro

Stewart School of Industrial & Systems Engineering
Georgia Tech, USA

Risk Averse and Distributionally Robust
Multistage Stochastic Optimization

► **Monday, July 4, 2016, 12:30 - 14:00** *Building CW, Aula*

Abstract: In many practical situations one has to make decisions sequentially based on data available at the time of the decision and facing uncertainty of the future. This leads to optimization problems which can be formulated in a framework of multistage stochastic optimization. In this talk we consider risk averse and distributionally robust approaches to multistage stochastic programming. We discuss conceptual and computational issues involved in formulation and solving such problems. As an example we give numerical results based on the Stochastic Dual Dynamic Programming method applied to planning of the Brazilian interconnected power system.

Hans Georg Bock

Interdisciplinary Center for Scientific Computing (IWR)
Heidelberg University, Germany

Mixed-Integer Optimal Control
Theory, Numerical Solution and Nonlinear Model Predictive Control

► **Monday, July 4, 2016, 14:30 - 16:00** *Building CW, Aula*

Abstract: The presentation discusses theoretical and numerical aspects of optimal control problems with integer-valued control variables. Despite the practical relevance and ubiquity of integer or logical decision variables such as valves, gears or the start-up of sub-units in chemical plants, optimization methods capable of solving such nonlinear mixed-integer optimal control problems (MIOCP) for large-scale systems and in real-time have only recently come within reach.

Nonlinear MIOCP such as the minimum energy operation of subway trains equipped with discrete acceleration modes were solved as early as the late seventies for the city of New York. Indeed one can prove that the Pontryagin Maximum Principle holds which makes an indirect solution approach feasible. Based on the “Competing Hamiltonians Algorithm” (Bock, Longman ’81), open loop and feedback solutions for problems with discontinuous dynamics were computed that allowed a tested reduction of 18 per cent in traction energy. However, such "indirect" methods are relatively complex to apply and numerically less suitable for large-scale real-time optimization problems.

We present a new "direct" approach based on a functional analytic approach leading to a relaxed problem without integer gap, the so-called “outer convexification” which is then solved by a modification of the direct multiple shooting method as an "all-at-once" approach. Moreover, it can be arbitrarily closely approximated by an integer solution with finitely many switches. The gain in performance is enormous, orders of magnitude of speed-up over a state-of-the-art MINLP approach to the discretized problem, where the NP hardness of the problem is computationally prohibitive. Real-time applications by a “multi-level real-time iteration” NMPC method for on-board energy optimal cruise control of heavy duty trucks and minimum time control of a race car around the Hockenheim race track are presented.

José Fernando Oliveira

Faculty of Engineering
University of Porto, Portugal

Waste Minimization: the Contribution of Cutting and Packing Problems
for a More Competitive and Environmentally Friendly Industry

► **Tuesday, July 5, 2016, 08:30 - 10:00** *Building CW, Aula*

Abstract: Cutting and Packing problems are hard combinatorial optimization problems that arise in the context of several manufacturing and process industries or in their supply chains. These problems occur whenever a bigger object or space has to be divided into smaller objects or spaces, so that waste is minimized. This is the case when cutting paper rolls in the paper industry, large wood boards into smaller rectangular panels in the furniture industry, irregularly shaped garment parts from fabric rolls in the apparel industry, but also the case when packing boxes on pallets and these inside trucks or containers, in logistics applications. All these problems have in common the existence of a geometric sub-problem, which deals with the small object non-overlap constraints.

The resolution of these problems is not only a scientific challenge, given its intrinsic difficulty, but has also a great economic impact as it contributes to the decrease of one of the major cost factors for many production sectors: the raw-materials. In some industries raw-material may represent up to 40% of the total production costs. It has also a significant environmental repercussion as it leads to a less intense exploration of the natural resources from where the raw-materials are extracted, and decreases the quantity of garbage generated, which frequently has also important environmental impacts. In logistics applications, minimizing container and truck loading space waste directly leads to less transportation needs and therefore to smaller logistics costs and less pollution.

In this talk the several Cutting and Packing problems will be characterized and exemplified, based on Gerhard Wäscher's typology (2007), allowing non-specialists to have a broad view over the area. Afterwards, as geometry plays a critical role in these problems, the geometric manipulation techniques more relevant for Cutting and Packing problems resolution will be presented. Finally, aiming to illustrate some of the most recent developments in the area, some approaches based on heuristics and metaheuristics, for the container loading problem, and based on mathematical programming models, for the irregular packing problem, will be described.

Gerrit Timmer

ORTEC
Free University of Amsterdam, The Netherlands

Making an Impact with OR:
Lessons Learned from 35 years of Experience in Applying OR

► **Tuesday, July 5, 2016, 10:30 - 12:00** *Building CW, Aula*

Abstract: Improving business processes using optimization techniques can lead to huge benefits. Yet it is far from trivial how to apply mathematical modelling and optimization to realize those benefits. Moreover, the incredible advances in computer power; the explosion of data being available and the impressive advances in algorithmic ingenuity, make that models that are suitable today will not capture what is possible in the future.

In the past 35 years, I have been in the position to observe hundreds of projects in various industries and application areas, where subtle differences in circumstances and approach led to the impact varying from huge to none at all. I will summarize this experience in a number of lessons learned. Moreover, the lessons learned will be translated into directions for further research and may stimulate to see and grasp the endless opportunities for our field to have a huge impact in the future.

Emma Hart

Institute for Informatics and Digital Innovation
Edinburgh Napier University, United Kingdom

Lifelong Learning in Optimization

► **Tuesday, July 5, 2016, 12:30 - 14:00** *Building CW, Aula*

Abstract: The previous two decades have seen significant advances in optimisation techniques that are able to quickly find optimal or near-optimal solutions to problem instances in many combinatorial optimisation domains. Despite many successful applications of both these approaches, some common weaknesses exist in that if the nature of the problems to be solved changes over time, then algorithms needs to be periodically re-tuned. Furthermore, many approaches are inefficient, starting from a clean slate every time a problem is solved, therefore failing to exploit previously learned knowledge.

In contrast, in the field of machine-learning, a number of recent proposals suggest that learning algorithms should exhibit life-long learning, retaining knowledge and using it to improve learning in the future. I propose that optimisation algorithms should follow the same approach - looking to nature, we observe that the natural immune system exhibits many properties of a life-long learning system that could be exploited computationally in an optimisation framework. I will give a brief overview of the immune system, focusing on highlighting its relevant computational properties and then show how it can be used to construct a lifelong learning optimisation system. The system is shown to adapt to new problems, exhibit memory, and produce efficient and effective solutions when tested in both the bin-packing and scheduling domains.

The proposed system is an example of an ensemble method, in which multiple heuristics collaborate. The final part of the talk will focus on why ensemble approaches to optimisation represent a promising way forward for optimisation in the future.

Pablo Moscato

School of Elect Engineering and Computer Science
University of Newcastle, Australia

Information-based Medicine and Combinatorial Optimization: Opportunities and Challenges

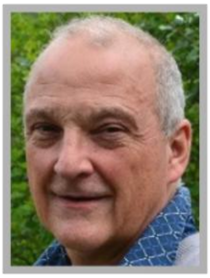
► **Tuesday, July 5, 2016, 14:30 - 16:00** *Building CW, Aula*

Abstract: Operations Research (OR) methodologies, as well as their practitioners, are in high demand. They can address new problems that arise from the disruptive technologies that will have the highest economic impact in the future. Disruption comes hand-in-hand with new technologies for Next-Gen Genomics, mobile internet, automation of knowledge work, the Internet of Things, the Cloud, Advanced robotics and Autonomous and near-autonomous vehicles. These areas bring great challenges but also great opportunities.

One spin-off that will change the world is that these new technologies will generate large-scale datasets allowing an unprecedented ability for OR practitioners to “personalise” solutions. One clear example comes from the field of Personalised Medicine which seeks to consider the best interests of the patient/individual at the centre of all decisions. Personalization will disrupt institutional practices, and drugs and treatments will necessarily be "tailored" to the individual profile. Obviously, one of these disruptive technologies (Next-gen Genomics) is a keystone for the changes ahead, but the automation of knowledge work will also prove vital for cost-effective decisions. The future of OR will be shaped by its new role as a nexus between disciplines.

The interdisciplinary nature of this new area of large-scale data-driven decisions has led to the emergence of a new name for a field of research: Data Science. There are many challenges in this field and they generally involve large scale optimization. However, personalization brings a particular challenge: the development of new mathematical models and powerful algorithmic approaches for large scale instances.

Based on the lessons we learned when introducing these new mathematical models, which were developed to provide new diagnostic and treatment methods, I will discuss our personal journey in Information-based Medicine, with examples of the application of techniques of Combinatorial Optimization, Artificial Intelligence, Machine Learning and Machine Teaching to the area of Data Science and Large-scale Data Analytics.



Marc Pirlot

Computer Science and Management Group
University of Mons, Belgium

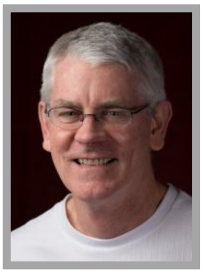
Preference Elicitation and Learning in MCDA Perspective: Specificities and Fertilization through Inter-disciplinary Dialogue

► **Wednesday, July 6, 2016, 08:30 - 10:00** *Building CW, Aula*

Abstract: Capturing, modeling and predicting preferences has become an important issue in many different disciplines, among which we may cite psychology, decision analysis, machine learning, artificial intelligence, information retrieval, social choice theory. Preferences also play a major role in applications such as marketing and electronic commerce.

Although they work with the same notion, the different communities have specific issues to deal with and they use their own methods and standards. In recent years, several workshops were organized with the aim of bringing together people working in preference related domains, yet coming from various research horizons. Let us mention for instance, the Dagstuhl Seminar 14101 on Preference Learning and the DA2PL (From Decision Analysis To Preference Learning) Workshops, the next one scheduled November 2016 in Paderborn, Germany.

In this talk, we shall first sketch the way different communities look at preference learning and contrast them with the peculiarities of Multiple Criteria Decision Analysis. We then mainly focus on the inter-relations with the Machine Learning community, aiming to identify what are the issues we have in common and what can be learned from them in a Decision Analysis perspective. We illustrate the commonalities and discrepancies between both approaches by presenting some recent research works. The last part of the talk will propose and describe four research avenues which we see as structuring the recent and forthcoming efforts regarding preference elicitation and learning in the field of multiple criteria decision analysis. In these four trends, the interactions with disciplines such as Optimization, Artificial Intelligence and Machine Learning are likely to become increasingly important.



Stephen J. Wright

Computer Sciences Department
University of Wisconsin-Madison, USA

Optimization in Data Analysis

► **Wednesday, July 6, 2016, 10:30 - 12:00** *Building CW, Aula*

Abstract: Optimization formulations and algorithms are central to modern data analysis and machine learning. Optimization provides a collection of tools and techniques that can be assembled in different ways to solve problems in these areas. In this tutorial, we survey important problem classes in data analysis and identify common structures in their formulations as optimization problems and common requirements for their solution methodologies. We then discuss key optimization algorithms for tackling these problems, including first-order methods and their accelerated variants, stochastic gradient methods, and coordinate descent methods. We also discuss nonconvex formulations of matrix problems, which has become a popular way to improve tractability of large-scale problems.

Giovanni Rinaldi

Institute for Systems Analysis and Computer Science (IASI)
Italian National Research Council (CNR), Rome, Italy

Maximum Weight Cuts in Graphs and Extensions

► **Wednesday, July 6, 2016, 12:30 - 14:00** *Building CW, Aula*

Abstract: Max-Cut, i.e., the problem of finding a cut of maximum weight in a weighted graph, is one on the most studied and best known hard optimization problems on graphs. Max-Cut is also known to be equivalent to Unconstrained Quadratic Binary Optimization, i.e., to the problem of minimizing a quadratic form in binary variables. Because of its great interest among the optimizers, several approaches, also of a quite diverse nature, have been proposed to find good or provably good solutions, which makes it also very interesting as a benchmark problem for new algorithmic ideas. We review some of the most successful solution methods proposed for this problem and for some extensions where, instead of a quadratic form, we consider a polynomial of degree higher than two.

EURO Gold Medal (EGM 2016)

The EURO Gold Medal is the **highest distinction within OR in Europe**. It is conferred on a prominent person or institution, for an outstanding contribution to Operational Research. Although recent work should not be excluded, care should be taken to allow the contribution to stand the test of time. The potential prize recipient should have a recognized stature in the European OR community. Significance, innovation, depth, and scientific excellence should be stressed. The award is not only a significant honour for the laureate personally, but also important for the general promotion of OR as leading scholars and their contributions are made better known via the Medal.

Jury of the EURO Gold Medal 2016

Berç Rustem (United Kingdom) - Chair	Kaisa Miettinen (Finland)
Luk Van Wassenhove (France)	Eugene Levner (Israel)
M. Grazia Speranza (Italy)	

When and Where?

► The EURO Gold Medal 2016 will be awarded at the opening session (Sunday, July 3, 2016: 16:30-18:00; Building CW, Aula) and the laureate(s) will give a speech.

Most Recent Laureates

2015: Alexander Schrijver (The Netherlands)	2012: Boris Polyak (Russia)
2013: Panos M. Pardols (Greece)	2010: Rolf Möhring (Germany)

EURO Distinguished Service Medal Award (EDSM 2016)

The EURO Distinguished Service Medal is awarded for **recognition of distinguished service to the Association of European OR Societies (EURO) and to the profession of OR**.

Jury of the EURO Distinguished Service Medal 2016

Valerie Belton (United Kingdom) - Chair	Luka Neralic (Croatia)
Ulrike Leopold-Wildburger (Austria)	Jacques Teghem (Belgium)
Roman Słowiński (Poland)	

When and Where?

► The EURO Distinguished Service Medal 2016 will be officially delivered at the opening session (Sunday, July 3, 2016: 16:30-18:00, Building CW, ground floor, Aula).

Most Recent Laureates

2015: Bernard Roy (France)	2012: Dominique de Werra (Switzerland)
2013: Theodor Stewart (South Africa)	2010: Maurice Shutler (UK)

EURO Award for the Best EJOR Paper (EABEP 2016)

EURO has three annual awards available for papers published by European Journal of Operational Research (EJOR): **best survey paper**, **best application paper**, and **best theory/methodology paper**.

Jury of the EURO Award for the Best EJOR Paper 2016

Horst Hamacher (Germany) - Chair	José Fernando Oliveira (Portugal)
Sebastian Lozano (Spain)	Julius Žilinskas (Lithuania)
Stein Wallace (Norway)	

When and Where?

- Winners for each category will be announced at the closing session (Wednesday, July 6, 2016: 16:00-17:45; Building CW, ground floor, Aula).

EURO Doctoral Dissertation Award (EDDA 2016)

The purpose of the EURO Doctoral Dissertation Award is to distinguish **an outstanding PhD thesis in Operational Research** defended in the countries having an OR society that is member of EURO.

Jury of the EURO Doctoral Dissertation Award 2016

Ahti Salo (Finland) - Chair	Karl Schmedders (Switzerland)
Richard Hartl (Austria)	Emilio Carrizosa (Spain)
Bernardo Almada-Lobo (Portugal)	

When and Where?

- Three finalists will present their work at a special session during the conference (**Tuesday, July 5, 2016: 10:30-12:00; Building CW, 1st floor, Room 123**).

  The EURO Doctoral Dissertation Award 2016 will be awarded at the closing session (Wednesday, July 6, 2016: 16:00-17:45; Building CW, ground floor, Aula).

Finalists of the EURO Doctoral Dissertation Award 2016

Ruth Domínquez Martin: Planning and Operations in Fully Renewable Electric Energy Systems

Raca Todosijević: Theoretical and Practical Contributions on Scatter Search, Variable Neighbourhood Search and Matheuristics for 0-1 Mixed Integer Programs

Jørgen Thorlund Haahr: Reactive Robustness and Integrated Approaches for Railway Optimization Problems

Most Recent Laureates

2015: Joachim Arts (The Netherlands)	2012: Carolina Osorio (Switzerland)
2013: Christian Raack (Germany)	2010: Claudia D'Ambrosio (Italy)

EURO Excellence in Practice Award (EEPA 2016)

The EURO Excellence in Practice Award, sponsored by IBM, is for the submission and presentation describing **an application of Operational Research in practice**. The criteria for the evaluation of the papers are: scientific quality, relevance to Operational Research, originality in methodology, implementations and/or field of application, a real impact on practice, and appreciation by the organisation involved with the application.

Jury of the EURO Excellence in Practice Award 2016

Ton G. de Kok (The Netherlands) - Chair	Marco Laumanns (Switzerland)
Ulrich Dorndorf (Germany)	Markus Bohlin (Sweden)
Erik Demeulemeester (Belgium)	

When and Where?

- Six finalists will present their work at special sessions during the conference (**Monday, July 4, 2016: 12:30-14:00** and **14:30-16:00; Building CW, 1st floor, Room 123**).

  The EURO Excellence in Practice Award 2016 will be awarded at the closing session (Wednesday, July 6, 2016: 16:00-17:45; Building CW, ground floor, Aula).

Finalists of the EURO Excellence in Practice Award 2016

Kerem Akartunali, Euan Barlow, Matthew Revie, Diclehan Tezcaner-Öztürk, Evangelos Boulougouris, Sandy Day: A Novel Framework of Simulation and Optimisation for Offshore Wind Farm Installation Logistics at SSE and SPR

Christian Artigues, Emmanuel Hébrard, Pierre Lopez, Gilles Simonin: Scheduling Scientific Experiments for Comet Exploration on the Rosetta/Philae Mission

Andreas Fügener, Jens O. Brunner, Armin Podtschaske: Duty and Workstation Rostering Considering Preferences and Fairness: A Case Study at a Department of Anaesthesiology

Thorsten Koch, Benjamin Hiller, Marc E. Pfetsch, Lars Schewe: Evaluating Gas Network Capacities

Tobias Harks, Felix G. König, Jannik Matuschke, Alexander T. Richter, Jens Schulz: An Integrated Approach to Tactical Transportation Planning

Karin Thörnblad: Using Mathematical Optimization for Scheduling Heat Treatment Production

Most Recent Laureates

2015: Jesse O'Hanley

2013: Andreas Brieden, Steffen Borgwardt, Peter Gritzmann

2012: Mikael Rönnqvist, Patrik Flisberg, Mikael Frisk

2010: Pinar Keskinocak, Faramroze Engineer, Larry Pickering

ROADEF/EURO Challenge 2016

The French Operational Research and Decision Support Society (ROADEF) has organized jointly with the European Operational Research Society (EURO) the ROADEF/EURO challenge 2016 dedicated to inventory routing problem in collaboration with Air Liquide. It started last year in 2015 during the EURO conference in Glasgow.

The goal of this challenge has multiple aspects. First, it allows some of our industrial partners to follow recent developments in the fields of Operations Research and Decision Analysis. Second, through the **junior category** young researchers have the opportunity to face up to a complex industrial optimization problem. Third, through the **senior category**, this challenge allows qualified researchers to demonstrate their knowledge and share their know-how and expertise on the practical problems. Moreover, a scientific prize dedicated to qualitative submissions is proposed.

When and Where?

► The finalists will present their work at special sessions during the conference (**Monday, July 4, 2016 and Tuesday, July 5, 2016: 08:30-10:00; Building CW, 1st floor, Room 123**).

Awards related conference sessions at a glance

	Sunday, July 3	Monday, July 4	Tuesday, July 5	Wednesday, July 6
Morning A		MA 08:30-10:00 **ROADEF/EURO** (CW, 123)	TA 08:30-10:00 **ROADEF/EURO** (CW, 123)	WA 08:30-10:00
Morning B		MB 10:30-12:00 **EJOR** (CW, 1) **Memorial session** (CW, 123)	TB 10:30-12:00 **EDDA** (CW, 123)	WB 10:30-12:00
Midday C		MC 12:30-14:00 **EEPA 1** (CW, 123) **EthOR** (CW, 1)	TC 12:30-14:00	WC 12:30-14:00
Afternoon D		MD 14:30-16:00 **EEPA 2** (CW, 123)	TD 14:30-16:00 **MAI Roundtable** (CW, 123)	WD 14:30-15:30
Afternoon E	SE 16:30-18:00 **Opening Session** **EGM, EDSM** (CW, Aula)	ME 16:30-17:30	TE 17:30-18:30	WE 16:00-17:45 **Closing Session** **EDDA, EEPA, EABEP, ROADEF** (CW, Aula)

EURO Awards

EGM: EURO Gold Medal

EEPA: EURO Excellence in Practice Award

EDSM: EURO Distinguished Service Medal

EABEP: EURO Award for the Best EJOR Paper

EDDA: EURO Doctoral Dissertation Award

Other Prizes

ROADEF/EURO Challenge Prizes

EthOR: Ethics in OR Award

► MAP OF EXHIBITION AREA

Exhibition Area

Publishers and Operational Research related software companies will be exhibiting in the exhibition area. It is situated within the ground floor of Building CW, which is the central venue of the EURO 2016 conference. The area will be open throughout the duration of conference.

► Opening times of exhibition area:

► Sunday, July 3, 2016: 12:00 - 20:00

► Monday, July 4, 2016: 08:00 - 18:00

► Tuesday, July 5, 2016: 08:00 - 16:30

► Wednesday, July 6, 2016: 08:00 - 18:00

Exhibition Plan

EY

website: ey.com/pl

EY is a global leader in assurance, tax, transaction and advisory services. The insights and quality services we deliver help build trust and confidence in the capital markets and in economies the world over. We develop outstanding leaders who team to deliver on our promises to all of our stakeholders. In so doing, we play a critical role in building a better working world for our people, for our clients and for our communities.

At EY's IT Advisory Services we focus on your challenges to help deliver improved business performance by addressing the IT and business agenda together. We work directly with CIOs and others to create a more effective IT organization. This allows IT to drive process efficiencies throughout the organization and better support and deliver transformational business change. We also provide a wide range of cybersecurity services combining our experience in performance improvement with the technical and engineering skills of the best talent on the market.

For more information about our organization, please visit ey.com/pl.

► **EY** — Building CW, ground floor, stand 13

Amazon

website: www.amazon.com, www.amazon.jobs

Innovating to give customers what they want, when they want it

Fulfillment is at the heart of the Amazon experience. We deliver millions of products to hundreds of countries worldwide. Our teams possess a wide range of skills and expertise, from business analysis and inventory management to engineering. With more than 120 Fulfillment Centers worldwide and 29 in Europe, Amazon Fulfillment is growing at a pace that requires the best and brightest talent to be involved in our company, so with their help we can continue to make history.

Amazon’s evolution has been driven by innovation. It’s part of our DNA. We are doing things every day that have never been done before – providing a huge selection of products while continuing to fulfill orders quickly. We accomplish this by using ingenuity and simplicity to solve complex problems.

Millions of people count on Amazon to provide them with their favourite products – our Software Engineers and Research Scientists help make that possible. We use machine learning, data analytics, and complex simulations to ensure Amazon has the products customers want and that we can deliver them quickly. We employ many of the tried-and-true technologies that are taught in academia and used by other companies; however, due to the increasing scale of our business and the evolving nature of online commerce, we are constantly innovating in order to build the next generation of solutions that will define the future of our industry.

We create. We build. We take ownership of what we do – whether we’re developing a new technology in-house or launching a new Fulfillment Center. Together, we’re constantly creating ideas, services and products that make life easier for Amazon’s millions of customers. Regardless of role, each and every Amazonian is completely focused on working hard, having fun and making history.

We strive to hire the brightest minds and to provide a range of career opportunities for professionals and academics who have diverse academic backgrounds.

► **Amazon** — Building CW, ground floor, stand 2

Elsevier

website: elsevier.com *type*: publisher

Elsevier publishes leading journals in OR/MS and Decision Sciences, including European Journal of Operational Research, Computers & Operations Research, and International Journal of Production Economics. Elsevier journals occupy 8 of the Top 10 Impact Factor positions in the Operations Research & Management Science category of Thomson Reuters' Science Citation Index.

Come to the Elsevier booth, where our representatives will be happy to discuss your personal publishing options across our range of journals. You can also sign up to receive feedback on your research from top Editors during the conference. To find out more, and get the most out of your time at EURO 2016, visit elsevier.com/exhibitions-update/EUROConf.

► **Elsevier** Building CW, ground floor, stand 11

FICO

website: fico.com *type*: analytics software and tools

FICO (NYSE: FICO) is a leading analytics software company, helping businesses in 80+ countries make better decisions that drive higher levels of growth, profitability and customer satisfaction. The company's groundbreaking use of Big Data and mathematical algorithms to predict consumer behavior has transformed entire industries. FICO provides analytics software and tools used across multiple industries to manage risk, fight fraud, build more profitable customer relationships, optimize operations and meet strict government regulations. Many of our products reach industry-wide adoption — such as the FICO® Score, the standard measure of consumer credit risk in the United States. FICO solutions leverage open-source standards and cloud computing to maximize flexibility, speed deployment and reduce costs. The company also helps millions of people manage their personal credit health. FICO: Make every decision count™.

► **FICO** Building CW, ground floor, stand 10

► BRONZE SPONSORS

Springer Nature

website: www.springernature.com *type*: publisher
tel: +49.(0)6221.487-0 fax: +49.(0)6221.487-366

Springer Nature is one of the world's leading global research, educational and professional publishers, home to an array of respected and trusted brands providing quality content through a range of innovative products and services.

Springer Nature is the world's largest academic book publisher, publisher of the world's most influential journals and a pioneer in the field of open research. The company numbers almost 13,000 staff in over 50 countries and has a turnover of approximately EUR 1.5 billion. Springer Nature was formed in 2015 through the merger of Nature Publishing Group, Palgrave Macmillan, Macmillan Education and Springer Science+Business Media.

► **Springer Nature** Building CW, ground floor, stand 3

Palgrave Macmillan

website: palgrave.com *type*: publisher

Palgrave Macmillan is a global academic publisher for scholarship, research and professional learning. We publish monographs, journals, reference works and professional titles, online and in print. With a focus on humanities and social sciences, Palgrave Macmillan offers authors and readers the very best in academic content whilst also supporting the community with innovative new formats and tools.

► **Palgrave Macmillan** Building CW, ground floor, stand 4

Taylor & Francis

website: taylorandfrancis.com *type*: publisher

Taylor & Francis boasts a first-class journal portfolio publishing Operational Research and Management Science articles as well as a wide range of scholarship from related disciplines. Our journals are edited by some of the most prominent academics in the world and offer a variety of accommodating options for our authors. Our high impact journals include International Journal of Production Research and International Journal of Management Science and Engineering Management, now in its tenth year.

► **Taylor & Francis** Building CW, ground floor, stand 9

Wiley

website: eu.wiley.com *type*: publisher

Wiley is the leading publisher in the fields of Business and Management, providing access to quality content written by the field's foremost thinkers.

Wiley takes the lead among publishers with our unparalleled experience in meeting the many and diverse needs across the entire global Business and Management community. Students, academics, teachers and professionals are all supported across the span of their careers, and across the diversity of sub disciplines in the field. We provide this support through a variety of media, including books, textbooks, course offerings, major reference works and our unrivalled journals program with 6.3 million downloads last year alone. Our broad portfolio encompasses strategy, leadership, entrepreneurship, supply chain management, organizational behavior, ethics, human resources, and more.

► **Wiley** Building CW, ground floor, stand 7

Research in Germany - Land of Ideas

website: www.research-in-germany.org/en www.daad.de/en/

"Research in Germany" is an international research marketing campaign, funded by the German Federal Ministry of Education and Research (BMBF), which seeks to strengthen and expand R&D collaboration between Germany and international partners. The organisations involved in the campaign, e.g. the Alexander von Humboldt Foundation, the German Academic Exchange Service (DAAD), the German Research Foundation (DFG), the Fraunhofer-Gesellschaft and the BMBF International Bureau, organise joint communication activities and events which present German innovation and research in key international markets.

The DAAD is the world's largest funding organisation for the international exchange of students and researchers. It grants scholarships, creates structures that promote internationalisation of higher education and offers expertise for academic international exchange. The Warsaw DAAD office has been supporting the Polish-German academic cooperation since 1997.

► **Research in Germany, DAAD** Building CW, ground floor, stand 8

AMPL

website: ampl.com *type*: software

AMPL's modeling language and system give you an exceptionally powerful and natural tool for developing and deploying the complex optimization models that arise in diverse business applications. AMPL lets you formulate problems the way you think of them, while providing access to the advanced algorithmic alternatives that you need to find good solutions fast. It features an integrated scripting language for automating analyses and building iterative optimization schemes; access to spreadsheet and database files; and application programming interfaces for embedding within larger systems. AMPL works with more than 30 powerful optimization engines including all of the most widely used large-scale solvers.

► **AMPL** Building CW, ground floor, stand 6

Poznań Supercomputing and Networking Center (PSNC)

website: pcss.pl *type*: supercomuting and networking center

Poznań Supercomputing and Networking Center (PSNC/PCSS), affiliated to the Institute of Bioorganic Chemistry of the Polish Academy of Sciences, was founded in 1993 to build and develop computer infrastructure for science and education in Poznań and in Poland. This infrastructure includes metropolitan network POZMAN, High Performance Computing (HPC) Center, as well as the national broadband network PIONIER, providing the Internet and network services on international, domestic and local levels. With the development of the computer infrastructure, PSNC has been managing research and development within the field of new generation computer networks, high performance – parallel and distributed – computations and archive systems, cloud computing and grid technologies. PSNC is working also on the themes of green ICT, future Internet technologies & ideas, network safety, innovative applications, web portals, as well as creating, storing and managing digital content. Since PSNC is a public entity, within its sphere of interests is the development of solutions for e-government, education, medicine, new media & communications.

► PSNC Building CW, ground floor, stand 12

Foundations of Computing and Decision Sciences (FCDS)

website: fcds.cs.put.poznan.pl *type*: journal

e-mail: fcds@cs.put.poznan.pl *editor-in-chief*: Jerzy Stefanowski

electronic edition available at De Gruyter Online: www.degruyter.com/view/j/fcds

Foundations of Computing and Decision Sciences (until 1990 “Foundations of Control Engineering”) is a quarterly peer-reviewed international journal published by Poznań University of Technology since 1975. One of the specific features of the Journal is its focus on the links between Computing (understood in the sense defined in the report of the ACM Task Force on the Core of Computer Science chaired by Peter J. Denning: Computing as a Discipline, CACM, Vol. 32, No. 1, 1989) and broadly understood Decision Sciences.

► FCDS Building CW, ground floor, stand 5

IFORS 2017 (Quebec, Canada)

website: ifors2017.ca July 17 - 21, 2017

21st Conference of the International Federation of Operational Research Societies. Quebec City, the capital of the province of Quebec, Canada, is delighted to host the IFORS 2017 conference under the theme of “OR/Analytics for a better world”. The conference will be held between 17-21 July 2017.

Quebec City is a dynamic and modern French-speaking North American city with a unique “Old France” charm. The program committee chaired by M. Grazia Speranza is committed to preparing a high quality scientific program with diverse participants sharing their vision, knowledge and experience of operational research and analytics. The venue is the Quebec International Convention Center, conveniently located in the heart of Quebec City and one of Canada’s top convention destinations with renowned hospitality and exceptional service.

We thereby invite you to participate to IFORS 2017 and be part of the great IFORS community by organizing a session, giving a talk, or meeting new and old friends and colleagues!

► IFORS 2017 (Quebec, Canada) Building CW, ground floor, stand 1

Welcome Reception - Get Together Party

► **Sunday, July 3, 2016, 18:00 - late**
After Opening Session

Around **Building CW** (Lecture Centre)
Address: Piotrowo 2, 60-965 Poznań

Having collected your conference bag and attended the opening session, meet your friends and colleagues at the Get Together Party at Poznan University of Technology! On Sunday evening taste a typical Polish barbecue accompanied by lots of world-class Polish beer.

Farewell Party

► **Wednesday, July 6, 2016, starting 18:00**
After Closing Session

Around **Building CW** (Lecture Centre)
Address: Piotrowo 2, 60-965 Poznań

After the Closing Session enjoy a relaxing evening with Polish food and drinks. Let us surprise you with the details...

Snack & Beer at Old Market Square (Stary Rynek)

► Monday, July 4, 2016, evening **Restaurants in the proximity of Old Market Square**

Spend a nice evening at the charming Old Market Square! In the conference bag you will receive a coupon for a snack & beer that you can realize at July 4, 2016 (Monday), in one of the eight restaurants in the close proximity of the Old Market Square. The coupon lets you order a beer and an indicated snack. Note that all additional orders will be charged separately according to the price list of the given restaurant.

1	**Room**: Stary Rynek 80/82 (www.roompoznan.pl)	Beer: Żywiec 0.3l. Snack: tartar steak on toasts.
2	**Bordo Restaurant & Cafe**: Żydowska 28 (www.facebook.com/CafeBordo)	Beer: Miłosław Pilzner, Fortuna Czarne, Książęce 0.5l. Snack: gravlax (raw salmon, cured in salt, sugar, and dill)
3	**Pekin Chinese Restaurant**: 23 lutego 33 www.pekin.pl	Beer: Tyskie Gronie, Lech Pils 0.5l Snack: spring rolls with meat filling (3 pieces)
4	**Bistro La Cocotte Restaurant**: Murna 3a www.facebook.com/lacocotte.poznan	Beer: lwowskie. Snack: carrot chips and crispy gralic-basil bread with salsa.
5	**Czerwona Papryka**: Stary Rynek 49 www.czerwonapapryka.com.pl	Beer: Tyskie 0.3l (or wine 125ml or juice 0.2l) Snack: olives with anchovies or garlic; grilled plumbs with bacon; patatas bravas, mushrooms with garlic and parsley
6	**Bazar 1838**: Paderewskiego 8 www.bazar1838.pl	Beer: Żywiec 0.33l Snack: focaccia with tomatoes and olive tapenade
7	**Chłopskie Jadło**: Fredry 12 www.chlopskiejadlo.pl/pl/poznan-fredry/	Beer: Tyskie Gronie 0.5l Snack: appetizer (360g)
8	**Sphinx**: Św. Marcin 66/72 www.sphinx.pl/restauracja-70/	Beer: Tyskie Gronie 0.5l Snack: onion rings (200g)

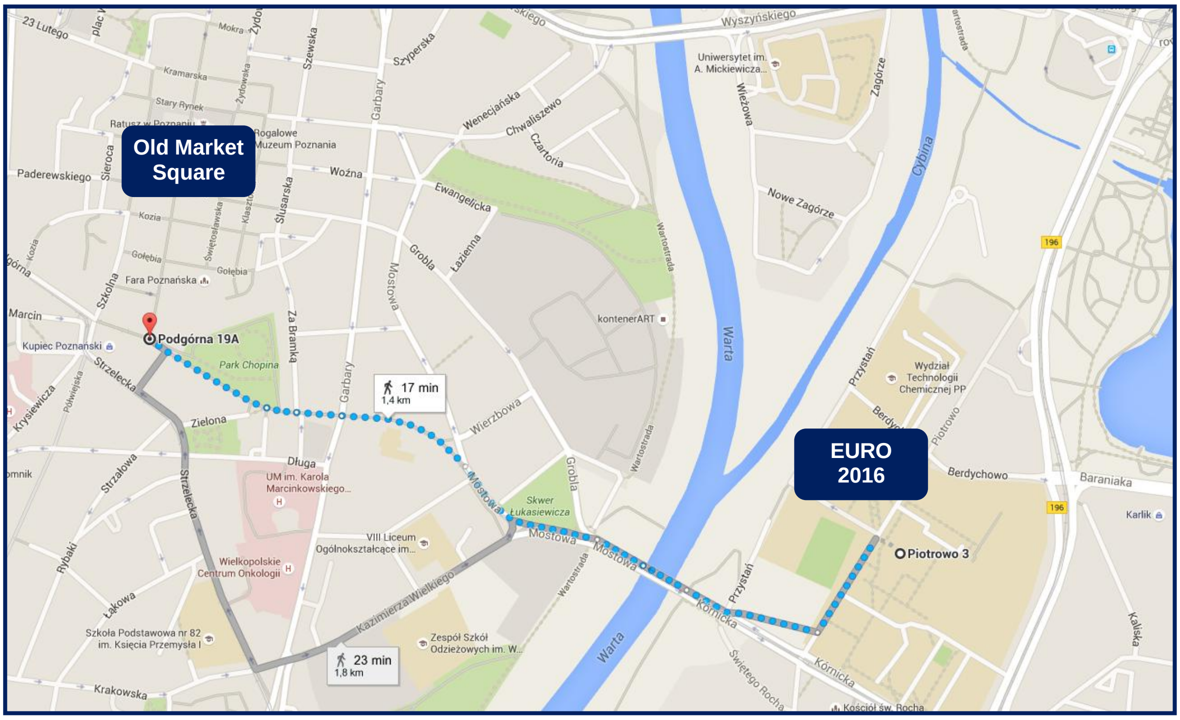
Old Market Square (Stary Rynek)

The square was originally laid out in around 1253. The chief building of the square is the Old Town Hall (Ratusz). Other central buildings include a row of colourful merchants' houses, the old town weighing house, and the guardhouse. Other features of the square are a punishment post (pręgierz) and beautiful fountains. On each side of the square you can see rows of former tenement houses, many of which are now used as restaurants, cafés and pubs.

How to reach Old Market Square from EURO 2016 venue?

Have a short walk! Poznan University of Technology is located very close to the Old Market Square and it takes just several minutes to get there on foot.

Turn right onto Kórnicka. Continue onto Świętego Rocha bridge and Mostowa. Slight left onto Dowbora-Muśnickiego. Continue onto Bernardyński Square, Zielona, and Podgórna. From there you will be already able to see the OMS. Turn right onto Wrocławska, and you are there!



Alternatively, take a tram. Go to Politechnika tram stop, take a tram (line 5, 13, or 16), heading to Wrocławska. It will be the third stop on your way (3 minutes in a tram).

Conference Dinner

► **Tuesday, July 5, 2016, 19:00 - late**	Poznań International Fair Międzynarodowe Targi Poznańskie **Address**: Głogowska 10, 60-101 Poznań

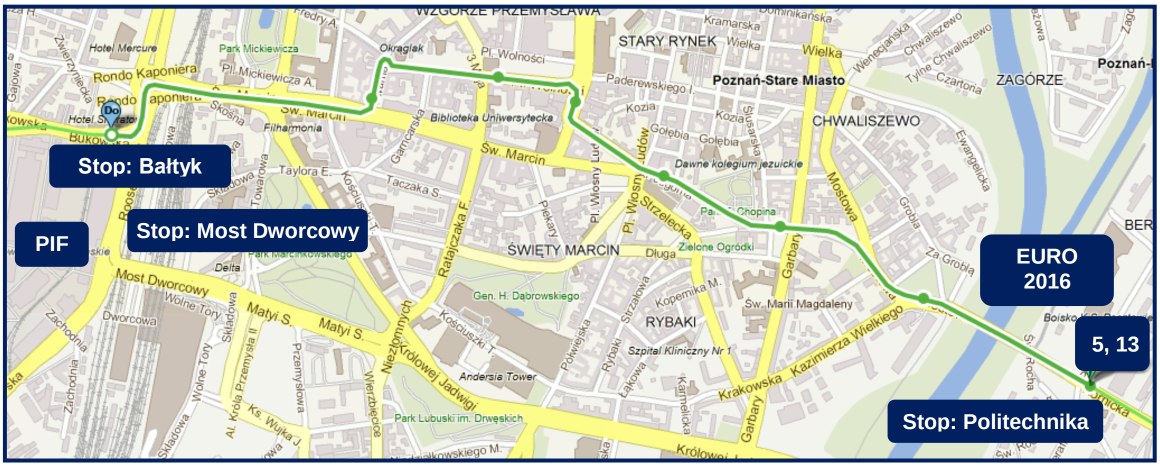
The EURO 2016 formal conference dinner takes place on the evening of Tuesday 5 July. Guests will enjoy welcome drinks on arrival (served at 19:00) followed by a short musical performance and Polish-themed locally sourced three course meal with after dinner coffee.

Reminder: Right before the conference dinner (17:30 - 18:30) at the same venue of Poznań International Fair, you are invited to attend the central plenary lecture of Robert Aumann (2005 Nobel Memorial Prize in Economic Sciences).

How to reach Poznań International Fair from EURO 2016 venue?

Take a tram! There are two routes you may follow.

Go to Politechnika stop, take a tram (line 5 or 13), heading to Bałtyk. The tram will pass close to the Old Market Square, a symbol of Poznań's modernism - Okrąglak (The Round House), Kaiser's Castle, and June 1956 Events Monument. After about 12 minutes in a tram you will be at the Bałtyk stop. Take a short work walk to the entrance of Poznań International Fair (Międzynarodowe Targi Poznańskie). ***Consult this option with the JakDojade application as its frequently changed.***



Alternatively, have a short walk to Serafitek stop, take a tram (line 6 or 18), heading to Most Dworcowy. After about 9 minutes in a tram you will be at the entrance of Poznań International Fair!

► GENERAL INFORMATION

Time Zone

Polish summer time (GMT+2hrs) starts and ends on the last Sundays of March and October (1 hour ahead of British time).

Reach Poland by Telephone

- ► Country code: 00 48 (+48)
- ► Poznań area code: 00 48 61 (+48 61)

Electricity

Electricity in Poland is 230V, 50Hz AC. Plug sockets are round with two round-pin sockets. Therefore if you are coming from, e.g., the UK, Ireland, or USA you will be needing a plug converter.

Language

Poland's official language is Polish. English can be spoken in most service points, hotels, restaurants and at city information desks. The official language of EURO 2016 is English. No simultaneous translation will be provided.

Internet

Internet access is typically free and widely available in Poland, with practically every café and restaurant offering wi-fi to customers with laptops and smartphones. In the area of Old Marget Square, Kolegiacki Square and Freedom Square you can get Poznań Internet Free. At the conference venue WiFi access is provided with eduroam and PUT-events-WiFi network.

Useful phone numbers

112 - emergency (all services)
999 - ambulance
998 - fire brigade
997 - police
986 - municipal wardens (straż miejska)

Conference participants are kindly requested to keep their mobile phones switched off in the rooms during the scientific sessions.

Smoking

Smoking is banned in government offices, schools, museums, theatres, airports, railway and bus stations and in public transport, stadiums, hospitals and playgrounds. It is also banned in one-room restaurants and bars. Failure to comply may result in fine. Smoking is allowed in restaurants, pubs and cafes with specially designated smoking rooms

Currency

Poland's legal tender is the Polish zloty (PLN), which is divided into 100 groszy. USD 1 = ca. 3.93 PLN; €1 = ca. 4.40 PLN (rates as of May 20, 2016) Polish zloty bank notes are issued in denominations of 10, 20, 50, 100 and 200 zlotys, while coins are for 1, 2, 5 zlotys and 1, 2, 5, 10, 20 and 50 groszy. The currency may be converted at exchange points, in banks and some hotels.

- ► **Currency exchange offices** (Kantor) are easy to find in Poznań, but as with any international destination, it's imperative to check the rates. The general rule is you should avoid changing all your money at city entry points, particularly at the airport where the rates are high, and at the hotels.

ATMs

Major credits cards are accepted in most hotels, restaurants, and shops. It is common to use contactless credit cards.

- ► **Three ATMs** (in Polish: bankomat) **are available at the conference venue** (two inside conference buildings (Building CW, ground floor and Building WE, ground floor). More ATMs are available in the Malta Shopping Centre (Galeria Malta) which is located 500 metres away from the main conference venue in the direction of Lake Malta. ATMs can be also easily found at the airport and at the main railway station.

Larger shopping centres

Galeria Malta	**Stary Browar (Old Brewery)**	**Poznan City Center**
Address: Maltańska 1	Address: Półwiejska 42	Address: Matyi 2
www.galeriamalta.pl	www.starybrowar5050.com	www.poznancitycenter.pl
Mon-Sat: 10-22 / Sun 10-20	Mon-Sat: 9-21 / Sun 10-20	Mon-Sun 9-21

Public Transport in Poznań

Poznań is crisscrossed by several tram routes (one at night) and bus lines (twenty at night). During the day these run from around 05:00 to 23:00 with trams and buses running approximately every 10-15 minutes. With a timetable of services both day and night and divided into week day, Saturday or Sunday and Holiday services, public transport is the most efficient means of getting around the city. Timetables can be viewed by the *JakDojade* application: http://poznan.jakdojade.pl.

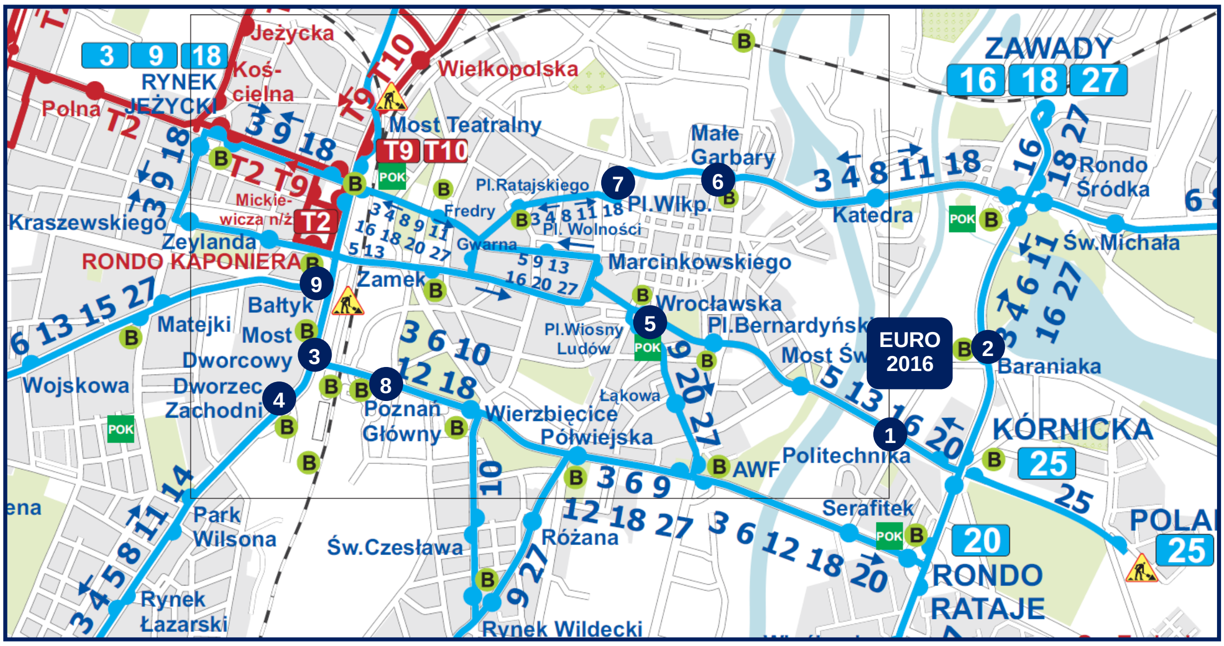
JakDojade Application: http://poznan.jakdojade.pl

You can use *JakDojade* on both desktop computer and mobile devices. We recommend using *JakDojade* whenever planning your journey with public transportation.

Tickets

During the registration to the conference **you will receive your badge which will serve as a 4-day ticket for public transport** in Poznań. If you need to use public transport before the registration or you are planning to stay in Poznań after the conference, bear in mind that tickets are timed. The cheapest option is **3 PLN for 10 minutes** - which might get you 3 or 4 stops. A **40-min ticket for 4.60 PLN** is the safer bet. Single Proximity Cards (Papierowa Karta Jednorazowa) must be validated in the reader at the entrance to the vehicle. If you plan on travelling often, you may want to consider a 24h or 48h ticket.

Tickets are bought from **automated machines found on most (specially marked) buses and trams as well as at most transport stops** (marked with B at the map below).



To travel around the city with public transportation, we recommend using trams

The **tram stops** which are closest to the EURO 2016 **conference venue** (Poznan University of Technology, Campus Piotrowo) are **Politechnika (1)** (trams 5, 13, 16, and 20) and **Baraniaka (2)** (trams 3, 4, 6, 11, 16, and 27).

The stops close to **Poznań International Fair**, which is the venue for the gala dinner and plenary lecture by Robert Aumann, are **Most Dworcowy (3)**, **Dworzec Zachodni (4), and Bałtyk (9).**

The stops closest to the **Old Market Square** are **Wrocławska (5)**, **Małe Garbary (6)** and **Plac Wielkopolski (7)**. For the **Railway Station**, go to **Poznań Główny (8)** or **Dworzec Zachodni (4)**.

► MOVING AROUND THE CITY

Getting from/to the Airport by Public Transport

There are bus stops right in front of the passenger terminal and in its close vicinity:

- Express Line L is connecting the airport with the main train station (journey time about 20 minutes; distance 6km);
- a regular bus line 59 which starts and finishes at Kaponiera Roundabout (directly in the city centre, close to the main train station; journey time around 30 minutes).

Public transport tickets are available at the newspaper stands both in the arrival hall (in T3 terminal) and in the departure hall (in T2 terminal), as well as in the ticket booth located at the bus stop in front of the departure hall. In all L busses and in some units of line 59, ticket vending machines are available. Stickers at the bus entrance inform about a possibility of an on-board ticket purchase.

TAXI

The cheapest, safest and most comfortable way to order a taxi is to use one of taxi corporations. This guarantees honest prices and short waiting periods. All corporations offer free-of-charge arrival at the customer`s location.

Fares

Start-up fare 6.00 - 7.00 PLN

Normal Tariff (per 1km) 2.00 - 2.50 PLN

Sunday/Night Tariff (per 1km) 3.50 - 5.00 PLN

TAXI Corporations

RADIO TAXI 519 ph. +48 61 8 519 519	RADIO TAXI STOP ph.+48 61 8 222 333	MULTI-TAXI ph. +48 61 96 66	RADIO TAXI LUX ph. +48 61 96 62
RADIO TAXI ph.+48 61 96 22	EXPRESS TAXI ph.+48 61 96 24	EB TAXI ph. +48 61 8 222 222	HALLO TAXI ph. +48 61 821 62 16

Destinations

To get with taxi to the EURO 2016 **conference venue**, indicate "**Piotrowo 2**" Street (Politechnika Poznańska; Poznan University of Technology) as your destination.

To get with taxi to **Poznań International Fair**, which is the venue for the gala dinner and central plenary lecture by Robert Aumann, indicate "**Głogowska 10**" Street (Międzynarodowe Targi Poznańskie) as your destination.

BIKE RENTING/SHARING SYSTEM: NextBike

Poznań offers a self-service city bikes rental system. **One of the bike rental stations is located right at the entrance to the EURO 2016 conference venue.**

How it works?

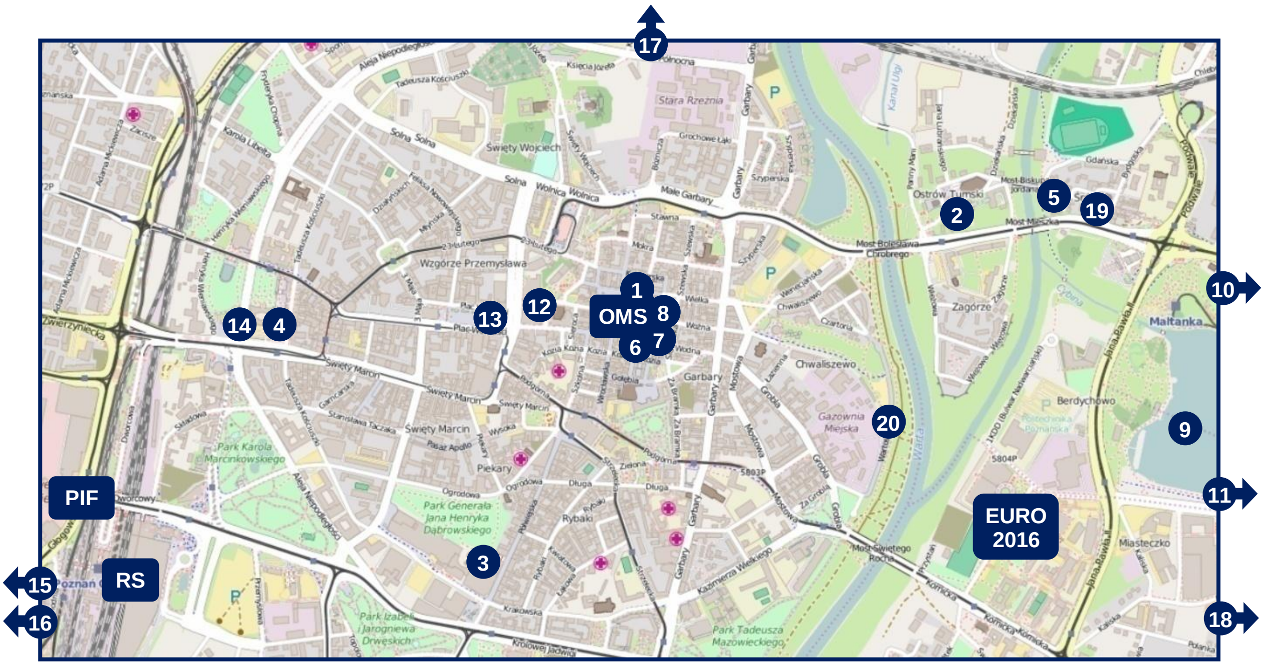
Join in: register at **https://nextbike.pl/en/cities/poznanski-rower-miejski/**, fill in the required data, accept the rules and pay the min.10 PLN of the initial fee. You may use the city bikes on 24/7 basis.

Rent: go to the terminal, press “Rent”, provide your mobile phone number and PIN and follow the instructions on the screen.

Return the bicycle: you do not have to go to the terminal. Simply place the bicycle in the electrical lock.

Highlights of Poznań

Poznań is an extraordinary city - open and dynamic, filled with unique places and attractions. Here are a few tips which will allow you to enjoy your stay to the fullest - the 20 highlights of Poznań.



PIF Poznań International Fair Międzynarodowe Targi Poznańskie

RS Railway Station

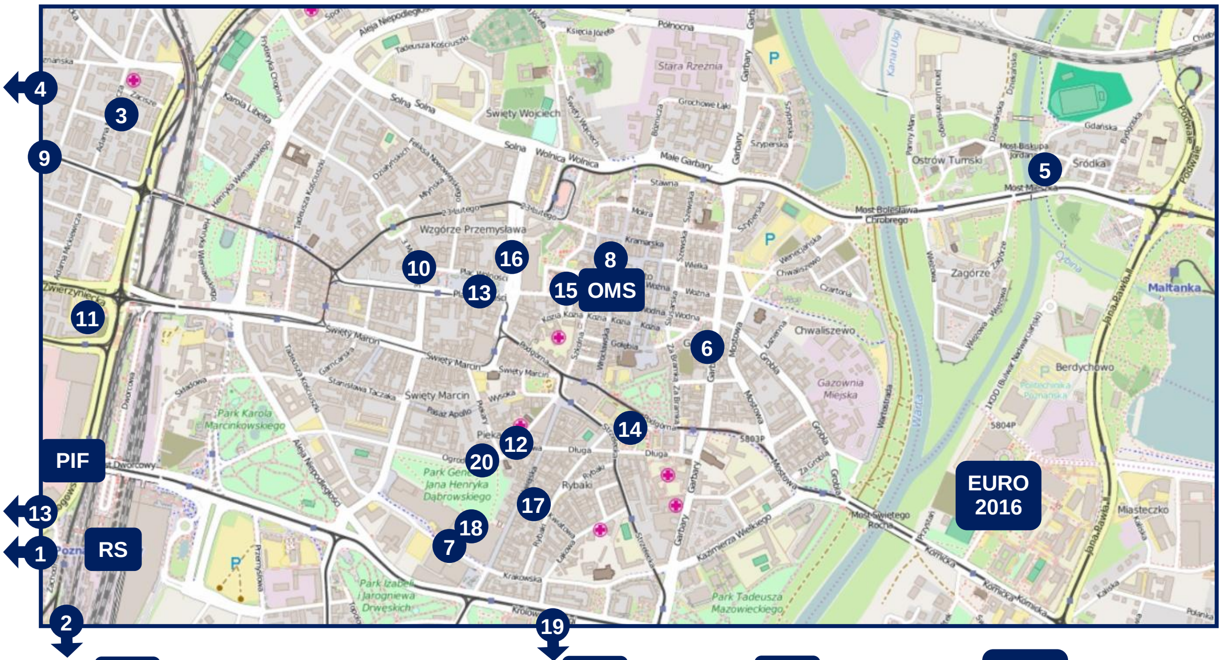
OMS Old Market Square

EURO 2016 Conference venue

1. **City Hall**: the pearl of the Renaissance from the 16th century. Every day at high noon two billy goats appear in the tower, butting their heads 12 times.
2. **Cathedral**: the first Polish cathedral, built in the 10th century. Golden chapel contains the sarcophagi and statues of first Polish rulers.
3. **The Old Brewery**: multiple award-winning trade, art, culture, and business center. Former Hugger's brewery.
4. **Kaiser's Castle**: the huge neo-Romanesque building was constructed for German Emperor William II. Now the castle serves as a cultural centre "Zamek".
5. **Porta Posnania ICHOT** attracts its visitors with a multimedia display, presenting the fascinating history of Cathedral Island.
6. **Parish Church of St Stanislaus**: one of the most monumental Baroque churches in Poland.
7. **Górka Palace**: one of the most wonderful Renaissance baronial mansions in Poland, with a beautifal sandstone portal and an inner courtyard.
8. **Poznan Croissant Museum**: you can see the original shows which reveal the secrets of Saint Martin Croissants and other Poznan's prides.
9. **Lake Malta** has one of the oldest man-made rowing venues in Europe; a beautiful walking area.
10. **Malta Thermal Baths** Sport and Recreational Centre is a perfect place to rest and relax. Sport and recreational pools filled with thermal water.
11. **Malta Ski** Sport & Recreation Centre with a year-around artifical slope and Adrenaline alpine coaster.
12. **National Museum**: rich collections of paintings by famous Polish artists (Malczewski, Matejko, Wyspiański) and Poland's only Claude Monet.
13. **Freedom Square** with the classical building of Raczynski Library and a beautiful fountain in form of a sail.
14. **June 1956 Events Monument**: two crosses commemorating the 1956 protests and subsequent protests against the Communist political system.
15. **Poznań Palm House** in Wilson Park with 17 thousand plants of 700 species and subspecies from the warm and hot climates.
16. **INEA Stadium**: venue of UEFA EURO 2012, holds up to 43,000 viewers.
17. **Citadel Park**: Poznań's favourite relax location with an open-air excibition of Magdalena Abakanowicz sculptures. Have a stroll around the park!
18. **LECH Visitors Centre** is a beer lovers' paradise and the only place where you can find out about the process of producing LECH beer.
19. **Beautiful 3D Wall Mural** painted to remember historical Środka market district (must see!).
20. **KontenerART** is a mobile centre of culture and art. Come and chill with friends by the Warta river and City Beach.

Poznań's Best Restaurants

Poznań, thanks to its trade fair, academic and tourist traditions has taken good care of the palates of its guests from every corner of the planet. However, in the recent years, more and more restaurants have been focused on the presentation of our culinary Polish heritage. Below are some tips on the best restaurants in the city. Before the visit, please consult their opening times as in Poland the restaurants are not open till late as, e.g., in Southern Europe.



PIF Poznań International Fair / Międzynarodowe Targi Poznańskie

RS Railway Station

OMS Old Market Square

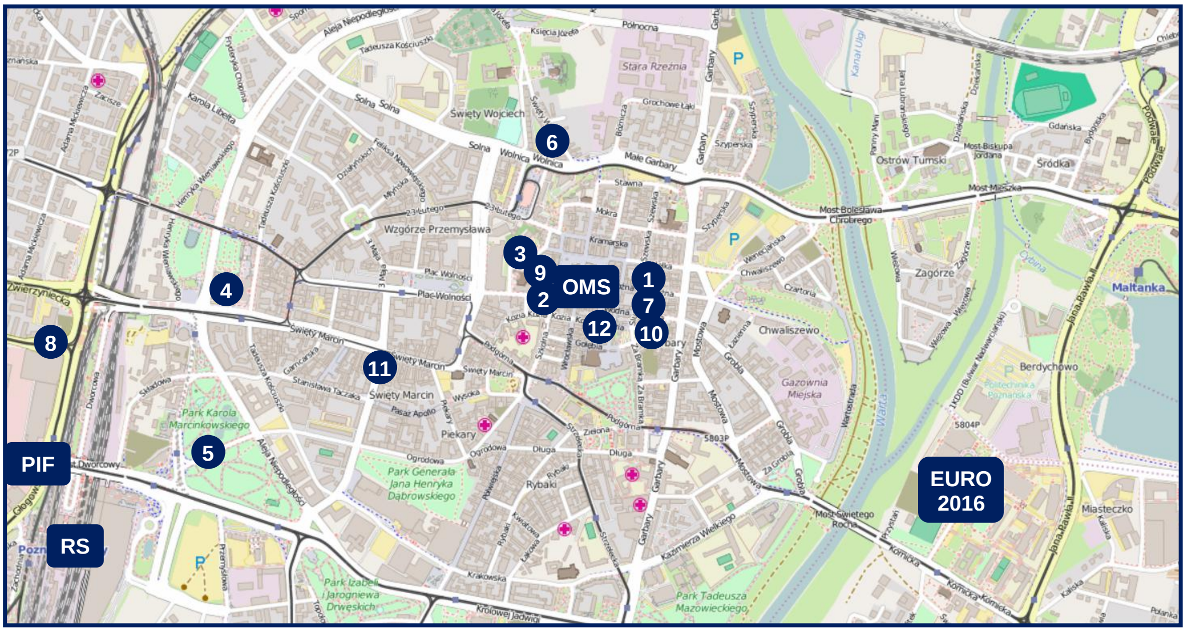
EURO 2016 Conference venue

1. **Cucina** (City Park): Wyspiańskiego 26A
   Chef draws inspiration mostly from Mediterranean cuisine, Oriental flavours and traditionally Polish hints.
2. **A nóż widelec**: Czechosłowacka 133
   It offers Polish cuisine with a designer touch. Chef succeeded at implementing an extremely brave project.
3. **Oskoma**: Mickiewicza 9A
   Polish tradition, quality produce, the creative freedom, a very young team and an award-winning chef.
4. **Zagroda Bamberska**: Kościelna 43
   It serves traditional Wielkopolska (Greater Poland) cuisine with a modern twist.
5. **Vine Bridge New Polish Cuisine**: Ostrówek 6
   It is Poland's smallest restaurant! The dishes served here are based entirely on local and regional produce.
6. **Dark Restaurant**: Garbary 48
   It is the first *restaurant* in Poland where everything takes place in complete darkness.
7. **Blow Up Hall 50/50**: Kościuszki 42
   The restaurant of the 5-star Blow Up Hall 50/50 Hotel is located in the central part of Old Brewery.
8. **Ratuszowa**: Stary Rynek 55
9. **D42**: Dąbrowskiego 42
10. **Papavero**: 3 maja 46
11. **Concordia Taste**: Zwierzyniecka 3
    Located in a newly renovated 19th century former printery turned Concordia Design Center.
12. **Muga**: Krysiewicza 5
    It appreciates good and refined cuisine. The guests are offered designer creations which include both seasonality and European trends.
13. **Enjoy Restaurant**: Reymonta 19
    Innovative trend of modern Polish cuisine, which is a guarantee of unusual culinary experiences.
14. **Papierówka**: Zielona 8
    It is a green escape in the middle of the city, where you can relish a light regional cuisine.
15. **Brovaria**: Stary Rynek 73-74
    It is a unique micro-brewery, an excellent restaurant and a romantic, three-star hotel.
16. **Warto nad Wartą**: Al. Marcinkowskiego 27a
    Its menu is based in Polish cuisine with a modern twist.
17. **Manekin**: Kwiatowa 3
    It is crepe/pancake heaven and offers all the usual options plus more maverick choices.
18. **Piano Bar Restaurant & Cafe**: Półwiejska 42
19. **SPOT.**: Dolna Wilda 87
20. **Figaro**: Ogrodowa 17

Beer in Poznań

Beer – a beverage most strongly embedded into European history and culinary tradition – is invariably associated with a sense of community and spending time together. The city's social life revolves around pubs, brasseries, and clubs. A multiplicity of brands and variants, and the brewers' impressive offer enable everyone to not only find their own group of friends, but also their own beer.

Connoisseurs in passionate pursuit of new flavours have their own meeting places. It is for them that original products from around the world is imported from around the world and served next to the local beer brands. Take a journey through Poznań's pubs, brasseries and clubs. Follow the beer trail and meet the fascinating people who create the unique atmosphere of this city.

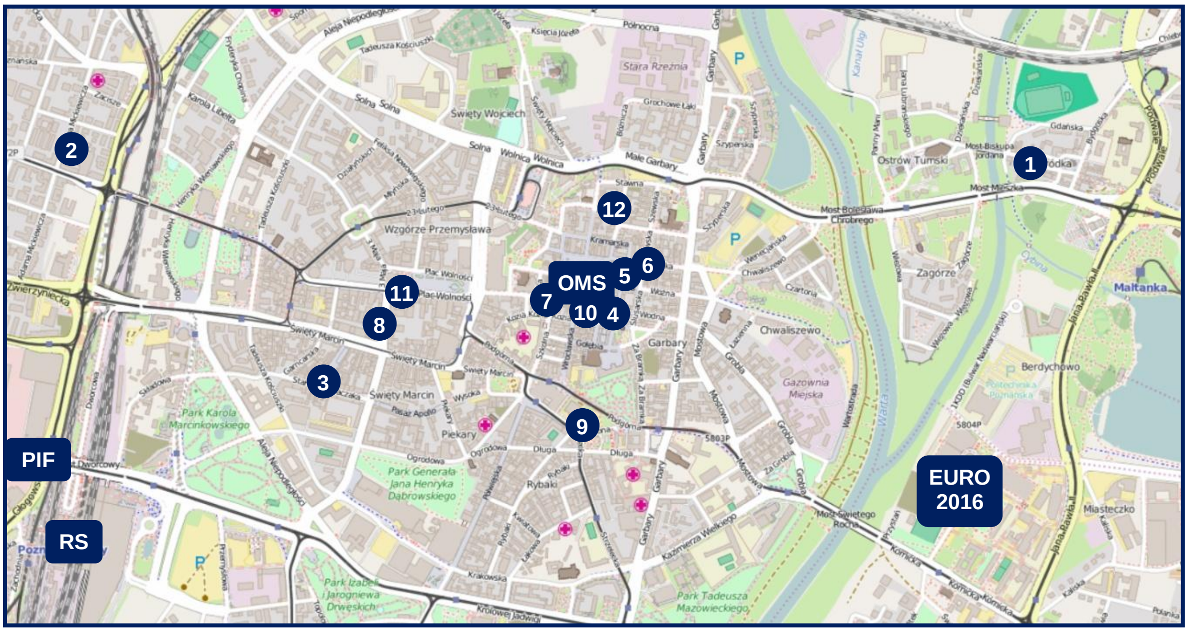


PIF Poznań International Fair Międzynarodowe Targi Poznańskie — **RS** Railway Station — **OMS** Old Market Square — **EURO 2016** Conference venue

1. **Basilium**: Woźna 21
   Over 150 brands from small Polish breweries.
2. **Brovaria**: Stary Rynek 73-74
   The only in-restaurant brewery in Poznań.
   The amber liquid is produced in 3 variants: wheat, honey, and pils.
3. **Dragon**: Zamkowa 3
   The locale serves a few draught and bottle beer sorts. Multilevel summer outdoor place.
4. **Dubliner Irish Pub**: Święty Marcin 80/82
   One of the few places serving Guinness and the Irish cider. Famous for the live music.
5. **Fort Colomb**: Powstańców Wielkopolskich
   One of the few remains of the inner fortifications ring of a powerful stronghold erected by the Prussians.
6. **Klub u Bazyla**: Święty Wojciech 28
   A true music club which pffer a few dozen kinds of beer.
7. **Kriek Belgian Pub & Cafe**: Wodna 23
   Belgian pub with around 170 beer sorts on offer.
8. **SomePlace Else** (Sheraton): Bukowska 3/9
   On the more price end of Poznań's watering holes, but it is woth it too.
9. **Warzelnia**: Stary Rynek 71
   One of the few places where you can try the famous Polish expert beer - Tyskie - from a tank.
10. **Za kulisami**: Wodna 24
    For the beer enthusiasts, there are at least 10 regional sorts and draught beer - dry and sweet.
11. **Ministerstwo Browaru**: Ratajczaka 34
    A Small pub with a few hundred sorts of both international and local beers.
12. **Piwiarnia Warka**: Świętosławska 12
    A pub serving one of the famous Polish pale, bottom-fermented lager beers - Warka.

"Słodkie" - coffee and cake

The tradition of “słodkie” (coffee and cake, served in the afternoon) is Poznań at its finest. “Słodkie” is a must; we have to go out for “słodkie”; “słodkie” is the appropriate suggestion to serve to unexpected afternoon visitors. What is interesting, it can sometimes be offered even prior to the main meal. Luckily, there is no need to spend hours slaving over a hot stove, preparing your own baked goods. What are the pros there for, if not to please your palates with a slice of lovely apple pie, or a mouth-watering cheesecake. Of course, “słodkie” would not be what it is without a nice cup of steaming coffee - especially one brewed professionally from carefully selected coffee beans.



PIF Poznań International Fair Międzynarodowe Targi Poznańskie **RS** Railway Station **OMS** Old Market Square **EURO 2016** Conference venue

1 **La Ruina**: Śródka 3
La Ruina is famous among the lovers of coffee and cheesecake. This tiny cafe is located a few meters from Porta Posnania and the Cathedral church.

2 **Brisman Kawowy Bar:** Mickiewicza 20
This place is famous for coffee prepared in all various ways. They have true barista pros - finalists of barista championships and masters of “latte art”.

3 **Taczaka 20**: Taczaka 20
It is the heart of the Taczaka street. We will eat here pastas, salads and sandwiches, homemade cakes and great coffee.

4 **Cafe Misja**: Gołębia 1
Located exactly in the centre of the city of Poznań - in the historical complex of the former Jesuit college.

5 **Stacja Cafe**: Woźna 1

6 **Gołębnik**: Wielka 21

7 **Zielona Weranda**: Paderewskiego 7
Apart from excellent homemade cakes and desserts, it offers a unique atmosphere and some time to relax in a garden at the heart of the city.

8 **Kawiarnia Stragan:** Ratajczaka 31
The only place in Poland indicated by *BuzzFeed* as one of the "25 cafes in the world you need to visit before you die". Great salads and bagels.

9 **Caffe Bimba**: Zielona 1
A tiny cafe is visible from afar. This is because it is an old tram, known in Poznań dialect as “bimba”, turned into a scrubbed and bright cafe.

10 **Weranda Caffe**: Świętosławska 10
Delicious homemade cakes, pies and desserts. Quiet summer garden in the city centre.

11 **Cafe Bar Da Vinci**: Wolności Square 10

12 **Piece of cake**: Żydowska 29

EURO 2016
3-6 07.2016 POZNAŃ

FINAL PROGRAMME

COMPLETE VERSION

Technical Program

Sunday, 16:30-18:00

■ SA-01

Sunday, 16:30-18:00 - Building CW, AULA MAGNA

Opening Session

Stream: Opening and Closing sessions
Chair: *Daniele Vigo*

1 - **Opening Session**
Daniele Vigo, Joanna Józefowska

Opening session of the EURO 2016 Conference.

Monday, 8:30-10:00

■ MA-01

Monday, 8:30-10:00 - Building CW, AULA MAGNA

Keynote Marielle Christiansen

Stream: Plenary, Keynote and Tutorial Sessions
Chair: *Wout Dullaert*

1 - Optimization of Maritime Transportation
Marielle Christiansen

In this tutorial, we will give a short introduction to the shipping industry and an overview of some OR-focused planning problems within maritime transportation. Examples from several real ship routing and scheduling cases, elements of models and solution methods will be given. Finally, we present some trends regarding future developments and use of OR-based decision support systems for ship routing and scheduling.

■ MA-02

Monday, 8:30-10:00 - Building CW, 1st floor, Room 7

Evolutionary Multiobjective Optimization 1

Stream: Evolutionary Multiobjective Optimization
Chair: *Ernestas Filatovas*

1 - Experimental Analysis of Design Elements of Scalarizing Functions-based Multiobjective Evolutionary Algorithms on TSP with Profits
Andrzej Jaszkiewicz, Mansoureh Aghabeig

In this paper we systematically study the importance, i.e., the influence on the performance, of design element differentiating scalarizing function-based multi-objective evolutionary algorithms (MOEAs). This class of MOEAs include Multi-objecitve genetic local search (MOGLS) and Multi-objective evolutionary algorithm based on decomposition (MOEA/D) and proved to be very successful in multiple computational experiments and practical applications. The two algorithms share many common elements and differ in two aspects only. Using two versions of the traveling salesperson problem with homogeneous and heterogeneous objectives we show that the main differentiating factor is the mechanism for selection of parents, while the selection of weight vectors either random or uniform is practically negligible if the number of uniform weight vectors is sufficiently large.

2 - ND-Tree: a Fast Online Algorithm for Updating a Pareto Archive
Thibaut Lust, Andrzej Jaszkiewicz

In this paper we propose a new method called ND-Tree for fast online update of a Pareto archive composed of mutually non-dominated solutions. The method is composed of a data structure and corresponding algorithms for querying and updating the data structure. ND-Tree may be used in any multiobjective metaheuristics, e.g., in an multiobjective evolutionary algorithm to update the external archive of potentially efficient solutions. We experimentally compare ND-Tree to simple list, quad-Tree, and M-Front methods using artificial and realistic benchmarks. Finally, we apply ND-Tree within two-phase Pareto Local Search for up to 6 objectives traveling salesperson problems. We show that with this new method substantial computational time reductions can be obtained.

3 - Experiments with large-scale evolutionary multiobjective optimization for Intensity Modulated Radiation Therapy
Janusz Miroforidis, Ignacy Kaliszewski, Dmitry Podkopaev

Intensity Modulated Radiation Therapy (IMRT) is a widely used technique in cancer treatment. For many years multi-objective optimization methods are used in IMRT to determine patient treatment plans. This is a natural consequence of the fact that targeting tumour one need also to protect other organs at the same time. To determine "the best" treatment plans, linear and non-linear objective and constraint functions are used (or planned to be used) in optimization models for IMRT. These elements of optimization models evolve due to continuous advances in cancer treatment.

Optimization problems in IMRT are, in general, hard to solve due to arbitrary type of objective functions, and due to high-dimensionality of decision spaces. This prompts to use evolutionary multi-objective optimization methods, that have been already successfully applied to many practical optimization problems regardless of the type of objective and constraint functions.

We present the preliminary results of the use of evolutionary multiobjective optimization to determine treatment plans in IMRT on a clinical data. We examine also the possibility of supporting this heuristic method by exact methods, such as linear programming.

4 - NSGA-NBI: a preference-based multi-objective evolutionary algorithm
Ernestas Filatovas, Juana Lopez Redondo, Jose Fernandez, Olga Kurasova

Evolutionary multi-objective optimization (EMO) approaches have received great attention during the last decades. Classic EMO algorithms aim to find a set of well-distributed points on objective space that approximate the entire Pareto front. However, they are computationally expensive, and an analysis of the obtained solutions is cumbersome for the Decision Maker (DM). This is why EMO algorithms that incorporate DM's preference information have gained in popularity during the last decade. One easy and understandable way for a DM to express preference information is by means of Reference Points (RPs). Preference-based EMO algorithms approximate the part of the Pareto front that is close to the RP provided by the DM. However, only a few preference-based EMO approaches are able to obtain well-distributed solutions covering the complete "region of interest" defined by the RP. We propose to combine the main concepts of the NSGA-II algorithm with the NBI method, and develop a preference-based EMO algorithm, NSGA-NBI, that is able to achieve a good approximation of the region of interest defined by the RP provided by the DM. The proposed algorithm has been experimentally evaluated using several performance measures and compared to other algorithms by solving a set of benchmark problems. The results highlight advantages of the proposed algorithm.

■ MA-03

Monday, 8:30-10:00 - Building CW, 1st floor, Room 13

MADM Application 1

Stream: Multiple Criteria Decision Analysis
Chair: *Yi-Hsien Wang*

1 - Determining the Key Factors of Evaluation Model for Promoting Operation Abilities of Hot Spring Hotel
Chie-bein Chen, Hsiao Ching Chen, Ming Shen Chang, Yen-Llin Chen

Hot spring hotels are mostly small and medium scale. They face more and more development of recreation areas and fierce competition. How to allocate the limited resources effectively, improve the hot spring hotel operational abilities and attract more consumers in appropriate service modes are the managers main thought of industry issues. Previous studies almost considered the managers' or consumers' views, through analytic hierarchy process (AHP), SWOT and interviews to investigate hotel service quality, customer satisfaction or customer loyalty, and their related factors and operational capabilities. However, the consumers' demand and managers' views are considered simultaneously very rare. Therefore, this study attempts to consolidate consumers' demand and managers' views establishing a model and using fuzzy analytic hierarchy process to aid managers evaluating the key factors and finding the priorities on the key factors for promoting the hot spring operational abilities.

2 - Comparative Analysis of Information Value of Strategic Alliances and Mergers and Acquisition: Competitive Dynamics Perspective
Shih-Cheng Lee, Yi-Hsien Wang, Wan-Rung Lin, Cheng-Shian Lin, Ya-Feng Chang

With the drastic changes of the industrial environment, the dynamic relationship between Co-opetition patterns, individual jump of the firms of the supply chain and the patent risk of the overall chain has become a risk management issue of increasing concern. Hence, rapidly M&A and strategic alliance as the main management strategy to face the market challenges and promote competitive advantage. This study plans to use the market commonality and resource similarity to measure the competing relationships of firms (Chen, 1996). This study collected the Merger acquisition and strategic alliance data from 2005 to 2013 as our study sample. Based on the framework for competitive dynamics analysis, these sample data of strategic alliance and M&A are used to examine if there exist statistically significant abnormal returns in the quadrant of market commonality and resource similarity. The expected results show that the different influence on information disclosure, and scale effect are significant. This findings show that the investors rationally compare the differences of information effect of M&A and strategic alliance and adjust their portfolio allocation accordingly.

3 - The Effect of Internet Sentiment Tracking on Stock Returns and Volatility of Listed Company - A Case of Taiwan Financial Holding Industry
Yi-Hsien Wang, Fu-Ju Yang, Hai-Yen Chang, Yu-Ting Mai

With the advancements of technology, internet is widely used in the world. The behaviors of internet users like usage or the reactions of information leave a digital trace and affect other people's actions (Bordino, et al., 2012). Nowadays people can crawl text through the internet technology to obtain information, and use sentiment analysis to produce internet sentiment tracking. Internet sentiment tracking represents the internet evaluation on specific target. The positive (negative) sentiment tracking represents positive (negative) sentiment. Emotions can profoundly affect individual behavior and decision-making (Bollen, et al., 2011). Hence, this study employ EGARCH to estimate stock returns and volatility of the internet sentiment tracking activities, and to investigate the effect of internet sentiment tracking activities on market reaction of Taiwan listed financial holding companies during 2014 - 2015. This study can provide investors better reference information when making investment decisions.

4 - Herd Behavior in Online Shopping
Yi-Fen Chen, Yu-Chen Tseng

When people follow others on the Internet, online herd behavior occurs. This study investigates the increased sales volume and inventory on framing effect and the influence on consumer online herd behavior in online shopping. This study presents three experiments that examine herd behavior in online shopping. Experiment 1 investigated herd effect using a 2 (Number of scale: large / small) × 2 (Sales volume framing: relative number / absolute number) × 2 (Brand Familiarity: familiar / unfamiliar). In experiment 2, 2 (Inventory: inventory / no inventory) × 2 (Brand familiarity: familiar / unfamiliar) online experiment was conducted. Online experiment 3 examined herd effect using a 2 (Number of scale: large / small) × 2 (Sales volume framing: relative number / absolute number) × 2 (Time interval: short / long). The experiments involved 870 people who have online shopping experiences from Taiwan. The results and implications of this research are discussed.

■ MA-04
Monday, 8:30-10:00 - Building CW, ground floor, Room 6

OR in Quality Management

Stream: OR in Quality Management
Chair: *Ipek Deveci Kocakoç*
Chair: *Gokce Baysal Turkolmez*

1 - An Application of Six Sigma to Enhance Restaurant Service Quality
Li-Fei Chen, Chao-Ton Su

Service quality is one of the most critical factors to the long-term success in the service organization. How to reduce customer complaints and service defects have attracted substantial attention in service sector industries. This study focused on the restaurant service which is a large and critical component of the service sector industries. Six Sigma is a project-driven quality improvement approach that can be utilized to pinpoint error sources and determine methods to eliminate them. The Six Sigma project is executed according to the Define, Measure, Analyze, Improve, and Control (DMAIC) phases. Decision tree (DT) approach, commonly used in data mining, can crystallize the inferred rule set, facilitating the analysis and understanding of causal mechanisms underlying a problem, and consequently enabling proper decisions. This study proposed a method of integrating DT into the Six Sigma analysis toolset to enhance effectiveness for use in improving restaurant service quality. DMAIC was utilized as the framework with which to determine customer complaints and decrease the reoccurrence of service defects. The DT was used to analyze the causes of service defects and create a rule set, depicting the causal structure between restaurant service attributes and customer complaints using customer complaint data and facilitating decisions for improvement. A case study in which the proposed integration method was used to improve service quality in chain restaurants was investigated.

2 - Bootstrapping control chart for skewed process
Shih-Chou Kao

When control charts based on a normal distribution are used to monitor a skewed process, their false alarm rates could be raised. Although many studies indicate that a bootstrap sampling is a good resampling method, a sampling distribution of an estimator or an extreme value are hardly estimated by the method under the conditions, small sample sizes or skewed processes. To overcome the problem, samples are first divided into datasets of h units by the stratification. The control limits are determined based on the percentile method by the bootstrap with the weights of the strata. The bootstrapping control chart can effectively monitor out-of-control signals for Weibull process. Furthermore, the estimated Type I risks of the control chart are used to determine the weights of the strata in accordance with various skewness and sample sizes. The determined weights can be used to construct a bootstrapping control chart.

3 - Multiobjective Evolutionary Optimization Approach to Multiresponse Surface Problems
Gokce Baysal Turkolmez, Ipek Deveci Kocakoç

Practical applications involve multiresponse measurements. Optimization of multiresponse surface problems is more complex than the single-response situation. In this paper, we present the usage of multi-objective evolutionary optimization to optimize multiple quality characteristics of multiresponse surface problems. These methods generate more alternative solutions called Pareto-optimal. The aim of this paper is to reach a better solution set for determining quality characteristics. The solution of the problem will be compared to the other solutions in literature.

■ MA-05

Monday, 8:30-10:00 - Building CW, 1st floor, Room 8

Multiobjective Optimization in Supply Chain Management and Logistics 1

Stream: Multiobjective Optimization
Chair: *Sandra Huber*
Chair: *Martin Josef Geiger*

1 - A Multiobjective Approach to Solve Container Ship Loading Planning Problem with Uncertainty
Ricardo Coelho Silva

Many decisions are made every day and some of them are based on previous knowledge, which may not be represented by precise rules. In these cases, the decision makings depend on the perceptions, which are uncertain, and they cannot be measures by a precise number. A way to modelling these perceptions is to use Fuzzy Logic, which models subjective features in the decision making techniques. It is part of Soft Computing, which is a collection of techniques that solve problems by using approximate reasoning and methods of optimization and/or functional approximation. With this in mind, a multiobjective approach, which is based on Soft Computing techniques, is developed in this work to set up the containers in a ship minimizing the loading time and observing the equilibrium of the ship. The first objective is to organize the different types of containers inside of the ship subject to operational constraints from the port and the priority of the containers. In addition, the ship can fall over if the weight of the containers has not been computed in order to maintain the equilibrium, which is the second objective. The theoretical examples illustrate the efficiency of this model and the obtained results are compared with other approaches to validate the proposed model.

2 - Strategic decision support for the Bi-objective Location-Arc Routing Problem
Sandra Huber

An intelligent decision support tool for a complex supply chain management problem is developed. In order to solve the bi-objective Location-Arc Routing Problem (LARP) facilities have to be located and routes must be determined simultaneously. The first objective is the minimization of the total costs which are the fixed cost of opening the facility, the fixed cost for the vehicles as well as the travelled distances. Additionally, a second objective related to a service aspect is investigated: the total sum of the delivery times for servicing the required demands. This idea arises since, e.g., in a snow plowing application lead times for satisfying the required demands play an important role for the safety of people using the road network. To the best of our knowledge, this paper presents the first study devoted to the bi-objective LARP. The trade-off between the proposed objectives is investigated on adapted benchmark instances.

■ MA-06

Monday, 8:30-10:00 - Building CW, ground floor, Room 2

Spatial Multicriteria Evaluation: insights and future developments

Stream: Multiple Criteria Decision Aiding
Chair: *Valentina Ferretti*

1 - Planning activities at sea: integrating MCDA and GIS
Alexandru Olteanu, Patrick Meyer

Based on two projects between Telecom Bretagne and the Marine Hydrographic and Oceanographic Service (SHOM) in France, this contribution is linked to integrating multi-criteria decision aiding (MCDA) and geographical information systems (GIS) with the aim of evaluating and proposing solutions to the problem of planning activities at sea. The first project focused on the problem of ordinal evaluation of sea areas within the French jurisdiction with respect to the need of the SHOM to perform hydrographic surveys and the development of a software prototype (MODEL) for supporting it. The second project, currently in its first stages, will build upon the first by considering any planning activity at sea. This project will integrate the entire decision aiding process and aid in collaboratively situating and structuring the problem as well as validating the recommendations from which the decision-makers will choose the final one.

2 - A framework for assessing errors in Spatial Multi-Criteria Evaluation decision problem structuring.
Luc Boerboom, Montse Gibert Fortuny, Valentina Ferretti

Spatial multi-criteria evaluation (SMCE) has become more accessible methodology with the development of special tools in desktop and web-based geographic information systems software applications. The SMCE implementation in the ILWIS geographic information system has recently been included in the Spatial Development Framework methodology which was developed with the United Nations Habitat organization. Consequently its use has been propelled into substantial regional planning problems of regional reconstruction after war and national urban policy implementation. The intense use has led to a large number of observations, lessons and examples of erroneous practices and bottlenecks of decision problem structuring. In this paper we start with an explanation of the Spatial Development Framework methodology and the role of SMCE in this methodology. We describe three use cases from which we draw examples of erroneous practices and bottlenecks of decision problem structuring. Then we derive from literature a framework with an overview of these erroneous practices in order to improve the quality and the speed of analyses. And finally we apply this framework to the experiences in the three cases studies.

3 - SOMERSET-P: An integrated modelling platform for territorial and environmental planning
Jean-Philippe Waaub, Jean-François Guay

This contribution proposes an integrated strategic environmental assessment approach of regional planning scenarios. It combines Soft System Methodology, spatial analysis and multi-criteria decision aid support. It is illustrated by the municipality of Ste-Claire (Quebec, Canada) case study. The work of Commission on the Future of Agriculture of Quebec, held across the whole province from 2006 to 2009, provided data on stakeholder and societal expectations. Problem setting, definition of land use scenarios and assessment criteria were made out from this material and subjected to a heuristic analysis with the Soft Systems Methodology. Each scenario is built according to a hierarchy of objectives. Scenarios are then assessed in accordance to twelve decision criteria and related indicators of performance. The spatial translation and spatial analysis of the impacts of the scenarios were performed within ArcGIS geographic information system and integrated into a multicriteria analysis software implementing the PROMETHEE and GAIA methods. The following main elements were computed to support the stakeholder negotiations: scenario strengths and weaknesses, individual and multi-stakeholder scenario rankings and visual analysis of conflicts and synergies between criteria, and between stakeholders, sensitivity and robustness analysis. The negotiation process was simulated in order to determine a compromise proposition to the ultimate decision maker.

4 - A multi-criteria approach for the construction of Land-use Change Spatial Composite Indicators
Valentina Sannicandro, Raffaele Attardi, Alessandro Bonifazi, Maria Cerreta, Carmelo Maria Torre

Global trends in land-use change for urban growth and development are a current relevant phenomenon that questions the actual efficiency of land-use policies in preserving natural uses of the soil as an unrenewable resource. Land-use change from natural uses to artificial ones causes multiple effects in terms of environmental costs that result in the loss of ecosystem integrity, functioning and services. These effects should be accurately accounted alongside of the economic and social impacts in the evaluation of urban development scenarios, taking into consideration multiple synergic and/or conflicting stakeholders' points of view and interests. According to the research activity of M.I.T.O.

project the paper introduces the construction of Land-use Change Spatial Composite Indicators (LuC-SCI) through a multi-criteria evaluative approach in order to provide decision-makers for a deeper insight on trends in land-use change and their multidimensional impacts. The paper focuses on the construction of a theoretical and methodological framework for SCI to guarantee transparent and democratic evaluation process. One main issue is investigated: the selection of suitable weighting and aggregation procedures for SCI. This issue, indeed, is one of the most debated in Composite Indicators domain and it still reveals its scientific relevance in environmental and planning decision-making.

■ MA-07

Monday, 8:30-10:00 - Building CW, 1st floor, Room 123

ROADEF/EURO OR Challenge presentation (I)

Stream: EURO Awards and Journals
Chair: *Eric Bourreau*
Chair: *Vincent Jost*
Chair: *Safia Kedad-Sidhoum*
Chair: *David Savourey*
Chair: *Marc Sevaux*
Chair: *Jean André*
Chair: *Michele Quattrone*
Chair: *Rodrigue Fokouop*

1 - A heuristic approach for Air Liquid Inventory Routing Problem
Irma Yazmín Hernández-Báez, Federico Alonso-Pecina, Alma Delia Nieto-Yáñez, Roberto López-Díaz

We propose a two phase approach combining local search and meta-heuristics for the ROADEF/EURO challenge 2016, dedicated to the Air Liquide Inventory Routing Problem related to the distribution of bulk gases. In first phase, a feasible solution is obtained using a greedy heuristic algorithm. In this phase, the objective is that costumers runs out of liquide gas are resupplied first. In second phase, a local search using different neighborhoods is performed in orden to improve the obtained solution in first stage.

2 - A Matheuristic for the Inventory Routing Problem with Shifts
Yun He, Christian Artigues, Cyril Briand, Nicolas Jozefowiez, Sandra Ulrich Ngueveu

Based on the first solutions given by several constructive randomized heuristics implementing different scheduling and assignment strategies, we develop a local search method. The local search begins with the first solutions (feasible or not) and performs movements such as deletion, insertion and exchange in a shift or among shifts to repair or improve the current solution in condition that no more stockouts are generated. An assignment heuristic is added to balance the delivered quantity in each shift modified in the local search and search for a better solution in terms of logistic ratio. A MILP model for driver/trailer shift scheduling and customer assignment is also constructed to guide the local search in a global way. The MILP model assigns drivers to trailers and decide the starting and ending time of a shift, then it decides which customers to visit by an aggregation of the customers demands. Results and other comments will be presented later in the conference.

3 - Challenge ROADEF/EURO Revival
Eric Bourreau

Challenge ROADEF exists from more than 15 years. Since 2010, it has been integrated in EURO Conference for important dates: starting or ending of on going challenge. Actually, we are in the 10th challenge; propose by Air-Liquide where competitors try to solve some large-scale instances of Inventory Routing Problem (IRP). Previous challenges were related to Crane Management (IP), Frequency Allocation (AP), Price Collecting, Car Sequencing, Timetabling, Load Balancing, Airline Scheduling, Energy Management and Railway Management. As it can be seen, this is a rich database of problematic, with additional real life constraints but also a rich database of industrial size instances solved by many various approaches. More information at http://challenge.roadef.org/

In this presentation, we will propose to extend these one-year-long competitions to some online on-going benchmarking. We will focus of 2005 Challenge propose by Renault to experiment the new workflow.

■ MA-08

Monday, 8:30-10:00 - Building CW, 1st floor, Room 9

MCDA and finance

Stream: Multiple Criteria Decision Aiding
Chair: *Michael Doumpos*
Chair: *Constantin Zopounidis*

1 - Detecting the most relevant criteria in the evaluation of innovative SMEs' creditworthiness
Silvia Angilella, Sebastiano Mazzù

The assessment of innovative SMEs' creditworthiness is a difficult and multifaceted task, since their track records are insufficient or lacking. Innovative SMEs face many financial constraints when they have to request credit from banks. From a managerial and decisional point of view, it is useful to detect which are the most relevant criteria that improve SME's risk category, according to the bank's rating model chosen. This presentation deals with the financing of innovative SMEs in the context of Multi Criteria Decision Aiding. We focus on detecting which are the most important criteria determining the assignment of an innovative SMEs to a better risk class. Within the multicriteria model of ELECTRE-TRI, we aim to find the smallest modifications of the weights of criteria which induce an innovative SME to be assigned to a less risky class. To illustrate the whole optimization model we show an application to a sample of innovative SMEs based on AIDA dataset.

2 - Financial distress in the European energy sector: A prediction model and the effect of country characteristics
Constantin Zopounidis, Kostas Andriosopoulos, Michael Doumpos, Emilios Galariotis, Georgia Makridou

The energy sector experiences a number of major global challenges, related to the increasing volatility in the energy and commodity markets and the imposition of global policies for energy sustainability, efficiency, and security, as well as environmental awareness. In addition to such issues, the initiatives taken in Europe towards a harmonized and liberalized EU energy market will have significant impact on the viability of firms in the energy sector. Within this context, the first objective of this study is to develop prediction models for assessing the likelihood of financial distress of European energy firms. To this end we use an up to date (large) sample of distressed and non-distressed covering (almost) all EU countries. The construction of the prediction models is based on novel techniques from the field of multiple criteria decision making (MCDM). For the construction of the models traditional financial variables are first examined. Furthermore, we consider additional non-financial country-level data related to market structure, energy demand/consumption, security, and prices. The combination of financial data at the firm-level with country-level variables about the local energy markets lead to useful findings about corporate viability, competitiveness, and performance in the EU energy market.

3 - Stability aspects in discrete venturesome investment models
Vadzim Mychkou, Vladimir Emelichev, Yury Nikulin

In multicriteria discrete optimization problems stability research is usually tied with studying a discrete analogue of the Hausdorff continuity (semicontinuity) for dot-valued mappings i.e. mappings that assign each gang of possible data to a given set of optimal solutions. Despite the abundance of approaches to the stability analysis in discrete optimization problems, the two mainstream approaches can be defined: qualitative and quantitative. As a part of the qualitative approach, research is concentrated on identifying the different types of problem stability or establishing interconnections between different types of stability. The key point here is stability radius, which is defined as the radius of the largest uncertain data neighborhood preserving some optimal property in the space of perturbed problem parameters. Any perturbed problem with parameter point within the neighborhood is "close" to the original problem. In this study, we consider the most general case where different Holder norms are used in the parameter space mentioned above. Here we obtain lower and upper bounds for the stability radius of the vector investment problem with well-known in the theory of decision-making criteria of extreme optimism regarding portfolio returns.

4 - A 2-additive Choquet integral model for French hospitals rankings in weight loss surgery
Brice Mayag

In a context of Multiple Criteria Decision Aid, we present a decision model explaining some French hospitals rankings in weight loss surgery. To take into account interactions between medical indicators, we elaborated a model based on the 2-additive Choquet integral. The reference subset, defined during the elicitation process of this model, is composed by some specific alternatives called binary alternatives. To validate our approach, we showed that the proposed 2-additive Choquet integral model is able to approximate the hospitals ranking, in weight loss surgery, published by the French magazine "Le Point" in August 2013.

■ MA-09

Monday, 8:30-10:00 - Building CW, 1st floor, Room 12

OR and the Arts

Stream: OR and the Arts
Chair: *Semih Kuter*
Chair: *Gerhard-Wilhelm Weber*
Chair: *Joanna Józefowska*

1 - 3D Model Optimization of a Heritage Artifact for Mobile Applications
Ewa Lukasik

One of the crucial problems in the domain of computer graphics is 3D model optimization due to many restrictions related to available computing resources (memory, computational speed, etc.). Many methods have been proposed for simplification and/or optimization of the mesh, compressing textures and packing them into the appropriate file format as well as appropriate mapping (splitting the faces of the 3D object on a 2D space and producing the texture for it). All these optimization steps were undertaken in the case of transferring a precise interactive 3D model of a heritage artifact - a historical clavichord - to the mobile environment.

The clavichord, badly damaged through ages, had been accidently found, precisely documented and restored with great attention to preserve original elements by heritage conservators. The blueprints and photographic documentation served as a base for the construction of a 3D digital model of the instrument and its faithful textures, including valuable paintings on the soundboard. Every single part was individually modeled up to a hundred tuning pins and even more catches. The mesh counted 180000 nodes and textures used more than 80 MB. The model was presented at the exposition in the museum. If displayed on a multi-touch monitor it enabled playing the virtual instrument and observing the mechanism work.

The optimization process for a mobile environment reduced the model up to 90% of its capacity and enabled a wider audience "take the artifact home".

2 - Creating Art Based on Mathematics — Revisiting OR via "Deep Learning"
Gamze Nalçacı, Meltem Atay, Gerhard-Wilhelm Weber

Art and mathematics are foundations of human civilization since the beginning of humankind. We can express identical concepts by the terms of art and mathematics; from this perspective they are also considered as the language of nature. From rainbows, snowflakes, sunflowers, body of nautilus, and all kind of objects or events in nature can be described using both art and mathematics. Symmetrical patterns, fractal geometries, Fibonacci sequence and golden ratio are the well-known examples of the field where both mathematics and art converge.

Evolutionary art emerged earlier than mathematics, and from sixth century BC, applications of mathematical interactions with art gave birth to revolutionary fields from architecture to computer science and engineering. There are many fields of arts and unexpected associations between mathematical concepts and each of the arts. In this research, our aim is to bring these associations together in a new field of machine learning which is also known as "deep learning".

Theoretically, one can claim that in machine learning shallow network algorithms are mainly applications of mathematical optimization and it is also similar, for deep learning algorithms. In our research, we used Restricted Boltzmann Machine algorithms, which are applications of Boltzmann distribution, along with Markov-Chain Monte-Carlo method; we sampled geometric shapes in famous artworks from Google Art Project database. Using Convolutional Neural Networks, we reconstructed new computer-based digital art based on random shape input from selected images.

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■ MA-10

Monday, 8:30-10:00 - Building CW, ground floor, Room 1

OR and Ethics

Stream: OR and Ethics
Chair: *Robyn Moore*

1 - On the Role of Multicriteria Decision Aiding (MCDA) in Strategic Assessment of Olympic Games (OG)
Joao Clímaco, Rogério Valle

Multidimensional assessment of megaprojects is crucial today. There is a EU directive regulating Strategic Environmental Assessment (SEA), proposing a systematic evaluation of the consequences of policies or plans from an early stage of the decision process, involving economical, social and environmental issues. The Mega Sporting Events (MSE), such as O.G., are still more complex than mega projects. The original purity of the Olympic Chart is deeply contaminated by the globally mercantilized world. The public and private stakeholders are very diversified, involving local and global economic interests, financial and corruption risks, etc. Impacts of forced displacement of people, employment and tourism promotion, urbanism issues, very fast physical infrastructure works, etc, are relevant issues. In this communication, first we discourse on the extension of SEA framework to MSE; secondly we discuss the potential of MCDA in the assessment of MSE, trying to make the specification of the adequate characteristics of an approach taking into account some specificities of our problem, for instance, related to the combination of quantitative and qualitative issues, the promotion of the transparency, the public participation issues, the explicit consideration of several decision agents, etc. Finally, the comparison of MCDA with Cost-Benefit Analysis, is also tackled. The case of Rio de Janeiro Olympic Games is used as an example, emphasising the peculiarities of development countries.

2 - Unleashing third sector potential: a case of Community Operational Research (COR) in Aotearoa New Zealand
Robyn Moore

This paper is an account of Community Operational Research (COR) undertaken for a government-funded project in 2014/15 (High Performance Work Initiative - HPWI). HPWI programmes aim to help New Zealand enterprises be higher performers. The motive was to examine the challenges and opportunities faced by not-for-profits in New Zealand and deliver a 'Best Practice Toolkit" to assist third sector managers in improving their organisational performance. Volunteering and volunteer-involved organisations contribute close to 7 billion dollars to the New Zealand economy annually, while the associated social and environmental returns from volunteer activity are yet to be reliably quantified. Notably, New Zealand gains high ranking on social well-being indicators, and derives economic value from its globally-recognised socio-environmental credentials. Stakeholder analysis was used to ensure the toolkit would be useful to the broadest range of people and organisations, while problem-structuring was used to reach consensus on the toolkit through the development stages. The result is a cross-sector toolkit for supporting human resource management and operational best practice, available in online and print forms. Future research is warranted to test the effectiveness of the toolkit, as realities change.

3 - The EthOR award and the importance of OR education for Ethics
Pierre Kunsch

This presentation recalls the objectives of the creation of the EthOR award by the Euro working group 'OR and Ethics' at the occasion of the Euro/Informs 2013 conference in Rome. The third edition goes on during the Poznan conference, but some difficulties appear year after year to stimulate more OR contributions in the ethical field by young researchers and practitioners, more than often exclusively oriented to 'hard' modelling giving few or no thoughts to human aspects in decision processes. It is why OR education stressing ethical values is particularly important. The author describes his own experience with system-dynamics education contributing to develop ethical awareness even in 'hard' modelling of complex societal problems.

■ MA-11

Monday, 8:30-10:00 - Building CW, 1st floor, Room 127

Fuzzy Optimization and Applications

Stream: Fuzzy Optimization - Systems, Networks and Applications

Chair: *Gerhard-Wilhelm Weber*
Chair: *Ali Hamidoglu*
Chair: *Angel M. Gento Municio*

1 - Estimating the Membership Function of the Fuzzy Willingness-to-Pay/Accept for Health via Bayesian Modelling
Michał Jakubczyk

With multiple criteria quantifying the trade-offs between individual ones is often not obvious, especially when juxtaposing attributes of very different nature. When comparing health and money, the difficulty stems from the lack of adequate market experience and strong ethical component. This results in inherently imprecise preferences or even a reluctance to accept a crisp trade-off coefficient. Fuzzy sets can be used to model willingness-to-pay/accept (WTP/WTA), so as to quantify this imprecision. These sets need to be estimated, so as to use them in the formally supported decision making process. I show how to estimate the membership function of fuzzy WTP/WTA, via stated-preference surveys with Likert-based questions. I apply the proposed methodology to an exemplary data set on WTP/WTA for health collected among 27 experts in health technology assessment in Poland. The mathematical model is composed of two elements, describing parametrically, i), the shape of the membership function and, ii), how this function is translated into Likert options. The parameters are estimated in the Bayesian approach using Markov-chain Monte Carlo. The results suggest a slight WTP-WTA disparity (membership function for WTA flipped and shifted rightwards) and WTA being ca. twice as fuzzy as WTP (using both a standard and a newly proposed measures). The model is fragile to respondents with lexicographic preferences—not willing to accept any trade-offs between health and money.

2 - Supplier Selection in a Fuzzy and Probabilistic Environment
Ahmad Makui

The supplier selection problem is a multi-criteria decision making problem with quantitative and qualitative criteria. For selecting the best supplier, a tradeoff between tangible and intangible criteria is made in a supply chain. Supplier selection methods in different environments have been studied widely in the literature. In supply chain management, the performance of the potential suppliers is evaluated based on a multi criteria approach rather than focusing on a single-cost criterion. In addition, it is important to consider how uncertainty affects the decision-making process. Because human preferences are usually vague, it is not possible to estimate them by crisp numbers. Therefore, a realistic approach requires both linguistic and probabilistic evaluation. In this paper, two approaches are presented for the supplier selection problem in which criteria are both fuzzy and probabilistic. The first approach is based on the Borda ranking method and the second approach is based on the probability-possibility transformation. The proposed approaches are evaluated using computational results.

3 - An Inverse Function Based Maximizing Set and Minimizing Set Method to Rank Alternatives Under Fuzzy Multiple Criteria Decision Making
Ta-Chung Chu

Numerous works have been studied in fuzzy MCDM since fuzzy set theory was introduced by Zadeh in 1965. The final evaluation values of alternatives in the above works are usually fuzzy numbers and a proper ranking method is usually needed to defuzzify these fuzzy numbers into crisp values for decision making. However, formulae for the membership functions of final fuzzy evaluation values of alternatives in the above fuzzy MCDM works cannot be seen. In the suggested fuzzy MCDM model, ratings of alternatives versus qualitative criteria and importance weights of all criteria are assessed in linguistic values represented by triangular fuzzy numbers. Formulae for membership functions of final fuzzy evaluation values can be developed by α-cuts and interval arithmetic operations of fuzzy numbers. In addition, numerous methods in ranking fuzzy numbers have been proposed. Despite many merits, some of the above approaches are computational complex, and others are difficult to display connection between ranking procedure and the final fuzzy evaluation values under fuzzy MCDM. To resolve the above mentioned limitations, this work suggests an inverse function based maximizing set and minimizing set method using concept from Chen (1985) to rank alternatives under fuzzy MCDM. Formulae of ranking procedure can be clearly displayed for more efficient applicability. A numerical example is used to demonstrate feasibility of the suggested method.

4 - Risk management in supply chains
Angel M. Gento Municio, Alina Diaz Curbelo, Fernando Marrero Delgado

The management of risk in operations/supply chains has emerged as one of the main research topics in the recent operations and supply chain management (SCM) literature. SCM are increasingly prone to complexity and uncertainty. Therefore, making well informed decisions requires risk analysis, control and mitigation. The analysis of failure modes and their effects generally requires dealing with uncertainty and subjectivity inherent in the risk assessment process. A review of the literature reveals that although a number of studies have examined these issues, none of them have explicitly studied the correlation between agents and events of risk, and the interdependences between the events through the supply chain and their impact in strategic objectives. To address this problem, our paper proposes a new fuzzy risk assessment approach through a methodology. The methodology is based on the consideration that a risk agent may cause several events and an event may be caused by more than one agent. We introduce the Potential Aggregate Risk indicator that consider the relationship between agents and events risk in the process. The methodology provides a robust mathematical framework for collaborative modelling of the system and allows for a step by step analysis of the system for identifying and controlling risks in a systematic manner. This analysis allows the determination of priorities for decision-making and proactive approach to strategy management.

■ MA-12

Monday, 8:30-10:00 - Building CW, ground floor, Room 029

Retail sector

Stream: Sustainable Supply Chains
Chair: *Ramin Geramianfar*

1 - Design of a Sustainable Production and Distribution Network
Ramin Geramianfar, Amin Chaabane, Jacqueline Bloemhof

A mathematical formulation based on multi-objective optimization is proposed for the design of a sustainable production and distribution network. The first objective minimizes the total logistic costs, whereas the second objective monitors the carbon footprint of the production-distribution system. The social pillar of sustainability is also considered. The aim is to maximize the social responsibilities of the network by increasing the number of job opportunities created from manufacturing and transportation as well as decreasing the amount of food wastes caused by manufacturing sites. The Food supply chain is one example where we observe more and more attention to sustainability during the last years in different regions (Europe, North America and Asia) within the production and distribution operations. This sector consumes a lot of energy, especially for products that need to be conserved for a certain time such as Fast Moving Consumers Goods and frozen foods. Therefore, a case study of a North American Frozen Food industry is used to illustrate the applicability of the proposed model. The key contribution of this work is to support managers to analyse and plan "sustainable" supply chains, and to evaluate the supply performance based on total cost, GHG emissions, and delivery efficiency. Managers might also adapt their production and distribution decisions to improve the social impacts of supply chain operations.

2 - The effects of joint ordering on sustainability in fresh food logistics: a case study in the Dutch food retail sector
Heleen Stellingwerf, Jacqueline Bloemhof, Jack van der Vorst

Food distribution is accountable for a considerable part of global food waste and CO2 exhausts. In addition, the available transportation means are not efficiently used. This results in the need to organise food logistics more efficiently such that it will become more sustainable. Collaboration is often mentioned as an opportunity to improve food supply chain sustainability. However, the effects of logistics collaboration on sustainability have only scarcely been quantified. Moreover, companies are hesitant to implement collaboration because they find it hard to agree on te division of the gains resulting from collaboration. Therefore, we performed a case study in the Dutch food retail sector in which we analysed the economic and environmental effects of implementing Joint Ordering. In this form of collaboration, several companies order the services of a Logistics Service Provider (LSP) as if they were one company. In addition, we did numerical experiments to find a gain allocation method that fits this form of collaboration. Joint ordering allows the LSP to organise its services more efficiently such that costs and emissions are reduced. With this case study, we showed how Joint Ordering can improve both economic and environmental performance of the Dutch food retail sector.

3 - Supply Chain Network Competition Based on Retailers, Risk Attitude
Hêriş Golpîra, Somaye Rostami

In this paper a new mixed integer linear programming is proppsed to formulate a SCND problem under uncertain environment in compliance with retailers risk averseness to deal with the demand uncertainty in the robust manner. The SCND problem contains 3 levels of decisions which are: strategic, tactical, and operational decisions. Our research is familiar with the second and the third classes. However, it reflects the effects of the SC downstream risk-averseness, using the CVaR method. One of the most important problems in the field of SCND problems is competitiveness. Despite some relevant real-life examples there are few researchers that investigate the CSCs. Here are 3 types of competition: among potential candidates in the same tier, among potential candidates in different tiers and SCs competition. Our research is familiar with the first class which leads to SCNE. Formulating the robust SCND problem based on the retailers competition in order to achieve all of the market capacity, is the main contribution of the paper. The initial objective function covers the fixed production, alliance, and transportation costs. Reformulation of the constraint, which is including the uncertain demand, makes the model to be analytically solvable. The model finally reports the effect of the risk averseness level of the retailers on SCN designation.We find that the level of retailers' risk averseness has a significant impact on the SCN design and makes some competition in the whole network

■ MA-13

Monday, 8:30-10:00 - Building CW, ground floor, Room 3

VeRoLog: Exact methods for solving application-oriented VRP generalizations

Stream: Vehicle Routing and Logistics Optimization
Chair: *Claudio Gambella*
Chair: *Daniele Vigo*

1 - The Traveling Salesman Problem with Time-dependent Service Times
Duygu Tas, Michel Gendreau, Ola Jabali, Gilbert Laporte

The Traveling Salesman Problem (TSP) with time-dependent service times is a generalization of the classical TSP where the duration required to serve any customer is defined as a function of the time at which service starts at that location. The objective is to minimize the total route time, which consists of the total travel time plus the total service time. We describe the analytical insights derived from the properties of service time and fundamental routing assumptions, followed by computations of valid upper and lower bounds. We separately employ a number of subtour elimination constraints to measure their effect on the performance of our model. Numerical results obtained by implementing different service time functions on several test instances are presented.

2 - The Time Window Assignment Vehicle Routing Problem with Time-Dependent Travel Times
Remy Spliet

In this paper, we introduce the time window assignment vehicle routing problem with time-dependent travel times. It is the problem of assigning time windows to customers before their demand is known and creating vehicle routes adhering to these time windows after demand becomes known. The goal is to assign the time windows in such a way that the expected transportation costs are minimized. We develop a branch-price-and-cut algorithm to solve this problem to optimality. The pricing problem that has to be solved is a new variant of the shortest path problem which includes a capacity constraint, time-dependent travel times, time window constraints on both the nodes and on the arcs, and linear node costs. We develop an exact labeling algorithm and a tabu search heuristic that incorporates a polynomial time algorithm designed to optimize the time of service on a given delivery route. Furthermore, we present new valid inequalities which are specifically designed for the time window assignment vehicle routing problem with time-dependent travel times. Finally, we present numerical experiments to illustrate the performance of the algorithm.

3 - Vehicle Routing Problem with Floating Locations
Joe Naoum-Sawaya, Claudio Gambella, Bissan Ghaddar

We present a generalization of the vehicle routing problem which consists of intercepting non-stationary targets with a fleet of vehicles in order to bring them to a common destination. We propose a novel Mixed Integer Second Order Cone Program for the problem and exploit the problem structure using a Lagrangian decomposition and propose an exact branch-and-price algorithm.

■ MA-16

Monday, 8:30-10:00 - Building CW, 1st floor, Room 128

Robust Combinatorial Optimization I

Stream: Discrete Optimization under Uncertainty
Chair: *Dennis Michaels*

1 - Min-max-min Robust Optimization
Jannis Kurtz, Christoph Buchheim

The idea of k-adaptability in two-stage robust optimization is to calculate a fixed number k of second-stage policies here-and-now. After the actual scenario is revealed, the best of these policies is selected. This idea leads to a min-max-min problem. We consider the case where no first stage variables exist and propose to use this approach to solve combinatorial optimization problems with uncertainty in the objective function. We investigate the complexity of this special case for discrete and convex uncertainty sets. For the latter case we present an oracle based algorithm to solve the problem for any combinatorial problem with convex uncertainty.

2 - Min-max-min Robust Vehicle Routing
Lars Eufinger, Jannis Kurtz, Uwe Clausen, Christoph Buchheim

We study the robust capacitated vehicle routing problem (CVRP) with uncertain travel-times, which determines a minimum cost delivery of a product to geographically dispersed customers using capacity-constrained vehicles. We use a min-max-min optimization problem that is based on the idea of k-adaptability in two-stage robust optimization. We consider the case where no first stage variables exist and use this approach to solve CVRPs with uncertainty in the objective function. Our aim is to calculate k different solutions, which represent k different plans. In practice we can now easily calculate the objective values of the k solutions and choose the best plan according to the actual travel times. We present an oracle based algorithm to solve the min-max-min problem for any combinatorial problem with convex uncertainty. In addition we show how one can solve the occurring deterministic CVRPs using both heuristic and exact methods.

3 - Complexity and Approximability Results for Robust Perfect Matchings in Bipartite Graphs
Dennis Michaels, David Adjiashvili, Viktor Bindewald

The perfect matching problem under uncertainty is considered. The uncertainty is given by a collection of subsets of edges, where each of those subsets corresponds to a failure scenario that, if emerged, leads to a deletion of the corresponding edges from the underlying graph. For a given cost function, the task is to determine a cost-minimal subset of edges containing a perfect matching for every scenario. In this talk, we focus on bipartite graphs and failure scenarios consisting of only one edge. We show that the problem is already NP-hard under such mild restrictions, and present approximation results and algorithms for those cases.

■ MA-17

Monday, 8:30-10:00 - Building CW, ground floor, Room 0210

Transportation 1

Stream: Transportation
Chair: *Alexandre Iglesias*

1 - A solution method for congested transit assignment with explicit capacities
Esteve Codina, Francisca Rosell

In this paper we propose a method for solving the strategy based congested transit assignment of passengers to lines in a transit system, when there apply strict capacity constraints in the line capacities. Initially, the model was stated initially by Cominetti and Correa (2001) [Common-lines and passenger assignment in congested transit networks. Transportation Science 35 (3), pp 250-267] assuming that capacity limitations were imposed implicitly by effective frequency functions on boarding links. In this paper it is shown how exploiting the reformulation of the problem as variational inequalities made by Codina (2013) [A variational inequality reformulation of a congested transit assignment model by Cominetti, Correa, Cepeda and Florian, Transportation Science. 47 (2), 231-246], a simple adaptation of the MSA heuristic method can be derived using for each of the linear capacitated problems an ad hoc adaptation of the dual cutting plane method. The solutions of the method are always capacity feasible even in cases of extreme congestion. Computational tests have been carried out on several medium and large scale networks showing that the method presents a better performance.

2 - Transportation Planning in a Sharing Economy Setting
Moritz Behrend, Frank Meisel

The rise of the sharing economy fosters a shift from a purchase-based towards an access-based consumption. After all, the appeal of purchasing items that are used on rare or just temporal occasions dwindles when, as a member of a sharing community, one can access them need-based. Examples for such items are tools, children's clothing, or leisure equipment. The matching of supplies and demands of such items within a community can be coordinated via online platforms. The actual forwarding poses a transportation challenge, as the peer-to-peer exchange needs to address the highly inefficient "last mile" twice. We model the resulting logistics-planning problem on a network of given supplies, demands, and planned trips of the community members. Mathematical optimization models are developed to assign supplies to demands in a first step and, in a second step, to modify the given trips so as to pickup and drop-off the items at acceptable effort for the travelling community members. The optimization models resemble assignment problems and vehicle routing problems. In this talk, we discuss the problem setting and the developed models in detail. We analyze to which extent these problems can be solved using standard MIP-solvers like Gurobi and what logistical benefit a sharing community can gain from such an approach. For this purpose, we propose a first set of benchmark instances together with detailed computation results.

3 - On some practical issues with trip planning in transportation networks
Alexandre Iglesias, Dominique Feillet, Dominique Quadri

Within the course of a PhD thesis with our industrial partner Cityway, we aim to improve its multimodal trip planner. The problem can be described as follows: given a departure time and start/end locations, we want to find the best trip, which arrives at the earliest time possible while minimizing the number of transfers and other criteria like the total walking time. Before our work began, Cityway's trip planner computed shortest paths with a mono-objective Dijkstra algorithm on a time-dependent graph. Because of industrial constraints, and because we want to minimize regressions of a very rich code, we improved the existing product without changing the structure of the graph. Therefore we chose to implement a multi-objective algorithm based on Martins algorithm, and experimented on 3 very different public transportation networks. We will describe the new algorithm, and provide experimental results, in the matter of quality and compute time. We will then focus on the difficulties encountered linked to specific needs, like the reverse calculation to depart at the latest time possible. We will conclude with how we can apply the multi-objective code to other criteria, like fares or diversity of solutions.

■ MA-18

Monday, 8:30-10:00 - Building CW, ground floor, Room 023

Case Studies

Stream: Production and Operations Management
Chair: *Jânio Neri*
Chair: *Maria Mavri*

1 - Analyzing logistics risk in food supply chain using AHP and ANP methods
Thi Huong Tran, Sebastian Kummer

The recent emergence of a series of food scandals and a plethora of product recalls demonstrated the increasing complexity of managing the food supply chain. That leads to a significant attention of practitioners and researchers on risk management of the chain "from farm to fork". The food supply chains comprise distinctive characteristics namely great dependence on environment, close links to material, high requirement for storage and transportation, massive uncertainty of market, and strict quality requirement. As a result, various types of risk do exist, including quality risk, logistics risk, inventory risk, structural risk, information risk, cooperation risk, market risk, and environmental risk. In which, logistics risk has a significant impact on the integrity, performance and sustainability of food supply chain. Logistics risk in food supply chain stem from either unique characteristics of service (such as intangibility and labour intensity) or typical features of food especially perishable products as well as logistics technology and management. This paper, firstly, investigates logistics risk factors in food supply chain by literature review and expert interview. Next, Analytic Hierarchy Process (AHP) and Analytical Network Process (ANP) models are applied to investigate significant level as well as interrelationship of these risk factors. These analyses are conducted in the real case of seafood supply chain in Vietnam.

2 - Automated system of electronic waste management of a steel in Brazil
Jânio Neri, Kelly Costa, Eliane Christo, Amanda Mendes

Electronic waste is a recent problem due to advancement in technology in recent years and accelerated discard that these advances have caused to electronic components. These wastes have in their composition of heavy metals like lead and mercury, which are some of the most toxic substances known to human health. Currently there are selective collection programs, recycling and gathering for waste electrical and electronic equipment (WEEE), or e-waste as it is popularly known. This work aims to analyze and propose improvements to the issue the fate of these electronic waste in a large steel company in Brazil. Through the analysis of data collected in the company, it has developed a mapping of WEEE management process that resulted in an automated system that forms a database for temporary storage control and final destination of waste. This computer modeling has brought benefits to the company such as increasing the reuse rate of electronic equipment and greeting with Brazilian legislation.

Keywords: Waste electrical and electronic equipment (WEEE), information technology, management system

3 - A proposed research methodology to investigate the lack of lean manufacturing implementation in Libyan manufacturing companies
Mohamed Abduelmula, Martin Birkett, Chris Conner

Lean manufacturing systems have been developed to eliminate or reduce manufacturing waste and thus improve operational efficiency in manufacturing processes. The concept of lean thinking originated from the Toyota production system that determined the value-added activities or steps from non-value added activities or steps; and eliminating waste so that every step adds value to the process. This study examines the quality management processes which are utilized by Libyan manufacturing companies, and offers a methodology to develop lean manufacturing framework. The literature review identified very few studies relevant to the use of lean system and quality improvement techniques in Libya; and no previous studies related specifically to waste reduction and lean systems, and the barriers that prevent lean manufacturing from being implemented in Libyan manufacturing companies. There are several difficulties that are facing lean manufacturing implementation in Libya such as lack of top management support, poor awareness of the importance of the system from workers, absence of lean training programs, and inadequate infrastructure and economic support. A research methodology is presented in this study to determine the barriers behind the lack of lean manufacturing implementations in the Libyan manufacturing sector. A developed framework could help improve the understanding of difficulties that could face the implementation of the manufacturing systems, as a new and modern system.

4 - Defining the cost of producing an object by traditional and 3D manufacturing procedure
Maria Mavri, Evgenia Fronimaki, Stella Zounta

3D Printing or Additive Manufacturing (AM) is a technological process that converts digital files into solid objects. 3D printers use raw materials and based on a digital plan convert materials into an object, printing layer by layer. This technology allows the development of customized products without incurring any cost penalties in manufacturing as neither tools nor molds are required. The result of this technology is the redefinition of production systems as the new production line is the combination "Design-Sales-Printing". As all manufacturing companies, AM companies have to be concern about: costs (operational costs, distribution costs, overheads); quality (product quality; reliability); profitability and customer satisfaction. At the same time, AM companies differ from traditional manufacturing companies as they are flexible to operate without pressure to decrease manufacturing cost in order to increase outputs. They could increase their sales by selling new innovative product schemes. The goal of this paper is to develop a cost model that includes all necessary parameters (cost of hardware and printer, operational costs, energy cost, cost of designers and employees, cost of production time) in order to estimate the cost of producing the same object both by traditional and 3D manufacturing procedure.

■ MA-19

Monday, 8:30-10:00 - Building CW, ground floor, Room 021

Lot Sizing, Lot Scheduling and Related Problems 1

Stream: Lot Sizing, Lot Scheduling and Production Planning
Chair: *Pedro Amorim*

1 - Experiences from Implementing Production Planning Systems in Practice
Stefan Droste

Modelling and solving capacitated lot-sizing problems is a very active research topic. Therefore, much theoretical and practical progress has been made in formulating constraints in MIP (mixed-integer programming) models and solving these models by heuristic or exact methods. In many cases, benchmark instances are used, being generated from scientists for scientists.

At EURO 2013 we presented models and algorithms of our production planning system at INFORM GmbH with first practical experiences. In the last three years, this system was implemented at our first customers and is now running every night optimizing up to 7000 products while considering capacity constraints of 40 different resources. Due to the large scale of the instances, a decomposition heuristic and iterated solving of resulting MIPs is used.

While this approach is also common for solving benchmark instances, there were a number of problems rarely described in the scientific literature, e.g., numerical impreciseness in the customer's input data but also the solver's output, non-standard requirements of the customer, robustness in the face of data inconsistencies, and efficient usage of given hard time limits. In this talk we discuss the solutions of these problems, essential for our successful practical implementation.

2 - An Algorithm for General Infinite Horizon Lot Sizing with Deterministic Non-stationary Demand
Milan Horniaček

We present an algorithm for solving an infinite horizon discrete time lot sizing problem with deterministic non-stationary demand and discounting of future cost, with zero lead time and without backorders. Besides non-negativity and finite supremum over infinite horizon, no restrictions are placed on single period demands. (In particular, they need not follow any cyclical pattern.) Variable procurement cost, fixed ordering cost, and holding cost can be different in different periods. The algorithm uses forward induction and its essence lies in the concept of critical period. Period j following t is the critical period of t if satisfying demands in any set of periods between t and j, including j and excluding t, from an order in t is not more expensive than satisfying it from an order in a later period and j is the last period with this property. (If the critical period is the same for several consecutive periods, an order is placed only in the first of them.) When deciding whether to place an order in period t, all demands from t to its critical period are taken into account. Thus, for each period t, we determine the last period in which demand is served from an order in t, not (as in Wagner - Whitin algorithm) the period in which an order satisfying demand in t is placed. We can compute optimal ordered quantities for any finite number of consecutive periods without computing them for the rest of the time horizon of the model.

3 - Integrated procurement and reprocessing planning of perishable and re-usable medical devices in hospitals
Steffen Rickers, Florian Sahling

We present a new model formulation for a multi-product economic order quantity problem with product returns and reprocessing option (OORPP, Optimal Order and Reprocessing Planning Problem). Both the limited shelf life of sterile medical devices as well as capacity constraints of reprocessing and sterilization resources have to be considered. The time-varying demand is known in advance and must be satisfied by procuring new medical devices and/or by reprocessing used and/or expired ones. The objective is to determine a feasible procurement and reprocessing schedule that minimizes the incurring costs.

A relax-and-fix heuristic is combined with a fix-and-optimize heuristic to determine a procurement and reprocessing schedule for the OORPP. Our numerical results illustrate the high solution quality of this combined solution approach.

4 - Robust Optimization and Stochastic Programming Approaches for the Lot Sizing and Scheduling Problem
Eduardo Curcio, Pedro Amorim, Douglas Alem, Bernardo Almada-Lobo

In this work, a robust optimization model and a two-stage stochastic programming model are proposed to tackle demand uncertainty in the General Lot-sizing and Scheduling Problem (GLSP). These models use different methods/parameters to hedge against uncertainty. The robust optimization approach relies mainly on the budget of uncertainty and robustness level, whereas in the stochastic programming model the number of scenarios and the demand distribution pattern assumed play a key role. To compare the performance of both modeling approaches across distinct instances a simulation approach is developed. The results provided by the simulation expose the trade-offs between the modeling approaches. Moreover, the combination of the models with simulation contributes to the assessment and achievement of high quality solutions for the GLSP under demand uncertainty.

■ MA-20

Monday, 8:30-10:00 - Building CW, ground floor, Room 022

EWGLA: Hub Location

Stream: Location
Chair: *Sibel A. Alumur*
Chair: *Francisco Saldanha-da-Gama*

1 - An exact solution approach for single allocation hub location problems with multiple capacity levels
Borzou Rostami, Christopher Strothmann, Christoph Buchheim

In this paper we propose an exact branch-and-bound algorithm for single allocation hub location problems with multiple capacity levels. This problem is an extended version of the classical capacitated single allocation hub location problem in which the size of the hubs must be chosen from a finite and discrete set of allowable capacities. We develop a Lagrangian relaxation to obtain tight upper and lower bounds. The Lagrangian function exploits the problem structure and decomposes the problem into a set of smaller subproblems that can be solved efficiently. Upper bounds are derived by Lagrangian heuristics followed by a local search method. Moreover, we propose some reduction tests that allow us to decrease the size of the problem. Our computational experiments on some challenging benchmark instances from literature show the advantage of our approach over commercial solvers.

2 - p-hub location problems with economies of scale
H.a. Eiselt, Armin Lüer-Villagra, Vladimir Marianov

This presentation considers p-hub problems with the usual assumption that inter-hub traffic receives significant discounts. These discounts are based on the notion that inter-hub traffic is typically much heavier than traffic between spokes and hubs, so that economies of scale apply. However, it may very well turn out that traffic in an inter-hub connection is actually quite low, i.e., below a given threshold, so that a discount is not justified. Similarly, traffic in hub-to-spoke connections may be sufficiently high so as to justify a discount where none is given in the mathematical model. If a solution to such a "fundamental model" were to be applied, we would have to cancel discounts of come arcs as the flow does not justify their use. This results in non-optimal solutions. We formulate a mathematical model that locates p hubs, while awarding discounts in all direct connections, in which the traffic flow equals or exceeds a given threshold. Some standard problem set is solved, and the results are evaluated by way of some set of performance indicators, including the average route length, the average number of legs of a route, and the fraction of discounted arcs. Computing times range from a little more than a minute to about seven hours. The results show significant improvements with our model.

3 - Properties of a graph transformation to the hub and spoke structure
Jan Wojciech Owsinski, Jarosław Stańczak, Aleksy Barski, Krzysztof Sęp

Transport systems are quite often represented as graphs, where nodes correspond to stops, stations, airports, etc. Edges represent connections or transfers between two nodes. Such a real-life graph is often non-ordered and has a random structure. This fact largely results from the need to establish direct bilateral connections between certain pairs of nodes. In many cases, such an initial structure can be rearranged and transformed into a hub & spoke structure, where each final node-a spoke-is associated only with its hub - the interchange and communication node. Hubs have direct connections with the other hubs (in the ideal case with all the other hubs-the subgraph of hubs should constitute a clique). In such a situation, the longest communication between the spoke nodes, belonging to different hubs, may be treated as a path: SPOKE_A-HUB_1(-HUB_2)-SPOKE_B, with maximum two interchanges. It is possible to improve service frequencies and travel times on routes in such modified graph. Of course, such improvement is not always possible, or it can be difficult when, e.g., the hubs are poorly connected with each other and some travels may require a bigger number of transfers. However, even in the graph with an appropriate structure such a transformation must not always yield benefits. Estimation of a possible profit in terms of time and establishing the conditions for the profitability of such processing for the simple graph of connections is considered in this work.

■ MA-21
Monday, 8:30-10:00 - Building CW, ground floor, Room 025

Train scheduling: real-time and planning

Stream: Public Transportation
Chair: *Valentina Cacchiani*

1 - Ant colony optimization for the real-time train routing selection problem
Marcella Samà, Paola Pellegrini, Andrea D'Ariano, Joaquin Rodriguez, Dario Pacciarelli

The growth of demand forces railway infrastructure managers to use the existing infrastructures at full capacity. During daily operations, disturbances may happen and they may lead to conflicting requests, i.e., time-overlapping requests for the same tracks by multiple trains. The real-time railway traffic management problem (rtRTMP) aims to minimize the delay propagation using simultaneously timing, ordering and routing adjustments, decided in real-time. The problem size and the computational time required to find a good quality solution are strongly affected by the number of alternative routings available to each train. To ease the solution process, we study the real-time train routing selection problem (rtTRSP): a subset of routings for each train is chosen and used to solve the rtRTMP. The rtTRSP is modelled as an N-partite graph. Each partition represents the alternative routings of a particular train. The problem is solved using an ant colony optimization algorithm. Here, each ant progressively builds a solution by assigning one routing to each train. The assignment is the result of a stochastic selection, biased by heuristic information and pheromone trails. A pool of good quality solutions are generated and used to compute the input of a real-time railway traffic management solver. In a thorough experimental analysis, we show that the preliminary solution of the rtTRSP may have a remarkably positive impact on the rtRTMP solution.

2 - Benders Decomposition for the real-time Railway Traffic Management
Kaba Keita, Paola Pellegrini, Joaquin Rodriguez

The traffic in the railway network is often very heavy in critical points at rush hours. Hence, when a disruption occurs and the traffic is perturbed, conflicts may occur. Consequently, some trains must be stopped or slowed down for ensuring safety, and delays occur. Modifying trains route and schedule to limit delay propagation is the aim of the real-time Railway Traffic Management Problem (rtRTMP). Some optimization algorithms exist to tackle it. However, they can hardly solve very large instances when considering a microscopic representation of the infrastructure. In this study, we propose a Benders decomposition approach to increase the size of the instances which can be effectively tackled. In particular, we decompose the mixed integer linear programming formulation in RECIFE-MILP [Pellegrini et al, RECIFEMILP : An Effective MILP-based Heuristic for the Real-Time Railway Traffic Management Problem, IEEE Transactions on Intelligent Transportation Systems, 16(5), 2609-2619 2015]. In our Benders decomposition train routing and scheduling decisions are made in the master problem. Given these decisions, we compute the trains actual arrival times in the slave problem to deduce the total delay. By applying our Benders decomposition to RECIFE-MILP, we tackle instances representing traffic in the junction of Gonesse, in France. The results are promising.

3 - High Speed Train Timetable Planning for the Chinese Railways
Feng Jiang, Valentina Cacchiani, Paolo Toth

The Train Timetabling Problem (TTP) calls for determining, in the planning phase, an optimal schedule for a given set of trains, while satisfying track capacity occupation constraints. In this work, we consider TTP of the high-speed trains at the Chinese railways: we are given on input a set of feasible timetables for the trains already planned along the line, and the main goal consists of scheduling as many additional trains as possible. For each additional train, we are given its departure time, its traveling time between each pair of stations and its set of compulsory stops with the corresponding minimum stopping times. In order to schedule the additional trains, we are allowed to change their departure times and to increase their stopping times. Furthermore, we investigate the possibility of modifying the timetables of the already planned trains, even by changing their stopping patterns (i.e., we allow to add or remove some stops). A second objective we consider is to obtain a regular schedule, i.e., a schedule showing regularity in the train frequency at the main stations. We propose a heuristic algorithm to solve TTP with the described objectives, and test it on real-world instances of the Beijing-Shanghai line, that is a double-track line with 29 stations along which more than 300 trains run every day between 06:00 and midnight.

4 - Resolving infeasibilities in railway timetabling instances
Gert-Jaap Polinder, Leo Kroon, Marie Schmidt

One of the assumptions of current (cyclic) timetabling algorithms is that a feasible solution exists. If so, in most cases a timetable can be found rapidly, for example by the CADANS solver for the Dutch case. However, this assumption is not satisfied in most current railway cases. In fact, since railways are being used more intensively and frequencies of train lines are increasing, the conflicts in the timetabling problem become increasingly more important. No timetable exists satisfying all constraints. This has led to planners at Netherlands Railways not using CADANS anymore and doing the planning by hand.

In this paper, we propose an algorithm that can find a timetable by changing as few constraints as possible. Constraints on safety cannot be changed, while for example constraints on trip times or frequencies can be changed. Knowing the changed constraints, more insight is obtained into the reason for the conflict.

If no timetable exists, the Dutch solver CADANS returns a set of constraints that form a conflict. This is used to resolve it, together with some more constraints. Next, CADANS is used again to find a timetable or detect another conflict. In this way a timetable is obtained iteratively. For the full Dutch network, this procedure found around 25 conflicts and changed 40 constraints to find a feasible timetable. This was all done within 2.5 hours of computation time. Solutions were obtained within 45 minutes as well, but then more constraints were changed.

■ MA-22

Monday, 8:30-10:00 - Building CW, ground floor, Room 027

Routing and navigation with route quality measures

Stream: Combinatorial Optimization
Chair: *Evgeny Gurevsky*
Chair: *Sergey Kovalev*
Chair: *Mikhail Y. Kovalyov*

1 - An exact method for multi-objective multi-modal trip planning problem

Sergey Kovalev, Romain Billot

A multi-objective multi-modal trip planning problem is studied. In this problem a traveler is supposed to choose and rank a set of trip-related criteria like minimization of traveling time, minimization of public transport changes, or maximization of visited points of interest. A planner, equipped with supercomputing resources, applies a Boolean Linear Programming model to each problem related to a certain criterion. Problems are solved sequentially according to the lexicographic order determined by the traveler's ranking. BLP models are time-indexed, which means that each node in a multimodal network keeps the information not only about a geographical point but also about the discrete time of a departure or arrival event. The proposed solution method was tested on a real urban transport network with 22143 nodes and about 360000 arcs. The obtained results are promising and present a basis for using the proposed method in real conditions.

2 - Converting OSM data into a routable graph for pedestrians

Sebastian Naumann, Anita Graser, Markus Straub

Pedestrians usually do not walk on roads. They walk on sidewalks if available or on special ways where cars are not allowed. In order to get from one sidewalk to another one, roads have to be crossed. In the inner city, pedestrians usually find dedicated crosswalks (zebra crossings and signal controlled crossings). In peripheral areas, dedicated crosswalks are rare and pedestrians are forced to cross roads without such help. The main goal of this work is to create a routable graph from OpenStreetMap (OSM) - consisting of nodes and edges - which exactly represents the ways actually used by pedestrians. This means that if the OSM "sidewalk" tag is one of the possible values "left", "right" or both", the road is replaced by the sidewalk(s). Corresponding sidewalk edges as well as zebra crossing edges are constructed and finally connected. In order to enable road crossing not only at dedicated crosswalks, additional equidistant edges are inserted into the graph similar to dedicated crosswalks. To furthermore support realistic crossing of squares and plazas - which are represented as areas in OSM - visibility graphs are constructed for the square polygons and integrated into the routing graph. Results show that this workflow enables us to create a pedestrian routing graph, which supports more realistic pedestrian routing and navigation than the original OSM graph does.

3 - Combinatorial problems of risk management for routing and network design

Evgeny Gurevsky, Sergey Kovalev, Mikhail Y. Kovalyov

The principal object of this study are recently introduced combinatorial problems of risk management, which were investigated within the framework of routing and network design. Earlier publications explore the following three tasks: total risk minimization, maximal risk minimization and constrained risk problems. All these problems were proven to be either polynomially or pseudo-polynomially solvable.

Our main contribution deals with extending and improving the results obtained earlier. Namely, at first we show that the studied problems are also polynomially (resp. pseudo-polynomially) solvable for a new class of risk functions that is larger than that presented before. Secondly, we suggest an original resolution approach that outperforms, in terms of running time, the algorithms developed earlier. Finally, based on the suggested approach, we show how to find a set of efficient (Pareto optimal) solutions of a bi-criteria version of the considered problems.

4 - A study on the Hybrid Method of the Genetic Algorithm - Particle Swarm Optimization for the Transportation Problem with Fixed Costs and Non-linear Unit Costs.

Kiseok Sung

We present a hybrid method of the Genetic Algorithm - Particle Swarm Optimization for Transportation Problem with Fixed Costs and Non-linear Unit Costs(TFANUC). Since the TFANUC has the property of 0-1 mixed-integer program with non-linear objective function and linear constraints, it is hard to maintain the feasibility of the problem when we use either the Genetic Algorithm(GA) or Particle Swarm Optimization(PSO) only. The proposed method is a bi-level procedure consist of GA and PSO. The GA is used in the upper level to optimize the connectivity of the transportation path between each supply and demand pair. The PSO is used in the lower level to optimize the amount of transportation between each supply and demand pair. The proposed bi-level procedure is iterated until the certain criteria are satisfied by the solutions obtained. In the upper and lower level of procedure, the solutions are verified of the feasibility and modified if it is necessary to maintain the feasibility.

■ MA-23

Monday, 8:30-10:00 - Building CW, ground floor, Room 028

Dynamical Systems of Graphs and Networks

Stream: Graphs and Networks
Chair: *Jörg Rambau*
Chair: *Peter Hegarty*

1 - Techniques for analysing the Hegselmann-Krause dynamics

Edvin Wedin

Multi-agent systems are used in such diverse fields as biology, robotics and social sciences. They aim to simulate complex phenomena by defining a number of so-called agents, which move around in some state-space following rules which themselves depend on the current state of the system. A common feature of these systems is that the movement of an agent does not depend on all other agents, but only on the states of a select few of them, for example those whose states are sufficiently similar to its own.

One of the simplest dynamical systems with this feature is the so-called Hegselmann-Krause dynamics (HK-dynamics for short). For some normed state space, often the real line, each agent filters out those others whose states differ from its own by more than some given threshold, whereupon each agent, simultaneously and in discrete time, updates its state to the average state of those left by the filtering.

Already for these simple dynamics, not much is known for general initial conditions; most of the work on the topic has instead been concerned with the evolution of particular classes of configurations. Some of our own work considers configurations which are periodic, which take an unusual amount of time to converge, as well as random configurations in which the number of agents tends to infinity. In this talk, we discuss some of the techniques used, hoping they will find use in the study of not only this, but also related models.

2 - Opinions and diplomacy in the presence of uncertain confidence radii
Jörg Rambau, Andreas Deuerling

Confidence graphs emerge in the Hegselmann-Krause model for the dynamics of opinions of a finite set of agents. Opinions are represented by real numbers in the unit interval, the opinion space. There is one global parameter, the confidence radius. The confidence graph of a stage is the graph with all agents as nodes. Two agents are connected by an edge if the distance of their current opinions is at most the confidence radius. The opinion of any agent changes in each stage to the average opinion of all its neighbors in the confidence graph, in general changing he confidence graph of the next stage. In 2015, Hegselmann et al. introduced the notion of optimal control in this structure: an additional opinion of a single strategic agent can be placed freely into the opinion space. It participates in the dynamics in the same way as all other opinions. The goal is to have, after a given number of stages, as many opinions as possible in a given subset of the opinion space. Because of its mild mode of intervention such a control is called a "diplomacy". Hegselmann et al. have shown 2015 that globally optimal diplomacies are difficult to compute in practice, and modelling the dynamics of confidence graph is crucial for it. In this presentation, we show how the performance of optimal diplomacy changes if the confidence radius is uncertain and how robust optimal controls can be characterized. Parts of this research stem from the Master's thesis of Andreas Deuerling (Bayreuth).

■ MA-24

Monday, 8:30-10:00 - Building BM, 1st floor, Room 119

Defence and Security 1

Stream: Defence and Security
Chair: *Ana Isabel Barros*

1 - Force Structuring Optimization Model
Okan Arslan, Ahmet Kandakoglu

The plan that frames the structure of the aircraft and weapon systems of an air force is called a 'Force Structure Plan'. Under the pressure due to decreasing financial resources, it is of utmost importance to allocate the budget properly among alternative systems in order to obtain the desired operational results. In this context, the 'Force Structuring Optimization Model' (FSOM) serves as a platform to evaluate different scenarios for acquisition of aircraft and weapon systems. FSOM considers the budget, operational requirements and possible aircraft losses during an operation, and puts forward the required aircraft and weapon configuration to establish the desired impact on a set of targets. The applicability of the model is tested on several generic scenarios. FSOM resulted in a saving of 500K to 1M liras that would otherwise be outsourced. It currently provides support for robust solutions for the decision makers.

2 - Missile Target Rescheduling Problem of a Naval Task Group
Ahmet Silav, Esra Karasakal, Orhan Karasakal

In this study, we develop a new bi-objective model that considers rescheduling of surface-to-air missiles for a naval task group, where a set of them have already been scheduled to a set of attacking air targets. The model provides change on the initial engagement plan since the conditions during the engagement process change with new incoming threats, existing threats being destroyed or breakdown of an air defense system. The objectives of the model are defined as the difference between new and initial schedule and the survival probability of naval task group. We solve different size problems by augmented ϵ-constraint method and newly proposed heuristic procedures. In order to predict decision maker (DM) utility function, a learning algorithm based on artificial neural network approach that uses a set of evaluated alternatives is suggested. Assuming that the DM's preferences are consistent with a quasiconcave value function, we propose a new solution approach in order to generate efficient solutions.

3 - Integrated Scheduling Approach for Future Capability Development Based on Genetic Algorithm
Michael Preuß

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

4 - Solving a Military Training Problem as a Multiobjective Quadratic Assignment Problem
Slawo Wesolkowski, Nevena Francetic, Jeff Watchorn

The Quadratic Assignment Problem (QAP) is a well-known problem in operations research. The problem addresses the optimal placement of n facilities given a set of n locations, and a set of flows between facilities. The solution of the QAP is to minimize total assignment cost; that is, the sum of the flows between facilities multiplied by the corresponding distances between the locations. When additional quadratically related objectives (e.g., operational and travel expenses) are created, the problem becomes a multi-objective QAP (mQAP). The systems which can be modelled by QAPs or mQAPs are numerous and complex (e.g., system scheduling, traffic flow analysis, and VLSI synthesis), with results which are important to both research and industry. Several methods for obtaining exact solutions of QAPs, which are generally applied to small problems (n < 30), have been outlined by Burkard. As solution spaces increase in size, exact solution methods are no longer feasible due to memory and computational time constraints; thus, heuristics are needed. Historically, genetic algorithms have been discounted from the set of possible heuristics in favour of other methods despite showing comparable results. However, it has been hypothesized that with more sophisticated reproduction or mutation schemes, a further gain in the performance of evolutionary algorithms applied to QAPs may be achieved.

In this paper, we present a new type of mQAP based on a military training problem with three quadratic assignment objectives and one linear assignment objective. The quadratically related objective analogous to the traditional QAP is the travel cost, where distances are computed between trainee and device locations (represented here by travel costs), while flows represent the number of trainees traveling to a device location. Moreover, training time and training cost depend on the type of device used for a given task training. However, training devices of different types have different capacities; that is, the number of trainees who can train at the same time. Depending on the combination of training devices chosen for completion of a task by all trainees, we obtain a variable "flow" of trainees through devices of each type. The capital cost (associated with acquiring a new device) is a linear assignment objective.

In this paper, we explicitly formulate the Training Device Estimation (TraDE) model as an mQAP which more clearly contextualizes the novelty and usefulness of the proposed mixing mutation operator. We use TraDE to explore mutation and cross-over operator combinations for multi-objective genetic algorithms for the use in mQAPs. In genetic algorithms, mutation and crossover operators are usually applied to a parent population in order to generate a child population. These mutations are applied in the form of random variations to chromosomes at a given mutation probability. The standard mutation operator is applied to the entire chromosome of a population member.

In our mQAP, each population member is described by a two-part multi-dimensional chromosome which defines the requirements of a specific training task by representing the device and location assignments for all trainees. Each solution is a multi-chromosome composed of numerous two-part genes (as many as there tasks). The first part corresponds to training device assignments and the second to device locations. The objective functions are based on the sum of the device assignments for all tasks. The standard mutation operator is not sufficient for our mQAP because the individual gene parts, although dependent, need to be treated independently in order to more efficiently explore the problem solution space.

We propose a modification to the standard mutation operator, the mixing mutation operator, where each part of a chromosome mutated concurrently with a standard operator, will now be mutated asynchronously. That is, for a population member represented by a multi-dimensional multi-chromosome (in this case a two-dimensional multi-chromosome), one of the dimensions will be chosen (with equal probability) and mutated. Our mixing mutation operator differs from previous operators on multi-chromosomes given that it mutates many more than one gene per chromosome and only mutates genes along a single direction (either trainee device assignments or device locations). One-dimensional multi-chromosomes have also been used for military fleet sizing problems where a standard mutation operator was used. Mixing mutation forces the exploration of a larger set of possible solutions for any problem which is formulated using a multidimensional chromosomes (whether or not they are multi-chromosomes).

In this paper, we propose a principled comparison between the standard and mixing mutation operators with and without the crossover operator. The comparison is carried out on a test problem in which all optimal solutions are known in order to better assess algorithm convergence (the initial problem addressed with the TraDE model was focused on a real world scenario where an exhaustive search was not possible).

We show that with the addition of a more sophisticated mutation operator, the rate of convergence of NSGA II to the Pareto front for the TraDE model, an mQAP, and the extent of Pareto front coverage was greatly increased. Additionally, the implementation of the mixing mutation operator in conjunction with a crossover operator yields an impressive average coverage rate of approximately 95% (as compared to 80% for the standard mutation/crossover combination) after 5,000 generations. The number of solutions which are discovered when the mixing operator without crossover is used is double the number of solutions which are discovered by the standard operator without crossover.

Moreover, combining mixing mutation with the standard crossover operator also yields results which are more consistent due to a lower standard deviation of the number of solutions in the non-dominated front. That is, the method does not only converge to a larger average number of solutions, it also converges with the lowest standard deviation between results. Thus, our study has demonstrated that when using the mixing mutation operator with NSGA II, an mQAP can be solved very effectively and efficiently.

■ MA-25

Monday, 8:30-10:00 - Building BM, ground floor, Room 19

General behavioural OR papers

Stream: Behavioural Operational Research
Chair: *L. Alberto Franco*

1 - Engaging with behavioural OR: On methods, actors, and praxis

L. Alberto Franco, Raimo P. Hämäläinen

In this presentation, we highlight the importance of the behavioural perspective to advance the discipline of operational research (OR). The power of this perspective lies in its ability to identify the conditions under which the impact of OR-supported processes is enhanced or hindered by behavioural factors, with a view to developing more effective OR practice. To help organise and guide the conduct of empirical studies in the sub-discipline of behavioural OR (BOR), we draw on practice theories from the social and organisational sciences to propose an integrative framework based on the three central concepts of OR methods, OR actors, and OR praxis. In discussing these concepts, we will refer to the developing empirical BOR literature to highlight alternative analytical foci. Finally, we will discuss the implications of the behavioural perspective for the OR community, particularly with regards to foregrounding OR praxis in academic papers, attending to a wide diversity of OR actors, developing OR competences, and the role of theory and research methodology.

2 - Path Dependence in Operational Research - How the Modeling Process Can Influence the Results

Tuomas Lahtinen, Raimo P. Hämäläinen

In Operational Research practice there are almost always alternative paths that can be followed in the modeling and problem solving process. Path dependence refers to the impact of the path on the outcome of the process. The steps of the path can include, e.g., forming the problem solving team, the framing and structuring of the problem, the choice of model, the order in which the different parts of the model are specified and solved, and the way in which data or preferences are collected. Behavioral and social effects are likely to be the most important drivers of path dependence in OR. We identify and discuss seven possibly interacting origins or drivers of path dependence: systemic origins, learning, procedure, behavior, motivation, uncertainty, and external environment. Awareness of path dependence and its possible consequences is important especially in major policy problems in areas such as environmental management and in long term policy analyses involving deep uncertainties. The existence of path dependence emphasizes the importance of early reflection in the beginning of the OR process. We provide several ideas on how to cope with path dependence.

3 - Manipulating Expert Risk Perception through Visual Information Format

Ross Ritchie

In this presentation we examine the impact of different visual information formats on experts' perceptions of risk. We report on an experimental study in which 367 police officers completed six electronically delivered briefing communications reporting their perceptions of risk, and recording information viewing time and time in judgement. In turn, these experiments manipulated the information format through use of colour coding (red, amber, green), technical abbreviations versus plain text and inclusion of uninformative data items. We test whether viewing time pressure acts as a mediator or moderator in perception formation. The results show that neither the use of colour coding nor incremental inclusion of uninformative data items affects the perceptions of risk or viewing time, whereas increasing the use of technical abbreviations does increase perceptions of risk. It was found that viewing time pressure acts a moderator on perceptions, but only under extreme criteria. Analysis of respondents also demonstrated a significant effect of the officer's rank, where an increase in rank led to a consistent reduction in perceived risk for the same information.

The research reported here contributes to further our understanding of the relationship between the type of visual information used by experts in hazardous and high information perishability situations and their perceptions of risk. Implications for the theory and practice of visual risk assessments will be discussed.

■ MA-26

Monday, 8:30-10:00 - Building BM, 1st floor, Room 109D

Dynamical Models in Sustainable Development 1

Stream: Dynamical Models in Sustainable Development
Chair: *Reza Fazeli*

1 - Renewable Energy Project Evaluation in Uncertain Regulatory Environment: Case of Offshore Wind Industry
Negar Akbari

Investments in renewable energy projects have experienced major growth in the past two decades. Yet the regulatory uncertainties associated with the renewable energy policies, may have a negative effect on the investments in the industry in the coming years. Large scale renewable energy projects are capital intensive, for which investors need a high degree of confidence in their decision making process. Hence models that take into account these uncertainties such as changes in Feed-in Tariffs and subsidy termination, are proposed for project evaluation. In this seminar, a model is proposed to assess project investments under different regulatory schemes and scenarios. The case of offshore wind industry is considered and the model aims to aid decision makers to evaluate the offshore wind projects and assess different options given incomplete information and uncertainty.

2 - A Service Network Design Model for Multimodal Municipal Solid Waste Transport
Dirk Inghels, Wout Dullaert, Daniele Vigo

A modal shift from road transport towards inland water or rail transport could reduce the total Green House Gas emissions and societal impact associated with Municipal Solid Waste management. This shift will however only take place if it shows to be at least cost-neutral for the decision makers. In this paper we examine the feasibility of using multimodal truck and inland water transport instead of truck transport for shipping separated household waste in bulk, from collection centres to waste treatment facilities. We present a dynamic tactical planning model that minimizes the sum of transportation costs, external environmental and societal costs. The so-called Municipal Solid Waste Service Network Design Problem allocates Municipal Solid Waste volumes to transport modes and determines the transportation frequencies over a planning horizon. The generic model is applied to a real-life case in Flanders, the northern region of Belgium. Computational results show that multimodal truck and inland water transportation can compete with the current truck transport by avoiding or reducing transhipments and using barge convoys.

3 - Optimizing the insertion of renewables in the Colombian power sector
Felipe Henao, Yeny Rodriguez, Isaac Dyner

Colombia is rich in natural resources and greatly focuses on the exploitation of water for economic and welfare purposes. About 65 percent of its power capacity is large hydropower, while the remaining 35 percent are fossil-based technologies. Predominantly, the participation of hydroelectricity is expected to increase in the near future. Alternative cleaner energy sources have been largely neglected despite the abundance of renewables and the likely complementarities between hydro, solar and wind power. This limited mix of energy sources creates considerable weaknesses for the system, particularly when facing extreme dry weather conditions, such as the El Nino event. In the past, El Nino have exposed the truly consequences of having a system heavily dependent on hydropower, i.e., loss of power supply, high energy costs, and loss of overall competitiveness of the country. This paper proposes a mix-integer lineal programming (MILP) model to optimise the insertion of renewable energy systems (RES) into the Colombian electricity sector and evaluate its financial, environmental, and technical implications. The model considers cost-based generation competition between traditional energy technologies with alternative RES, and how the latter may help the system overcome extreme weather conditions. Particular attention is paid to solar and wind technologies while seeking to minimize system costs, CO2 emissions, and number of blackout events.

4 - A combined multi-criteria and system dynamics methodology for mid-term planning of light duty vehicle fleets
Reza Fazeli

Given that the availability of resources to support technology development and deployment is limited, policy makers are in need of tools to assist them choosing the technologies that are better fitted to their geographic and socio-economic context. In this context, this work designs an original iterative procedure that integrates Multi-Criteria Decision Analysis (MCDA) with System Dynamics (SD) analysis of the alternatives for future passenger light duty vehicle composition. The proposed methodology consists of three main phases: The first phase identifies the alternatives and performs a MCDA analysis, which follows a sequential process of Pareto Optimality followed by a Data Envelopment Analysis based screening and a Trade-off Weights screening; the second phase analyzes the co-evolution of the refueling infrastructure and vehicle sales through time using SD approach; and the third phase ensures that the developed MCDA framework will be re-applied for comparing all the alternatives following an iterative procedure between phases 1 and 2. The applicability of the method were verified through the application to Portugal as a case study. This framework can assist decision makers, in simultaneously identifying the most suitable alternative fuel-technology vehicles and in evaluating the level of required support to achieve a successful transition.

■ MA-27

Monday, 8:30-10:00 - Building BM, ground floor, Room 20

Optimal Stopping and Game Theory

Stream: Dynamical Systems and Mathematical Modelling in OR
Chair: *Elzbieta Ferenstein*
Chair: *Katsunori Ano*

1 - Full-information best choice problem with distribution change in value of options
Aiko Kurushima

This talk presents a generalization of the full-information best choice problem with the case the distribution of the value of the objects changes in the process of selection. This generalization seems to be the situation we presume the economic shrinks or expands in near future. We assume that both the change time of distribution and the number of total options are known, and also the distribution of the options is uniform. We discuss mainly the case of shrinking economy, that is the options are distibuted uniformly between 0 and 1 before the change, and are distributed uniformly between 0 and some constant less than 1 after the change. We also comment the case of detecting the change point, where the change time is unknown. We present the optimal stopping rule for the problem.

2 - On some game with unbounded horizon
Marek Skarupski, Krzysztof Szajowski

In this talk we investigate the game with two players who observe objects: random variables from uniform distribution. They observe them sequentially and decide whether to stop or continue observations. The number of objects is random and comes from geometrical distribution. The aim is to find stopping moments that are a Nash equilibrium in this game. We consider differenttype of choosing the objects. Once one of the players has priority, second when the priority is random and the Nature decides at point at issue which player takes the current observation.

3 - A search allocation game with private information about the effectiveness of detection sensors
Ryusuke Hohzaki

This paper deals with a two-person zero-sum search game, in which a searcher searches for a target and the target moves to evade from the searcher. The searcher distributes a limited amount of search resource or detection sensors into a search space to detect the target and the target moves in it. The payoff of the game is the detection probability of the target. In almost all past researches on the search game, they assumed that both players knows the effectiveness of the searcher's resource, that is, the complete-information game. In this research, however, just the searcher knows the effectiveness because of his ownership of the resource. We derive an equilibrium for the search game and analyze the characteristics of optimal players' strategies. Through the analysis, we investigate the value of the information for the search game.

4 - Elfving stopping time problem with random intensity
Elzbieta Ferenstein, Anna Krasnosielska-Kobos

We consider a variation of the Elfving stopping time problem (Elfving 1967). In the classic case, elements of a sequence of independent identically distributed random variables (values of offers) are observed by a decision maker one by one at the moments of jumps of the Poisson process with a constant known intensity. One selection of an offer is allowed at the moment of its appearance, on the basis of current and past observations. There is no recall to the offers once rejected. The acceptance of the offer results in the reward equal to the discounted value of the offer. The goal of the decision maker is to maximize his expected reward. In our model, the stream of offers' arrivals is a doubly stochastic Poisson process. Its unknown intensity is a random variable which is independent of offers. In the paper, we analyze OLA (one look ahead) stopping time and the corresponding mean reward. In several examples, we compare optimal mean rewards with the OLA solutions.

■ MA-29

Monday, 8:30-10:00 - Building BM, ground floor, Room 7

Health Care Management under Emergency Aspects

Stream: Health Care Emergency Management
Chair: *Gerhard-Wilhelm Weber*
Chair: *Vahid Eghbal Akhlaghi*

1 - Optimization of Medical Bed Resources using Queueing Theory and Hill Climbing
Anders Reenberg Andersen, Bo Friis Nielsen, Line Blander Reinhardt

We present a solution approach to the problem of bed requirements planning, taking three medical wards and three different patient types into account. Our goal is to ensure bed resources are matched with demand as patients arrive to the hospital. If bed resources are insufficient, the patients are not necessarily lost from the system, but relocated to an alternative ward where treatment is commenced. We model the patient flow behavior using a homogeneous continuous-time Markov chain, and optimization is conducted using a Hill climber heuristic. We find the hospital may reduce the total number of rejected arriving patients by 11.7%, by re-distributing bed resources that are already available to them. Adding only 6 additional beds, this rate is reduced to 38.9% instead.

2 - A Simulation-Based Generic Framework for Workforce Planning of Health Centers in Turkey
Tugba Guler Sonmez, Volkan Sönmez

The rising costs in health care, along with the necessity of high quality have led to the need for more efficient and effective management of health centers. Resource planning, has a very important role in increasing quality of any health center. Due to complex structure of health centers, analysis with queuing theory can be insufficient. Moreover, resource plans of a health center should handle severe situations such as accidents as well as routine working days. Such necessities and conditions cause the simulation approach to be utilized in health centers. Additionally, within a computer environment it is possible to evaluate potential consequences of different scenarios without waiting them to happen in real life. In this study, it is aimed to develop a simulation based generic framework to support the decisions on resource planning of health centers. After constructing a general workflow by analyzing common health centers, a simulation model will be developed based on this general workflow. By using a software which will be developed based on the proposed framework, managers can plan workforce effectively, evaluate health centers' performance for different working conditions and simulate different scenarios in a computer environment considering average resource utilization, total waiting time and total number of patients being served. By using the proposed framework, an increase in the quality of services can be achieved and total time the patients spend can be reduced.

3 - Mathematical Models in Hospital Emergency Department: Literature Review
Andres Felipe Hurtado Ariza, Alejandra Quintana, Laura Amaya, Sebastian Hurtado, Lorena Reyes

The mathematical models have been considered as a strategic tool for making decision and improving global performance of patient flow in Hospital Emergency Department (ED). This paper presents an analytical review of literature, focusing in papers related to mathematical tools construction to operations management from ED. Part of the results of this paper is identify that most of the literature has been focused on solving problems related to capacity and scheduling of emergencies staff; and a minor part of literature refers to capacity of the service vs demand, long waiting lines for patients, inefficiency flow of patients, service saturation, among others. However, the most critical and most important problems at a hospital are related with timely health care emergencies, long lead times, low capacity to cover the high demands and the inefficiency in the patient flow. For all the above, this paper examines the different solution methods and how these methods have improved ED performance. To achieve this, the literature review considers papers over the period 2000-2015, intending to ensure an update review of current literature.

■ MA-30

Monday, 8:30-10:00 - Building BM, 1st floor, Room 110

System Dynamics Session 1

Stream: System Dynamics Modeling and Simulation
Chair: *Rogelio Oliva*

1 - The Challenge of Model Complexity: Improving the Interpretation of Large Causal Models through Variety Filters
Lukas Schoenenberger, Alexander Michael Schmid, John Ansah, Markus Schwaninger

While large, i.e., complex, causal models provide detailed insights for those who actually develop them, they often suffer from being inaccessible to outsiders of the modeling process. This is particularly regrettable in cases where large models are carefully crafted by experts and hold potential lessons to learn for academics and practitioners interested in the particular research field. To address this problem, we propose a set of variety filters, i.e., tools to reduce model complexity, to turn the interpretation of large causal models more efficient. A primary variety filter is the recently published algorithmic detection of archetypal structures (ADAS) method. ADAS is a method for the identification of influential structures within causal models, facilitating both model diagnosis and policy design. However, when applied to complex models, ADAS might come to its limits because the number of identified archetypal structures might be too high for a meaningful interpretation. Hence, we propose two additional filters, as precursors to ADAS: structural model partitioning and interpretive model partitioning. We demonstrate the proposed variety filters on the basis of the Obesity System Map—a model containing 108 variables and 297 interdependencies with millions of feedback loops. Through the filters, we are able to reduce model complexity drastically, while enhancing the comprehension of the model.

2 - Boom and Bust Dynamics of Management Tool Implementation

Markus Schwenke, Stefan Groesser

This article aims to promote a dynamic perspective on the issues of sustainable management tool innovation. In particular, we concentrate on tool implementation and subsequent rejection, a pattern that often occurs in businesses. Until now, most research on management tools has mainly relied on survey data, and has failed to account for the dynamics of implementation and subsequent rejection of a management tool. Since initial adoption does not guarantee sustainable implementation, we want to understand discontinuation of tools in order to obtain insights about measures to achieve long-term acceptance. Based on a revelatory case study, we present the process of management tool implementation by means of a systems model. We provide a theory about the underlying dynamics of the boom and bust phenomenon. We have found that environmental, organizational, and tool-related factors contribute to the implementation process. We provide insights on how to overcome the discontinuation by changing the underlying factors and discuss the effort that is associated with this endeavor.

3 - Business Models for Information Products in the Internet Age: A System Dynamics Approach

Evgenia Ushakova

Digital transformation affects the trade of goods and services within economy. Many of these changes have lead to the creation of new forms of information as well as the new opportunities for creating and distributing information products on the Internet. Being able to quickly build up and monetize their user bases, some of the new business models in the online information markets show tremendous growth rates, which often happen at the expense of the traditional business models. However, without sufficient profitability track record, the long-term sustainability of these business models is questionable. Drawing on the insights from information economics and system dynamics, this work presents simulation models to explore the underlying growth and decline dynamics.

4 - Analytical Functional Forms for Table Functions in SD Models

Rogelio Oliva

Since its inception, system dynamics has relied on piece-wise linear functions to rapidly model the non-linear relationship between model variables. These relationships were original entered as pairs of coordinate points to describe the range of the function at different argument values — thus the name 'table functions' — and the simulation software simply interpolated linearly between two points to find the function value for any given argument values. While this strategy allows for ease of interpretation, rapid and flexible modeling, and for fast computation of numerical simulation output, the table function formulations results cumbersome to calibrate and to modify to perform sensitivity analysis. Furthermore, table function formulations are not continuously differentiable, thus requiring to be substituted by a continuous analytical form to perform analysis based on model linearization, e.g., Eigenvalue Elasticity Analysis.

In this paper we present analytical formulations to replace common table functions in existing models as well as successful techniques and strategies to calibrate the analytical forms to existing tables. The hope is that this effort will eventually turn into an existing catalog of formulations that can be easily accessed by the SD community.

■ MA-31

Monday, 8:30-10:00 - Building BM, 1st floor, Room 111

Team Sports

Stream: OR in Sports
Chair: *Dries Goossens*

1 - A New Mathematical Model for the Team Formation Problem in Sports Clubs

Gercek Budak, Imdat Kara, Yusuf Tansel İç, Refail Kasimbeyli

The team formation problem for sports clubs is becoming a popular research topic as coaches of the teams need a systematical solution approach. This need occurs since finding a reliable solution is important financially and benchmark of the players are becoming complex by the improvements in data collectability of the players. In the Operational Research literature, there is little research about the topic, investigating team formation problem with different aspects of the problem. In this paper, we discuss and evaluate the previous approaches proposed by the researchers. Based on this analysis, we propose a new mathematical model for the team formation problem that can be used for team based sports clubs. The proposed model overcomes some disadvantages of the previous approaches. The model uses weights of positions and skills to maximize the assigned players' total performances. We first estimate the weights and the performance levels of players on each skill. Then, these weights are used as model parameters in the mathematical model that produces the optimal team for the upcoming match. We present preliminary results of our approaches for volleyball clubs team formation obtained by using suitable software.

2 - Towards a Performance Measure for Player Combinations in Football

Soumyakanti Chakraborty, Sumit Sarkar

The results in team games like football (soccer) depend to a large extent on the performance of different combinations of players. Although the role of individual performances is always significant, and occasionally decisive, it is undoubtedly secondary to the performance of the combinations of players, particularly, when we look at the performances of teams for an entire season. However, extant literature is largely silent on the performance measures of combinations of players; the focus has always been on measuring and analyzing individual performances. In this paper, we propose a method of analyzing the performance of the combinations of football players. We first develop a theoretical model of assessing the quality of play of the different combinations of players. The model also allows us to distinguish between the performances of individual players and the combinations of those same players by assigning scores to the players and their combinations. We then use the dynamic programming approach to calculate the performance measures of the each player, and all the different combinations of players in a team. Simulation ran on the theoretical model demonstrate the usefulness of the method for identifying the most potent combination of players on the pitch in real time. The method can be used to formulate strategies during the course of the match and can aid coaches and managers to explore multiple tactics.

3 - Internal Competition in Team Sports: Measures and Analysis
Uday Damodaran, Suma Damodaran

There is considerable literature on the measurement of competitive balance among teams in sports leagues. The impact of this competitive balance on spectator interest and therefore on the popularity of the leagues has also been well studied. However, surprisingly little attention has been focused on the analysis of the internal competition for spots within a team itself: how should this be measured, what are the factors that drive competition, and what are the consequences?

In this paper an attempt is made to arrive at measures of competitiveness within a team. Drawing on literature on dynamic competition analysis in industrial economics, an index of the extent of competitiveness within a team is constructed taking into account the inter-period number of entering, surviving and exiting players. A measure akin to the popular concentration ratio from economics is used to further study the extent of churn.

While the study uses data from cricket, the method can be applied to other team sports. Data for One Day Internationals played by the Indian and New Zealand cricket teams during the period 2000-2015 is used to demonstrate the methodology. An analysis of the antecedents and consequences of the churn is attempted.

4 - Application of Control Charts to Identify the Change Points in Run Chasing Strategy in Limited over Cricket Matches
Dipankar Bose

In any limited over cricket match, successful run chase depends on when the batting team decides to accelerate the run rate. Hence, it becomes important for the bowling team to identify the point when the batting team may start attacking. Cumulative Sum (CUSUM) and Exponentially Weighted Moving Average (EWMA) control charts have built-in change point estimators to estimate the change point. In this paper, we apply both the control chart techniques on limited over cricket matches and compare the usefulness of these control charts to estimate the change in run chasing strategy. Next, we incorporate the effect of the fall of wickets on the estimation of the change point(s). Finally, we generate descriptive statistics on change points from multiple matches to predict the effect of change point on the outcome of a match.

■ MA-33

Monday, 8:30-10:00 - Building BM, 1st floor, Room 113

Emerging Applications of Data Mining and Computational Statistics 1

Stream: Computational Statistics
Chair: *Pakize Taylan*
Chair: *Gerhard-Wilhelm Weber*
Chair: *Sureyya Ozogur-Akyuz*

1 - The Impact of Big Data Analytics on Supply Chain Performance in Grocery Retailing Sector in UK
Christos Papanagnou, Yana Mladenova

Big Data exploration has gained the attention of academics, policymakers and businesses in recent years. This research aims to evaluate the big data impact on supply chain performance in companies operating in the grocery retailing sector in UK. It examines to what extent companies are struggling while dealing with large amount of data, and the way they keep this data secured. In addition to this, this research evaluates the challenges related to recruiting specialists who possess all the required skills to handle data derived from tasks and actions related to supply chains and it identifies appropriate strategies that could be taken into account by managers. Both primary and secondary data were collected from grocery retailers by developing online semi-structured surveys while annual reports from grocery retailers were also analysed to capture the level of big data infiltration into grocery industry. After careful analysis it can be derived that managers nowadays are aware of only some aspects of big data such as predictive analytics, data mining and data security. They consider that data associated with supply chains remain untapped while lack of understanding and know-how in what manner to utilise the large amounts of data eliminates efforts. Hence, grocery companies striving for competitive advantage and eager to pertain to markets should develop strategies towards big data exploitation so that they can continue to adapt to the constantly changing business environment.

2 - Ensemble Clustering Selection by Optimization of Accuracy-Diversity Trade-off
Sureyya Ozogur-Akyuz

Clustering which is one of the unsupervised learning methods in machine learning considers grouping objects according to their similarities within the group. The aim of clustering is to group objects which have common features within the group but have dissimilarities with other groups. Clustering algorithms involves finding a common structure without using any labels similarly like other unsupervised methods. Recent studies show that the decision of the ensemble clusters gives more accurate results than any single clustering solution. Besides that, the accuracy and diversity of the ensemble are one of the important factors which affect the overall success of the algorithm. There is a tradeoff between accuracy and diversity, in other words, you sacrifice one while you increase the performance of the other. On the other hand, the optimum number of clustering solutions is one of the parameters that affect the final result. Recently finding the best subset of the ensemble clustering solutions by eliminating the redundant solutions has become one of the most challenging problems in the literature. The proposed study here aims to find a best model which optimizes the accuracy and diversity trade-off with selecting the best subset of cluster ensemble. Here, the number of clustering solutions in the subset of the ensemble is obtained automatically by the optimization model and the proposed model optimizes accuracy and diversity simultaneously.

3 - A Partial Parametric Path Algorithm for Multi-class Classification
Ling Liu, Francisco Prieto, Belen Martin Barragan

The objective functions of Support Vector Machine methods (SVMs) often include parameters to weigh the relative importance of margins and training accuracies. The values of these parameters have a direct effect both on the optimal accuracies and the misclassification costs. Usually, a grid search is used to find appropriate values for them. This method requires the repeated solution of quadratic programs for different parameter values, and it may imply a large computational cost, especially in a setting of multi-class SVMs and large training datasets. For multi-class classification problems, in the presence of different misclassification costs, identifying a desirable set of values for these parameters becomes even more relevant. In this paper, we propose a partial parametric path algorithm, based on the property that the path of optimal solutions of the SVMs with respect to the preceding parameters is piecewise linear. This partial parametric path algorithm requires the solution of just one quadratic programming problem, and a number of linear systems of equations. Thus it can significantly reduce the computational requirements of the algorithm. To systematically explore the different weights to assign to the misclassification costs, we combine the partial parametric path algorithm with a variable neighborhood search method. Our numerical experiments show the efficiency and reliability of the proposed partial parametric path algorithm.

■ MA-34

Monday, 8:30-10:00 - Building BM, 1st floor, Room 116

Stochastic Optimisation in Supply Chain Management 1

Stream: Supply Chain Scheduling and Logistics
Chair: *Roberto Rossi*
Chair: *Armagan Tarim*
Chair: *Steven Prestwich*

1 - Closed Inventory Routing Problem for Returnable Transport Items
Mehmet Soysal

Increasing concerns on supply chain sustainability have given birth to the concept of closed-loop supply chain which also includes the return processes besides forward flows to recover the value from the customers or end-users. In Closed Inventory Routing Problem (CIRP) literature, traditional assumptions of disregarding reverse logistic operations, knowing beforehand distribution costs between nodes and customers demand, and managing single product restrict the usage of the proposed models in current food logistics systems. From this point of view, our interest in this study is to enhance the traditional models for the CIRP to make them more useful for the decision makers in closed-loop supply chains. Therefore, we present a probabilistic mixed-integer linear programming model for the CIRP that accounts for forward and reverse logistics operations, explicit fuel consumption, demand uncertainty and multiple products. A case study on the distribution operations of a soft drink company shows the applicability of the model to a real-life problem. The results suggest that the proposed model can achieve significant savings in total cost and thus offers better support to decision makers.

2 - Optimal replenishment under price uncertainty
Esther Mohr

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

3 - Policy Learning for Lot-Sizing Stochastic Inventory Control Problem: a Neuro-Evolutionary Approach
Carlo Manna, Steven Prestwich, Roberto Rossi, Armagan Tarim

The lot-sizing stochastic inventory control problem with non-stationary demand is a well-known control problem. It takes into account the fixed cost of placing an order, and linear inventory holding and shortage costs, while the demand is a random variable with a known probability distribution. This problem can be solved using the well-known (s, S) policy, which has been proved optimal despite having a remarkably simple form. However, the conventional approach to determining the policy parameters uses Stochastic Dynamic Programming which is computationally expensive. Other approaches (mainly heuristics) exploit background information related to the structural properties of the optimal policy or the solution. We propose neuro-evolutionary approaches for finding near-optimal policies. Our approach combines machine learning techniques (neural networks) to express possible policies, with optimization techniques (evolutionary computation) to find near-optimal policies. We show that our approach finds near-optimal policies without exploiting any background information related to the structural properties of the optimal policy or the solution. We also find that there are many near-optimal policies with a very different structure to (s, S). We finally report numerical experiments that show the effectiveness of the proposed approach.

4 - A simple heuristic for perishable item inventory control under non-stationary stochastic demand
Roberto Rossi, Alejandro Gutierrez Alcoba, Belen Martin-Barragan, Eligius M.T. Hendrix

In this paper we study the single-item single-stocking location non-stationary stochastic lot sizing problem for a perishable product. We consider fixed and proportional ordering cost, holding cost, and penalty cost. The item features a limited shelf life, therefore we also take into account a variable cost of disposal. We derive exact analytical expressions to determine the expected value of the inventory of different ages. We also discuss a good approximation for the case in which the shelf-life is limited. To tackle this problem we introduce two new heuristics that extend Silver's heuristic and compare them to an optimal Stochastic Dynamic Programming (SDP) policy in the context of a numerical study. Our results demonstrate the effectiveness of our approach.

■ MA-35

Monday, 8:30-10:00 - Building BM, ground floor, Room 17

Optimization in Health Care

Stream: Computational Biology, Bioinformatics and Medicine
Chair: *Metin Turkay*

1 - Finding an Optimal Vaccination Profile to Control the Spread of Infection During an Epidemic
Reena Kapoor, Olivia Smith, Chaitanya Rao, Roslyn Hickson

Vaccination helps in preventing the spread of any infectious disease. While timely vaccination of the entire population would mean no epidemic, with a limited amount of vaccination, the decision "which part of the population should be targeted for vaccination" plays a crucial role in handling the size of epidemic. This decision is not always straightforward, especially when the population has heterogeneous susceptibility, infectivity and likelihood of death from infection.

We consider the problem of finding the optimal vaccination profile with the objectives of minimizing the final size (number of people infected during the epidemic) and number of deaths. We build the optimization model on previous work that enables the modelling of infectious disease spread through heterogeneous populations. The challenge in solving this problem is the fact that it involves a highly non-linear transcendental equation constraint in a continuous variable over a bounded interval. We characterize the analytically solvable cases and propose a linear program based branch and bound method to solve the general version of the problem. The method is computationally very efficient.

2 - Focus on Large Bioinformatics-related Projects
Damian Borys, Krzysztof Fujarewicz, Dariusz Mrozek, Krzysztof Psiuk-Maksymowicz, Jaroslaw Smieja, Andrzej Swierniak

Lack of easy-to-use software and hardware infrastructure that would support all stages of epidemiological cancer studies, as well as poor availability of data from clinical and experimental groups is one of the main reasons of unsatisfactory pace of advances. We have created an integrated system that encompasses all stages of biomedical research. It consists of three subsystems: local databases, managed by LIMS, a central data warehouse, and the computational cluster for complex biomedical data analysis.

Multivariate analysis of molecular data is used for diagnosis support, leading to personalized cancer treatment and new clinical recommendations. A platform for remote verification of research hypotheses and effective data analysis for cancer research is under development. Multi-version data model will provide access to research results of diverse origins and dimensions. Virtualization and secure of transmissions will allow users to work remotely.

Another project aims at supporting decisions on local treatment of breast, thyroid and prostate cancers, to achieve the reduction in therapy aggressiveness without compromising its efficacy. A mobile application for 3D visualization of the tumor volume based on different modalities of radiological imaging (including MR and PET/CT), as well as the tool of breast positioning in relation to the patient body are being developed, together with an algorithm for adequate tumor margin estimation based on molecular studies and imaging.

3 - Does Telecare have an Economic Effect when Used by Patients with Chronic Diseases in the Long Run?
Masatsugu Tsuji

This study aims to demonstrate that telecare (e-Health) is one essential measure for coping with increases in medical expenditure related to chronic diseases such as heart failure, high blood pressure, diabetics, and stroke. To do so, the long-term effects of telecare use by residents of Nishi-aizu Town, Fukushima Prefecture, Japan, between 2002 and 2010 is examined by comparing medical expenditure and days of treatment between telecare users (treatment group) and non-users (control group) based on receipt data obtained from the National Health Insurance. Our previous studies used receipt data obtained for the years 2002 to 2006. This study expands the period of analysis for four more years with respect to respondents who were included in previous analyses. 90 users and 118 non-users were included in both analyses. Using rigorous statistical methods, including system Generalized Method of Moments (GMM), which deals with the endogeneity problem, this paper demonstrates that telecare users require fewer days of treatment and smaller medical expenditures than non-users with respect to chronic diseases, even in the long run. To date, there have been no studies examining the long-term economic effects of telemedicine use, and thus the current study presents a new facet of research in this field. In particular, the economic foundation for the sustainability of the telecare (e-Health) project will be supported by this study.

■ MA-36

Monday, 8:30-10:00 - Building BM, ground floor, Room 18

OR for Sustainable Development

Stream: OR for Sustainable Development
Chair: *Tatjana Vilutiene*

1 - BIM-based Model for Process Management in Building Life-cycle
Tatjana Vilutiene, Leonas Ustinovičius

Article presents the model of the BIM-based design and refurbishment, which is based on pre-build indicators and allows assessing the building energy demand, and eco-building parameters. The approach presented in model created the knowledge-based decision-making environment for refurbishment strategies and quality control, herewith creates the preconditions to bridge the gap between expected and actual energy performance. Model integrates subsystems that enable the energy management and optimization. For comprehensive evaluation of modernization measures authors suggest to include the energy efficiency, eco-efficiency and economic parameters.

2 - A study on the travel time generalized cost function in Kaunas city
Andrius Barauskas, Vytautas Dumbliauskas

Generalized cost functions are widely used in macro models of transport systems. This function represents the disincentive to travel as distance (or time) increases and usually differs from region to region. This study focuses on the identification of the function's shape and estimation of its parameters in Kaunas city. The study rely on data which was obtained through resident trip's survey carried out during preparation of Kaunas City Master plan. A collected travel time data refers to an evening peak period and represents commuters' trips. Function shape and its parameters, estimated using least squares optimization, can be further used in transport modeling applications.

3 - Proposing Response Measures through Integer Linear Programming Models for the Distribution of Emergency Kits to Provide Victims of an Earthquake with Humanitarian Aid
Christian Cornejo, Ximena Rodriguez

Between January and September of 2014, there were 178 earthquakes registered in Peru, 9% of which occurred in the city of Lima, where 28.4% of the Peruvian population lives. The last strong earthquake that affected the country occurred on August 15th, 2007 and revealed the inefficiency of the distribution system managed by the National Institute of Statistics and Computing, to supply people greatly affected by the earthquake with emergency kits. The purpose of this study is to identify the variables that determine the number of fatalities due to an earthquake occurring in the Metropolitan Area of Lima and Callao, and to design an appropriate routing system to distribute the emergency kits needed to assist the victims. The number of fatalities was estimated using a multivariable econometric model that considered variables regarding the tectonic event in question, and characteristics of the affected areas. Integer linear programming models were designed to determine the routes of the vehicles. Vehicle Routing with Time Windows proved to be an adequate model to apply in this scenario, since it calculated the number of vehicles and the routes needed to promptly assist all victims with humanitarian aid. The proposed model will improve the response capacity of the entities involved in the Peruvian crisis management system.

■ MA-38

Monday, 8:30-10:00 - Building BM, 1st floor, Room 109M

Optimization for Sustainable Development Related to Industries 1

Stream: Optimization for Sustainable Development
Chair: *Herman Mawengkang*
Chair: *Sadia Samar Ali*

1 - Modeling a Reliable Water-Distribution Network Using Chance Constrained Programming
Asrin Lubis, Herman Mawengkang

As the number of population is growing, particularly in a big city such as Medan, Indonesia, the need of water treatment and distribution has become a high priority for the local Government to ensure that communities could gain access to safe and affordable drinking water. Therefore the distribution network should be designed systematically. We propose a chance constrained optimization model for tackling this problem considering reliability in water flows. The nonlinearities arise through pressure drop equation. We adopt sampling and integer programming based approach for solving the model. A direct search algorithm is used to solve the integer part.

2 - A Multi-objective Programming Model for Sustainable Production Planning of Crude Palm Oil
Hendaru Sadyadharma, Herman Mawengkang

Palm oil can be regarded as the world's highest yielding oil crop. Rapidly expanding populations and changing consumption patterns have resulted in sustained high process crude palm oil (CPO). Therefore the CPO industry plays an important role for economic development. However, the industry contributes to environmental degradation from both input and output sides of its activities. On the input side, crude palm oil mill uses much water in production process and consumes high energy. On the output side, manufacturing process generates large quantity of waste water, solid waste/ by-product and air pollution. In planning point of view for the CPO industry, there would be two conflicting goals such as return and financial risk and environmental costs This paper addresses a multi-objective programming model of the production planning of CPO. Starting from it two single objective models are formulated: a maximum expected return model and a minimum financial risk (pollution penalties) model. Then we solve the result model using an interactive method.

3 - Raising Social Awareness toward Local Natural Disaster Threats Using Societal Complexity Approach
Irwan Supadli, *Herman Mawengkang*

During and after natural disaster, such as, eruption of a volcano, many people have to abandon their living place move to a temporary shelter. Usually, there could be several time for the occurrence of the eruption. This situation, for example, happened at Sinabung volcano, located in Karo district of North Sumatra Province, Indonesia. These people have to stay for months in the shelter. Apparently, this condition creates serious problems to the society. They have become indifferent. In terms of the society, the local natural disaster problem belongs to a complex societal problem. This research is to find a way what should be done to these society to raise their social awareness that they had experienced serious natural disaster and they will be able to live normally and sustainable as before. Societal complexity approach is used to solve the social problems.

■ MA-39

Monday, 8:30-10:00 - Building WE, 1st floor, Room 107

Biomass-Based Supply Chains

Stream: Biomass-Based Supply Chains
Chair: *Magnus Fröhling*
Chair: *Taraneh Sowlati*

1 - Optimization-Simulation approach for Strategical decisions on Sustainability Bio-refinery Supply Chain
Andrea Espinoza, *Paulo Narvaez Rincon*, *Miguel Alfaro*, *Mauricio Camargo*

The increasing pressures on food supplies as well as the urgency for climate change mitigation are issues that have increased the interest on efficient use of natural resources, such as biomass. In order to take advantage of biomass potential, new technologies have been developed and the concept of bio-refineries was born. In order to use biomass at industrial scale in a sustainable way, a well-designed and well managed supply chain is a requirement. The objective of this work is to design and optimize the bio-refinery supply chain from a sustainable point of view. In order to reach this goal, it is necessary to decide which of the many hierarchical decisions involved in supply chain design will be optimized. Also, it is essential to consider the dimensions of sustainability, which are "Economic", "Social", "Environmental", "Technological" and "Political". Which determine the definition of the sustainable design criteria and optimization objectives. This results in a set of at least five objectives to be optimized, which could be contradictory. Under these conditions, not all optimization tools are suitable to solve this problem. Hence, a preliminary study is required. In addition, in order to study the behavior of the bio-refinery variables in face to uncertainty, an appropriate alternative is joining optimization and simulation. Finally, a preliminary model, integrating the proposed dimensions is presented.

2 - Multi-Agent-Simulation of a Biomass-to-Energy Market
Beatriz Beyer, *Lars-Peter Lauven*, *Jutta Geldermann*

Before European energy targets were implemented, energy sources were often limited to fossil fuels managed by a few companies. With the increase of renewable energy, input markets became much more diverse. Biomass as an energy source creates a complex market structure in and of itself, due to various biomass types, technologies and outputs. The different regulations and location factors throughout Europe make the energy market even more heterogeneous. During the ongoing EU-project BIOTEAM project partners from different countries analyse the sustainability of biomass-to-energy pathways as well as the relevant legislation. A common finding was a disparity between legislative intentions and impacts. Market maps have been used to offer advice on the market structure and beneficial regulations. While providing an overview of the market structure, these do not analyse in depth how the market actors' behavior would change, e.g., if new laws were implemented or shortages occurred. Multi-Agent-Systems for a dynamic simulation purpose are proposed in this work instead, with market actors being represented by agents. Thereby optimization and investment decisions are reached on an individual level but influence many agents simultaneously. Consequently, this approach does not necessarily lead to an optimal outcome. Nevertheless, it attempts to resemble reality more closely and can therefore provide a deeper understanding of the biomass market dynamics.

3 - From food waste to graphitic carbon - a sustainable development?
Florian Gehring, *Christian Peter Brandstetter*, *Eva Knüpffer*, *Stefan Albrecht*

The project PlasCarb (PC) aims to transform food waste into a sustainable significant economic added value product, i.e., high-value graphitic carbon (C) and renewable hydrogen (RH2) - thus integrating business with research. This will combine improving resource efficiency and lowering the dependence on imports of fossil resources with sustainability management. The technology combines anaerobic digestion (AD) with innovative microwave plasma processing. Its aim is being competitive and more sustainable against current end-of-life (incineration, landfill, biological treatment) and production technologies of H2 and C. A holistic sustainability analysis including environmental and socio-economic aspects will assess PC's whole value chain and process steps (AD, biogas upgrading, splitting of biogas methane into high value C and RH2 using plasma, and purification) regarding its sustainability potential. The methods of choice are life cycle assessment (LCA), life cycle costing (LCC) and social analysis, as well as comparisons against state of the art technologies. The holistic assessment is complemented by consideration of the process scale up and sensitivity analysis. Although the project is still running, crucial points identified so far are impacts from the energy consuming plasma process, the procedure of allocation of (food waste) impacts, the quality of biogas and the need of upgrading it.

4 - Design of bioenergy supply chains with long-distance, multi-modal transportation
Tobias Zimmer, *Patrick Breun*, *Frank Schultmann*

Like fossil-based refinery processes, the production of synthetic biofuels is subject to significant economies of scale. Biofuels from straw or wood are therefore most efficiently produced at a large-scale BTL (biomass to liquid) plant. With limited biomass resources in short distance, it can be challenging to supply the required amount of feedstock in a sustainable way. Long-distance transportation of raw biomass is limited by its low energetic density and high transportation cost. Densification processes such as chipping, pelletizing or pyrolysis can be applied to produce bioenergy carriers with increased energy content. Due to restricted truck capacities, train transportation is necessary to take full advantage of the densification effect in terms of lower transportation costs. This work investigates biomass densification in combination with multimodal transportation. The optimization problem is formulated as a mixed integer linear program with the objective of minimizing the total supply chain cost, including feedstock, transportation and processing cost. The model determines the optimum location of the central BTL plant and the configuration of the decentralized densification processes. This includes the number of pre-treatment plants as well as their locations, capacities and technologies. The model accounts for multiple feedstock types, economies of scale and the characteristic layout of the railway network.

■ MA-40

Monday, 8:30-10:00 - Building WE, 1st floor, Room 108

Optimization in Financial and Supply Chain Networks

Stream: Financial Engineering and Optimization
Chair: *Kamil Mizgier*

1 - Extreme Values in Property Damage and Business Interruption Insurance
Kamil Mizgier, Stephan Wagner

Business interruption insurance is considered to be one of the most efficient supply chain risk mitigation and risk transfer strategies, albeit one of the least studied. Its importance is growing as it bridges the time element of losses with the property damage when a major accident occurs. We empirically investigate a large set of business interruption claims and compare their characteristics with the property damage claims. Our results suggest that extreme losses are more likely to be triggered by the business interruption than by the property damage. In both cases the calculated tail exponents lead to finite premiums. Thus, both supply chain managers and insurance providers should optimally deploy financial resources to hedge against these losses.

2 - An Optimization Procedure for a Maximum Gamma and Constrained Theta Portfolio
Arik Sadeh, Dar Kronenblum

A large gamma portfolio of options is attractive for investors in order to get benefits from either increase or decrease in the value of the underlying asset. On the other hand, a large gamma portfolio has a negative theta which may lead to losses over time as theta reflects the impact of time costs. In this study, a delta neutral portfolio with maximum gamma and constrained theta was defined in order to capture opportunities with limited risk. An optimization model was designed and solved for small time steps within a planning horizon. The model was run for many simulation scenarios as well as real world data, followed by statistical tests.

3 - The Influence of Working Capital Management on Firm Performance: Thailand Evidence
Phassawan Suntraruk

The objective of this study is to investigate the influence of working capital management on performance of nonfinancial firms listed on the Stock Exchange of Thailand over the period 2000-2014. Using the panel data analysis, it is found that working capital management enhances firm performance in terms of operating performance and stock returns. Moreover, leverage and firm's size matter. Our results then suggest that efficient working capital management is one of key success factors for any business. It helps a firm ensure that a firm has ability to satisfy its maturing current liabilities and operating expenses, leading to smooth operations of firm's cash flow cycle.

■ MA-41

Monday, 8:30-10:00 - Building WE, 2nd floor, Room 209

Financial Mathematics 1

Stream: Financial Mathematics and OR
Chair: *Rei Yamamoto*
Chair: *Katsunori Ano*

1 - A Fuzzy Mixed-integer Programming Approach to Portfolio Optimization
Gulcan Petricli, Gül Gökay Emel, Tuba Bora

This study focuses on portfolio optimization problem. The existence of instability in social and political environment of countries and vagueness in decisions of investors very much affect the optimal portfolio and the amount invested. Therefore, a more realistic approach to socioeconomic situation of financial market is used where the portfolio is modified at the end of a typical time period. Instead of deterministic approaches, the proposed model was based on fuzzy linear programming portfolio optimization approach of Verdegay and Werners but with integer variables. It was examined in Turkish financial market, where socioeconomic instability was very high during 2013 and 2014. This time period was divided into five sub periods of which starting and ending dates were social, financial and political phenomenon. Data, used in the model was obtained from Borsa Istanbul (BIST). It included daily prices of dollar, euro, gold and BIST 30 index prices. Results show that investment amounts and also the approach used in the optimization directly affect the optimum portfolio with respect to number and type of instruments, risk and expected return. Further, it can be said that Verdegay approach is favorable for risk averse investors whereas Werners approach is much suitable for risk seeking investors.

2 - Optimal Multiple Pairs Trading Strategy using Derivative Free Optimization under Actual Investment Management Conditions
Rei Yamamoto, Norio Hibiki

Pairs trading strategy has at least a 30-year history in the stock market and it is one of the most common trading strategies today due to the understandability. There are many early studies about this strategy from theoretical and empirical aspects. Recently, Yamamoto and Hibiki (2015) studied about an optimal pairs trading strategy using a new approach under real fund management conditions such as transaction cost, discrete rebalance period, finite investment horizon and so on. However, this approach cannot be solved when we use multiple pairs in the strategy because this problem is formulated as a large scale simulation type non-continuous optimization problem. In this research, we formulate the model to find an optimal pairs trading strategy problem using multiple pairs under real fund management conditions as a large scale simulation type non-continuous optimization problem. And we propose a heuristic algorithm based on derivative free optimization (DFO) method for solving this problem efficiently.

3 - Stress Testing Model for Credit Portfolio using Vine Copula
Muneki Kawaguchi

Stress testing became more important on financial risk management after financial crisis of 2007-2009. The risk quantity is estimated based on the scenario that low frequency and large loss events occur on stress testing. The correlation among the variables is important, particularly the tail correlation is crucial on stress testing. In this paper, we propose the credit stress testing model with vine copula to consider detail of the tail correlation and compare this model with the expansion of one factor Merton model, which is used to evaluate the risk amount of credit portfolio. As a result, we find the average credit rating by this model clearly changes depending on the stress scenario, unlike one factor Merton model. We confirm this model captures the difference among the characteristics of industry sectors and provides the result depending on the industry sector of each borrower.

4 - Lundberg model with portfolio and asset management of surplus
Reina Takemura, Yasuhiro Ouchi, Yoshinori Kashizume, Katsunori Ano

We study the Lundberg model of the ruin probabiliity of the non-life insurance company with portfolio and asset management of surplus. This talk presents a new mathematical model by taking into account the asset management. We assume that the fluctuation of surplus follows Geometric Brownian motion, the instantaneous mean rate of return of risky asset follows Vasicek model and the instantaneous volatility of risk asset follows Cox-Ingersoll-Ross model. Portfolio will be rebalanced in future. It is too difficult to derive the ruin probability under these situation. We simulate the probability, which may be more realistic than the classical Lundberg model, and give the sensitive analyses by change of the parameters.

■ MA-42

Monday, 8:30-10:00 - Building WE, 1st floor, Room 120

Game Theoretical Models and Applications

Stream: Game Theory, Solutions and Structures
Chair: *Encarnación Algaba*

1 - A Relevance Index for Genes in a Biological Network
Giulia Cesari, Encarnación Algaba, Stefano Moretti, Juan Antonio Nepomuceno

Centrality measures are used in network analysis to identify the relevant elements in a network. Recently, several centrality measures based on coalitional game theory have been successfully applied to different kinds of biological networks, such as brain networks, gene networks, metabolic networks and chemosensory networks. We propose an approach, using coalitional games, to the problem of identifying relevant genes in a biological network. The problem has been firstly addressed by means of a game-theoretical model in Moretti et al. (2010), where the Shapley value for coalitional games is used to express the power of each gene in interaction with the others and to stress the centrality of certain hub genes in the regulation of biological pathways of interest. Our model represents a refinement of this approach, which generalizes the notion of degree centrality, whose correlation with the relevance of genes for different biological functions is supported by several practical evidences in the literature. The new relevance index we propose is characterized by a set of axioms defined on graphs describing a biological network and, furthermore, an application to the analysis of gene expression data from microarrays is presented, as well as a comparison with previous centrality indices.

2 - An Approach to Fair Division in the Social Context
Izabella Stach, Cesarino Bertini

A value for n-person cooperative games is a function giving a reasonable expectation of the sharing of the global winning among the players. A power index is a value for simple games, i.e., for games where the payment of each coalition can only be 1 (winning coalition) or 0 (losing coalition). Power indices approach is widely used to measure a priori voting power of members of a committee. The concept of "value" was first suggested by Lloyd Shapley in 1953, resulting in a breakthrough in the theory of cooperative games, as earlier attempts to solve cooperative games did not ensure existence and uniqueness of solution. In 1954 Shapley and Martin Shubik introduced the "Shapley and Shubik power index". In the following years, numerous other power indices have been created; some derived from existing values, others invented exclusively for simple games. In this work we analyze some power indices well defined in the social context where the goods are public. Some properties of power indices are considered. The aim is to achieve a global vision and to identify a group of properties that are desirable in the public good context.

3 - A Game Theoretical Approach to Allocate Profits in Public Transportation Systems
Encarnación Algaba, Vito Fragnelli, Natividad Llorca, Joaquin Sánchez-Soriano

In this paper we consider the problem of a set of transportation companies that operate in the same area, with different transportation modes. The companies offer to their customers combined tickets that allow the travellers to use more than one means of transport, independently from the company that operates the service. We face the problem of allocating the profit of using an infrastructure among all the agents that are involved in providing the service. We consider a theoretical traveller that goes from a given origin to a given destination according to a probability based on the origin-destination matrix; for each pair origin-destination the theoretical traveller chooses with equal probability one of the feasible paths available. We define a cooperative game in characteristic form, where the set of players corresponds to the set of companies and the characteristic function assigns to each subset of companies the worth associated to the set of feasible paths they may operate. We propose a simple way to allocate the price of the ticket among the companies that offer the combined ticket. The price of each feasible path is equally divided among all the companies that actually operate it. This rule turns out to be the Shapley value of the cooperative game.

■ MA-43

Monday, 8:30-10:00 - Building WE, ground floor, Room 18

Renewable Resource Assessment and Forecasting

Stream: Stochastic Models in Renewably Generated Electricity
Chair: *John Boland*

1 - The viability of electrical energy storage for low-energy households
Adrian Grantham

Distributed electrical energy storage has the potential to reduce the CO2 emissions of electrical energy use by enabling greater use of distributed generation such as from rooftop photovoltaic (PV) systems. But our electricity distributions systems were not designed to allow flow of power from consumers; as a consequence there can be limits to how much power can be exported from rooftop PV systems. Furthermore, falling feed-in tariffs mean that it is becoming more cost-effective to store excess PV energy on site rather than export excess energy to the grid and then import it later at a higher cost.

To determine the impact and viability of distributed electrical energy storage systems for residential consumers with rooftop PV systems, we use PV generation and household load from 38 low-energy homes, simulate the operation of energy storage, and calculate the impact on the amount and cost of imported electricity.

The Return on Investment (RoI) for PV and energy storage systems depends on many factors, including the cost of PV, the cost of energy storage, the cost of electricity, the price paid for exported energy, the power generated by the PV system and how and when energy is used by the household. We calculate the RoI for various configurations.

2 - Probabilistic forecasting of renewable energy sources
John Boland

One of the key obstacles in the way of wider implementation of renewable energy is its highly volatile and intermittent nature. This has boosted an interest in developing a fully probabilistic forecast of wind and solar resources, aiming to assess a variety of related uncertainties with a user-predetermined confidence. Forecasting with error bounds of wind, and especially solar energies, on very short time scales, that is less than four hours, is one of the main areas missing. This is also denoted variously as interval, density or probabilistic forecasting. I will describe the use of GARCH to construct density forecasts of wind farm output. For solar energy, there are two factors influencing the variance. There is a systematic change in variance with summer being higher than winter and middle of the day higher than the ends of the day. As well, there is a localised effect, with clusters of high and low variance, the ARCH effect. I will show how to combine these two effects to give a robust and effective density forecast.

3 - Optimal control of combined electrical and thermal storage with time-of-use electricity pricing
John Boland, Luigi Cirocco, Martin Belusko, Frank Bruno, Peter Pudney

Worldwide, more and more consumers of electrical energy are being billed using time-of-use pricing. In concert with this, renewable energy sources, electrical energy storage systems and thermal energy storage systems are giving consumers the opportunity to control when and if they import electricity from the grid.

We present a power flow model of a system combining a renewable energy source with limited electrical and thermal energy storage elements, and use Pontryagin's principle to derive necessary conditions for a control strategy that minimises the cost of energy imported from the grid. The optimal control has ten possible control modes for the storage systems, being combinations of charging, discharging and exporting back to the grid. Which mode should be used at any instant depends on the price of electricity relative to two critical prices, one for each of the storage systems. We use a realistic example to illustrate the optimal control of the system.

4 - Generation of wind energy forecasts using Copulas
Carlo Lucheroni, John Boland, Julia Piantadosi

Our main aim is to generate wind forecasts for distributed sites that have windfarms using multi-dimensional copulas and how these might change if the key parameters change. There are many copulas that could be used to construct a joint probability density function and match the known correlation coefficients. We will investigate this. Much more complicated is the problem of inserting time dependency in the copula formalism in order to better capture time-varying cross-correlation. Thus, the model construction should reflect the most appropriate data collection processes and the best statistical design in relation to the desired objectives.

■ MA-47

Monday, 8:30-10:00 - Building WE, 1st floor, Room 115

Stochastic Models

Stream: Stochastic Modeling and Simulation in Engineering, Management and Science
Chair: *Hiroshi Toyoizumi*
Chair: *Katsunori Ano*

1 - Multi-Information Source Optimization with General Model Discrepancies
Matthias Poloczek, Jialei Wang, Peter Frazier

In the multi-information source optimization problem we study complex optimization tasks arising for instance in engineering or the natural sciences, where our goal is to optimize a design specified by multiple parameters. In order to assess the true value of some design, we only have access to a variety of information sources, e.g., numerical simulations that employ models of the true objective function of varying complexity. These information sources are subject to model discrepancy, i.e., their internal model inherently deviates from reality. Note that our notion of model discrepancy goes considerably beyond typical noise that is common in multi-fidelity optimization: in our scenario information sources can be biased and are not required to form a hierarchy. Moreover, we do not require access to the true objective, which has severe implications for the machinery that can be applied to tackle the optimization problem. We present a novel algorithm that is based on a rigorous mathematical treatment of the uncertainties arising from the model discrepancies. Its optimization decisions rely on a stringent value of information analysis that trades off the predicted benefit and its cost. Moreover, we conduct experimental evaluations that demonstrate that our method consistently outperforms other state-of-the-art techniques: it finds designs of considerably higher objective value and additionally inflicts less cost in the exploration process.

2 - Optimal pitching order for Baseball.
Takehiro Takano, Hisashi Muto, Katsunori Ano

We consider the optimal pitching order model for Baseball. We want to minimizes the expected run in a Baseball game under the condition that 1,2,3,4,5 and 6 innings by starter, 7 and 8 innings by relievers and 9 inning by closer. This model is based on Markov chain of 25 states for Baseball. We exam it for Nippon Professional Baseball team, Orix using 2014 and 2015 seasons' data of Orix's pitchers such that Chihiro Kaneko, Motoki Higa, Tatsuya Sato and Yoshihisa Hirano.

3 - Simulation of Information Spread in Complex Network
Seiichi Tani, Yoshinori Iida, Ryuta Maruyama, Hiroshi Toyoizumi

Consider a problem of spreading information over a complex finite network in a model: 1) a node received information becomes a new source node, and a source node selects a target node among its neighbouring nodes to spread the information each step. 2) each node has no memory and has no knowledge about the structure of the network except the degrees of adjacent nodes. In the model, the time until every node has information depends on how source nodes select a target node. Toyoizumi et al. showed that Reverse Preference Control (RPC) is the best strategy to spread information to all nodes efficiently on a uncorrelated network [TTMO 2012]. It is derived from that we can approximate the probability that a node t is selected as a target node by a source node with the probability that a link incident with t is selected among all links in the network if the network is uncorrelated. However, it is expected that uncorrelatedness is spoiled locally on an actual network. Therefore, we generate complex networks by several methods, and simulate information spread on the networks to estimate the effectiveness of RPC.

4 - Effective Propagation of Information on Social Media
Hiroshi Toyoizumi

We discuss an algorithm to propagate information effectively on social networks. There are a couple of problems to propagate information on social network such as (1) redundant information repeatedly transmitted to the same person and (2) the limitation of window size of information appeared on the screen. We propose a model incorporated those features and evaluate propagation methods on social media.

■ MA-51

Monday, 8:30-10:00 - Building PA, Room D

Complementarity Problems, Variational Inequalities and Equilibrium

Stream: Mathematical Programming
Chair: *Sandor Zoltan Nemeth*

1 - In Quest of Good Cones
Roman Sznajder

Given a proper cone in a Euclidean space, its Lyapunov rank is defined as the dimension of the linear space of all Lyapunov-like transformations on this cone. This quantity is related to the number of linearly independent bilinear relations needed to express the complementarity set. Thus, the Lyapunov rank proves useful in complementarity theory and conic optimization. In this paper, we discuss the structure of the Lyapunov-like transformations on the Extended Second Order cone and compute its Lyapunov rank. For a proper choice of parameters, such a cone is perfect, that is, its Lyapunov rank is no less than the dimension of the ambient space, which makes it an interesting object in conic optimization. We will discuss some recent results on the Lyapunov rank. We also indicate that the Lyapunov rank of polyhedral irreducible cones and lp-cones is one.

2 - Proximal Extrapolated Gradient Methods for Variational Inequalities
Yura Malitsky
We present some novel first-order methods for monotone variational inequalities. They use a very simple linesearch procedure that takes into account a local information of the operator. Also the methods do not require Lipschitz-continuity of the operator and the linesearch procedure uses only values of the operator. Moreover, when operator is affine our linesearch becomes very simple, namely, it needs only vector-vector multiplication. Although the proposed methods are very general, sometimes they may show much better performance even for some optimization problems.

3 - Pursuing Cones, Convex Sets and Mappings with Good Order Preserving Properties
Sandor Zoltan Nemeth
A basic tool for solving complementarity problems, variational inequalities and isotonic regression problems in Euclidean spaces is the projection onto closed convex cones. The isotonicity (or order preserving property) of these projections with respect to a given order relation can facilitate finding the solutions of the above problems. The convex sets with an isotone projection onto them will be called isotone projection sets. We will discuss the following problems: (1) What are the cones which are isotone projection sets with respect to the coordinate-wise ordering? (2) What are the cones which are isotone projection sets with respect to an order defined by another proper cone? (3) How large can be the class of isotone projection sets with respect to the ordering defined by a proper cone? One of the best cones with respect to the last question is the Extended Second Order Cone, with respect to which all cylinders are isotone projection sets. However, there are no proper cones which are isotone projection sets with respect to the Extended Second Order Cone. Moreover, there are no proper cones with respect to which the Second Order Cone is an isotone projection set and this statement remains true if the Second Order Cone is replaced by any selfdual, smooth, strictly convex cone. It is also important, but difficult problem, to find the mappings that are isotone with respect to the ordering defined by the underlying cone.

4 - Consistent Conjectures Are Optimal Cournot-Nash Strategies in the Meta-Game
Mariel Adriana Leal-Coronado, Vyacheslav Kalashnikov, Francesc López-Ramos
In this paper, we investigate the properties of consistent conjectural variations equilibrium (CCVE) developed for a single-commodity oligopoly. Although, in general, the consistent conjectures are distinct from those of Cournot-Nash, we establish the following remarkable fact. Define a meta-game as such where the players are the same agents as in the original oligopoly but now using the conjectures as their strategies. Then the consistent conjectures of the original oligopoly game provide for the Cournot-Nash optimal strategies for the meta-game.

After the mathematical model is described, the concept of exterior equilibrium (i.e., the conjectural variations equilibrium (CVE) with the influence coefficients fixed in an exogenous form) is defined. The existence and uniqueness theorems for this kind of CVE are established. Then a more advanced concept of interior equilibrium is introduced, which is determined as the exterior equilibrium with consistent conjectures (influence coefficients). The consistency criterion, its verification procedure, and the existence theorems for the interior equilibrium are also formulated. Finally, the main results of this paper asserting that the consistent conjectural equilibrium in the original oligopoly provides the classical Cournot-Nash equilibrium in the meta-game, is proven.

■ MA-53
Monday, 8:30-10:00 - Building PA, Room A

Additional Educational Activities for OR

Stream: Initiatives for OR Education
Chair: *Ariela Sofer*

1 - Early Detection of University Students in Potential Difficulty
Anne-Sophie Hoffait, Michaël Schyns

This paper presents a novel approach, based on data mining methods, for the identification of freshmen who have a higher probability to face major difficulties to complete their first year. This is obviously a major concern, for the students who would just need some extra or specific help for being able to succeed, but also for the universities who have to maintain a high level of education with limited resources. We focus more specifically on early detection. The goal is to detect these students at registration time based on information easily available at this time; so as to be able to start academic achievement support before the start of the year or, in some cases, to help the student to select the most suitable orientation. We rely on some indicators of past performances and some environmental factors already identified in the literature. Our contribution is also to adapt three data mining methods, namely random forest, logistic regression and artificial neural network algorithms, to reach a high level of accuracy. We refine the conventional classification by creating subcategories for different levels of confidence: high risk of failure, risk of failure, expected success or high probability of success. Our methodology is illustrated on the real case of the University of Liege, a major University in Europe. With our approach, we can identify, with a confidence level of 90%, 10.5% students who will have strong difficulties if nothing is done to help them.

2 - Improving the Flow of of Graduate Students of the Engineering Course at the Federal Fluminense University throught a Simulation Analysis
Christian Vargas, Gabriela Aiex Teixeira, Lidia Angulo-Meza, José Rodrigues Farias Filho, Cecilia Toledo Hernandez, Mayara Rodrigues Fernandes

This work arises due to difficulties encountered by many students of Production Engineering at the Federal Fluminense University to finish his degree in the allotted time for completion of the course. Associating the availability of teachers and number of vacancies for enrollment of students in disciplines, is not an easy task. The study sought to simulate the flow of students from the Fluminense Federal University Production Engineering (Volta Redonda, RJ) based on mandatory subjects taken. Thus, it is possible to predict the amount of students who would form the time of completion of the course set by the university in accordance with the approval ratings and the number of places available for each subject of the course grade. To carry out the work, we used the Rockwell Arena' software. It was built a computational model based on production engineering flowchart (presented by the Universidade Federal Fluminense - Volta Redonda) and inserted their statistical data (collected in the System of Public Consultations UFF) of each of the 53 disciplines considered in the model. After analyzing the results, experiments were made that sought to understand the degree of influence of the system variables, and then propose changes that were intended to increase the rate of students who graduate at the end of 10 semesters.

3 - Preparing OR Students for the World of Big Data
Ariela Sofer, Steven Charbonneau, Jie Xu

The majority of OR students graduating in the coming years will encounter a data-rich work environment that is far more complex than in the past. Among the challenges in preparing OR students for the world of Big Data is finding good examples of very large applied problems that can be solved within the framework of a single course, and within the computational resources of the university or other available providers. We present examples of large complex applied problems that require student to use advanced modeling, employ advanced techniques and heuristics that allow for the solution of generally intractable problems, and to take advantage of the advanced features of commercial optimization engines and publicly available data. We will discuss the challenges in setting up these projects successfully, and the lessons learned.

■ MA-54

Monday, 8:30-10:00 - Building PA, Room B

Projection methods in optimization problems 1

Stream: Convex Optimization
Chair: *Simeon Reich*
Chair: *Rafal Zalas*
Chair: *Pál Burai*

1 - Convergence rates for projection algorithms with convex semi-algebraic constraints
Matthew Tam, Jon Borwein, Guoyin Li

The rate of convergence of projection algorithms can be arbitrarily slow in the sense that, for any sequence of real numbers decreasing to zero, there exists an instance of the feasibility problem and an initial point for which the sequence generated by the algorithm converge more slowly than the given sequence of reals (at least in infinite dimensions). While recent works have established linear convergence under commonly used constraint qualifications, it can be difficult to satisfy such qualifications, even in relatively simple cases. In this paper we give sufficient conditions to guarantee sub-linear convergence of projection algorithm which satisfy a weaker Hoelder regularity property. This property, and hence our results, hold, in particular, for problems having convex semi-algebraic constraints.

2 - On strongly convex functions of higher order
Attila Gilanyi, Nelson Merentes, Kazimierz Nikodem, Zsolt Pales

Related to the investigations of strongly convex functions introduced by B. T. Polyak in 1966, we consider higher order strongly Wright-convex functions and higher order Wright-convex functions with a modulus. We prove a decomposition theorem for such types of functions, we characterize them via generalized derivatives and we also show that the properties above are localizable.

3 - On recent development on linear convergence of alternating projections
Hieu Thao Nguyen, Russell Luke

A wide range of problems in optimization can be cast in the framework of feasibility problems, which in many circumstances can be efficiently solved by projection algorithms. In this talk, we on the one hand attempt to clarify relationships amongst various regularity notions that have been used for establishing linear convergence criteria for the alternating projection method. On the other hand, we discuss our recent development on the topic in both convex and nonconvex settings and make appropriate comparisons to known results in the literature.

■ MA-56

Monday, 8:30-10:00 - Building CW, 1st floor, Room 122

European O.R. Practitioner Network: Founding Meeting

Stream: Workshops and roundtable
Chair: *Richard Eglese*
Chair: *Josef Kallrath*

1 - European O.R. Practitioner Network: Founding Meeting
Ruth Kaufman, Josef Kallrath

The “European O.R. Practitioner Network" is being established to encourage and support the communication and exchange of ideas among practitioners in industry, in consultancy, and operating as freelancers.

At this founding meeting, we will discuss the network’s potential benefits, and what participants are looking for. Participants will be invited to describe their own activities in terms of application area, technical specialism, employer and geographical location, and their current professional challenges, and hot topics.

We will build on these discussions to explore how the network will operate, and what it might do.

The outcome of this session will be, for the newly-founded European Practitioner Network, a plan of action; and for the participants, a personal network already broadened by the contacts made during the session.

Monday, 10:30-12:00

■ MB-01

Monday, 10:30-12:00 - Building CW, AULA MAGNA

Keynote Mauricio Resende

Stream: Plenary, Keynote and Tutorial Sessions
Chair: *Inês Marques*

1 - Logistics Optimization at Amazon: Big Data & Operational Research in Action
Mauricio Resende

We consider optimization problems at Amazon Logistics. Amazon.com is the world's largest e-commerce company, selling millions of units of merchandise worldwide on a typical day. To achieve this complex operation requires the solution of many classical operational research problems. Furthermore, many of these problems are NP-hard, stochastic, and inter-related, contributing to make Amazon Logistics a stimulating environment for research in optimization and algorithms.

■ MB-02

Monday, 10:30-12:00 - Building CW, 1st floor, Room 7

Multiobjective Optimization in Business Analytics

Stream: Evolutionary Multiobjective Optimization
Chair: *Yu-Wang Chen*
Chair: *Julia Handl*
Chair: *Richard Allmendinger*

1 - Multi-Objective Formulations for Robust Optimization
Juan Esteban Diaz, Julia Handl, Dong-Ling Xu

We consider robust optimization settings where the fitness of solutions is best described by a distribution of outcomes and where the nature of this distribution is of potential interest in deciding solution quality. Previous work has suggested the simultaneous optimization of robustness and performance measures. However, there has been limited consideration of the impact the choice of robustness measure has on the search for robust solutions. Therefore, we set out to analyse different multi-objective formulations for robust optimization, in the context of a real-world problem addressed via simulation-based optimization. We also investigate how the level of noise in fitness estimates affects the quality of solution obtained with the different multi-objective formulations under constrained computational settings. Our experiments reveal that the allocation of more computations to fitness refinement is more beneficial than optimizing across more generations. We also find that the use of the sample minimum as a robustness measure has a detrimental impact on the optimization performance of the multi-objective optimizer analysed. This may be because it increases the computational effort required to obtain reliable estimates, compared to a less biased statistic such as the sample standard deviation. In brief, the choice of robustness measure and the sample size used during fitness evaluation are essential in designing a successful multi-objective methodology for robust optimization.

2 - Production Scheduling of a Multi-Product Biopharmaceutical Facility Using a Genetic Algorithm
Karolis Jankauskas, Lazaros Papageorgiou, Suzanne Farid

Previous research work in the area of capacity planning and scheduling of biopharmaceutical manufacture has been based mostly on discrete- as well as continuous-time mixed-integer linear programming (MILP) models. This paper presents a continuous-time, genetic algorithm-based model to optimise medium-term capacity plans for a multi-product biopharmaceutical facility. In the algorithm, each chromosome consists of dynamic length vectors containing product labels and batch numbers for each product generated at random, which are later evolved using genetic operators such as selection, crossover, and mutation. The solutions to the optimisation problem are built as ordered dynamic lists of product campaigns using the aforementioned vectors. Using the proposed model each key stage of a product campaign, such as the beginning of a campaign, first harvest, first batch and last batch, can be accurately scheduled. The model accounts for product campaign changeovers, campaign delays, and product approval times. Additionally, there is a penalty-free method for handling a constraint of meeting the specified demand on time, i.e., when late deliveries are not accepted. The model is also suitable for a variety of single objective as well as multi-objective optimisations using the NSGA-II.

3 - Management of a Large Proportion of Missing Data for Scientific Inference on the Basis of the Evidential Reasoning Rule
Huaying Zhu, Jian-Bo Yang, Dong-Ling Xu, Cong Xu

In a big data era, tremendous amounts of data have been recorded, but missing data impedes a transformation from data into valuable information. This paper investigates to deal with a large proportion of missing data for scientific inference on the basis of the Evidential Reasoning (ER) rule. The investigation is focused on an estimation of "data reliability" and its use in the ER rule, as well as the comparison of ER with other methods for inference with missing data. Several methods are compared in a case study of asthma control stage identification. An Interior Algorithm, a Sequential Quadratic Programming, an Active Set Algorithm and a GA are explored and compared for "data reliability" in the framework of the ER rule. The conclusion is that only IPA has relatively unsatisfactory results in accuracy. Due to missing data, different pieces of evidence acquired from a large dataset can have different prior distributions. How to manage the prior distribution is another concern and we have two options. One is to build an inference model without prior distribution and the other one is to treat a prior distribution as a piece of evidence. The first option is explored by applying the ER rule that allows prior free inference. The second one is explored by comparing several methods, like Decision Tree, Logistic Regression, ANN, SVM and so on. The results from the case study show that the prior-free ER method outperforms the others in inference with missing data.

4 - Modelling and Analysis of Hub-and-Spoke Networks with Random Hub Failure
Nader Azizi

In this research a bi-objective optimisation model is presented to design hub-and-spoke networks under heterogeneous hub failure probabilities. The resulting nonlinear mixed integer programing model is linearized using a standard linearization technique. To ease the computational burden, the objective function of the model is modified by exploiting some problem-specific information. The improved formulation are used to optimally solve a number of small size problems and to locate lower and upper bounds for medium size instances. To solve large problem instances, evolutionary approaches are discussed.

■ MB-03

Monday, 10:30-12:00 - Building CW, 1st floor, Room 13

MADM Application 2

Stream: Multiple Criteria Decision Analysis
Chair: *Jung-Ho Lu*

1 - A consensus process for group multiple criteria decision making with different types of decision information
Chen-Tung Chen, Wei-Zhan Hung, Hui-Ling Cheng, Kai-Yi Chang

Decision making is one of the most important issues for each organization. In general, it should consider multiple criteria for selecting the best alternative in the decision making process. For avoiding the limitations of knowledge and experience of each expert, a group multiple criteria decision making (GMCDM) method is usually applied to deal with the decision problems. Under this situation, it needs an effective method to aggregate the opinions of experts to reach the consensus opinion for dealing with decision-making problem. In fact, experts will express their opinions with different types in the evaluation process such as crisp value, linguistic variable and fuzzy number, etc. Therefore, a data normalize mechanism will be designed in this paper to transfer different types of experts' opinions into the common type. And then, an expert opinion adjustment framework will be proposed in this paper based on multiple types of decision information in GMCDM process. A new method is proposed in this paper to adjust the opinions of experts to reach the consensus opinion. A numerical example will be implemented to compare and analyze the different ways of automatic consensus adjustment mechanism. According to the comparison results, we can justify the effectiveness of proposed method. Conclusions and future research directions will be discussed at the end of this paper.

2 - Creating a Museum Culture Products Purchasing Evaluation Model for Customers by Using DEMATEL Technique

Chin-Tsai Lin, Jung-Ho Lu, Sih-Wun Wang

To create new ways of income for museums are to implement pictures, symbols, and cultural elements into cultural products. Many previous studies in marketing for products purchase behaviours only focus on two categories; there are price and functions, although this may be true in the past. The purpose of this study was to investigate the consumers purchase criteria of cultural products. For this study, it provides cultural product marketing strategies for museums based on visitors. Since developing a marketing strategy is a multiple-criteria decision-making (MCDM) problem. This study uses the decision making trial and evaluation laboratory (DEMATEL) technique to construct the cultural products purchase interactive relationship among the various criteria/sub- criteria and building each criterion's influential network relationship map (INRM). The results of this study provide museum marketing manager with an idea-based understanding of how to create marketing strategies that enhance visitors' needs.

3 - Wearable Devices and Health Accessing Indices for Determining Dynamic Insurance Rate

Wen-Tsung Wu, Chie-bein Chen, Hsin-Hung Lin

The purpose of this study is to propose a method to improve a way of paying the insurance rate. Wearable devices are used to detect the individual health condition. The logistic regression is used to classify health data which are collected by wearable devices and linear regression is used to construct the health accessing indices. In this study, the health assessing indices are classified to six levels based on the property of normal distribution. Under the data manipulations, Markov probability transition matrix is used to observe the health situations of insurer are shifted. After long term transition the health situations become stable, the number of insurers at different health level will be obtained. Thus, the dynamic insurance rate paying system will be established. A comparison of total amount for both new and old insurance systems will be conducted to decide which one is preferable. Consequently, this research results provide a reference to insurance companies and an idea of dynamic insurance rate paying system will improve and adjust existing insurance paying system.

4 - Multi-Realm Communications within Online Brand Communities

Pei-Ling Hsieh

Integration and management of online and offline communications is essential to developing successful and sustainable brand relationships between firms and consumers. However, the process through which this happens remains unexplored. Therefore, this study examined multi-realm communications within online brand communities (OBCs), and explored OBC value co-creation and brand relationship quality (BRQ) to connect the relationships among these antecedents and the brand relationship model. This study thus established various hypotheses. The results indicate that value co-creation influences both OBCs and brand commitment, whereas BRQ directly influences only brand commitment, and through its interaction with perceived OBC-brand similarity it also influences OBC commitment. Finally, brand commitment supports the existence of a bond between OBC commitment and brand loyalty. These findings have various implications and suggest various future research directions.

■ MB-05

Monday, 10:30-12:00 - Building CW, 1st floor, Room 8

Multiobjective Optimization in Supply Chain Management and Logistics 2

Stream: Multiobjective Optimization

Chair: *Sandra Huber*

1 - Maintenance Modelling for a System Equipped on Ship

Tomohiro Kitagawa, Tetsushi Yuge, Shigeru Yanagi

Maintenance activities for a system on ships have limitation when the ships are engaged in voyage. The reason is that the ships cannot have enough maintenance resources. Thus, some failures can be repaired even during voyage, but the others cannot be repaired on the voyage and are repaired after the end of voyage. When a system fails, in this paper, the former failure occurs with probability p and the latter occurs with probability 1-p and both types of failure are repaired minimally. The ratio will depend on the amount of shipboard spare items and maintenance tools. We consider that p can be correlated to a known cost function. We propose two management policies of the overhaul interval for an IFR system, one manages the overhaul interval by number of missions and the other manages it by the total mission time. The mean availability and the expected cost rate are formulated when every period of voyage follows an independent and identical exponential distribution. Then, we determine the optimal overhaul interval and p that satisfies a required availability and minimizes the expected cost rate for each policy. Finally, the optimal cost rates in two policies are compared numerically.

2 - A Multi-objective Model for Preventing and Responding to Attacks on Interurban Transportation Networks

Ramon Auad, Rajan Batta

In a previous paper, we solved the problem of maximizing the expected vehicle coverage with a time constraint, by developing a binary integer programming model. The considered objective was to maximize the expected vehicle coverage across the network, assuming preventive duties only, during a given time horizon and with a fixed amount of patrol vehicles. Now we extend that approach by also considering the response time to the occurrence of an attack. We use a scalarized multi-objective model with epsilon-constraints in order to include both stated objectives and plan to address two cases: one in which every unit can perform a preventive and responsive labor, and another in which the number of units for each prevention and response is given from the beginning as a decision.

3 - Solving Biobjective Minimum Cost Network Flow Problems

Andrea Raith, Antonio Sedeño-Noda

Minimum cost network flow (MCF) problems are widely applied in network optimization. Here we consider MCF problems with two objective functions. These biobjective minimum cost network flow (BMCF) problems with continuous variables can be solved by identifying all efficient extreme supported solutions. Integer versions of BMCF often apply a Two Phase approach where in Phase 1, again all extreme supported solutions must be found. Common solution methods for the continuous problem are a parametric network simplex method or iteratively solving weighted sum scalarisations until the whole set of solutions is obtained. The parametric network simplex method for BMCF must evaluate all non-basic arcs as candidates to enter the basis associated with a current solution. We present an improvement of the parametric network simplex method based on only evaluating a subset of all candidate entering arcs in each iteration. Using a variety of different test problem instances we show the proposed algorithm is especially effective in reducing runtimes for high density BMCF problems. We also explore the potential of parallelisation in algorithms for BMCF problems.

■ MB-06

Monday, 10:30-12:00 - Building CW, ground floor, Room 2

MCDA and Environmental Management 1

Stream: Multiple Criteria Decision Aiding
Chair: *Antonio Boggia*
Chair: *Luisa Paolotti*
Chair: *Lucia Rocchi*

1 - Highways roadside vegetation sustainable management: an application using SMAA
Lucia Rocchi, Eleonora Mariano, David Grohmann, Francesca Giugliarelli, Irene Petrosillo, Angelo Frascarelli

Road infrastructures cause the 41% of the total soil loss in Italy and are responsible also for several secondary negative effects on the land, as the fragmentation of habitat. A proper management of green buffer zone along the highway and at intersections may partially mitigate such effects. Those areas are usually degrade and wild or barely managed. Moreover, they are a cost item for highways balance. The present work shows a case study where six different management options, both productive and unproductive, are considered for five different Italian highways crossroad areas. The analysis compares the status quo with new hypothetical scenarios, to find the best solution for each one, using a sustainable vision. Therefore, criteria used in the application followed the three sustainability pillar: economic, environmental and social one. Due to the presence of several stakeholders involved, Stochastic Multicriteria Acceptability Analysis has been applied (SMAA). SMAA is a family of multicriteria methods particularly suitable in case of problem with inaccurate, uncertain or missing information. Moreover, the Decision Makers need not to express their preference because the method allows to explore the weight space. Therefore, it is possible to find when a certain alternative would be the preferred one. Among the different algorithms included in the SMAA family, this work applied the SMAA-2, which extended the original SMAA method.

2 - The model GeoUmbriaSUIT for territorial sustainability assessment: an application to Italian and Spanish case studies
Luisa Paolotti, Antonio Boggia, Asuncion Maria Agullo Torres, Francisco Jose Del Campo Gomis

The aim of this work is to show the potentialities of the model GeoUmbriaSUIT for evaluating territorial sustainability, through an application involving Italian and Spanish case studies. GeoUmbriaSUIT is a QGIS plugin for sustainability assessment in geographic environment, using multiple criteria, i.e., environmental, economic and social. It implements the algorithm TOPSIS, which defines a ranking based on distance from the worst point and closeness to an ideal point, for each used criteria. Through this model, a territorial area can be analyzed, evaluating the sustainability of territorial units within it. For example, the analyzed area could be a country, and the units to be evaluated the regions within it, or it could be a single region, and the units to be evaluated the municipalities within it. In this work, the different Regions of Italy, and the Autonomous Communities of Spain are separately evaluated. Subsequently, a comparison between the two applications is reported, describing the results in terms of territorial sustainability for Italy and Spain.

3 - Sustainable multipurpose strategies for farms conciliating economic and environmental objectives
Filippo Fiume Fagioli, Luisa Paolotti, Antonio Boggia

The objective of this work is to present how Multiple Criteria Decision Aiding (MCDA) can be efficiently applied in the agricultural sector and farm management, in order to evaluate the level of sustainability of farms production activities. Sustainable economic development involves maximising the net benefits of economic development, subject to maintaining the services and quality of natural resources over time. In farm management, it is fundamental to take into account multiple criteria, considering not only the economic aspects related to farmer profitability, but also those connected with environmental protection and sustainability. MCDA methods are basic tools in the field of environmental valuation and management, to be used to support decision making within the context of farm management, which has a multidimensional structure and in which several different aspects have to be considered at the same time. The main aim of the work is to determine which can be the guidelines for implementing sustainable planning strategies within farms. To reach the aim of the study, a set of farms located in a rural area of Central Italy will be evaluated, by means of different MCDA methods, considering both economic (e.g., gross production value, total costs) and environmental criteria (e.g., quantity of pesticides and fertilizers used), in order to evaluate the level of sustainability of each farm, and consequently to draw useful guidelines for sustainable planning and management.

4 - Multi-Criteria Analysis of the Impact of Ownership Structure on Firm Performance in Recycling Industry
Jelena Stankovic, Marija Dzunic, Vesna Jankovic-Milic, Zeljko Dzunic, Milivoje Pesic

The subject of the paper is multi-criteria analysis of financial performance of enterprises engaged in waste collection and recycling in Republic of Serbia. More precisely, the focus of the paper is on the assessment of their profitability considering ownership structure and the following performance measures: Return on Assets, Return on Equity, Debt Ratio, Equity Multiplier, Net Profit Margin, Current Ratio and Quick Ratio. The idea is to perform the ranking of recycling industry enterprises according to overall assessment that includes the above listed performance measures and to compare the rank differences between public and private owned enterprises. The sample includes accounting-based measures in five-year period for 172 top enterprises in Serbian recycling industry with the largest total assets. Beside the differences in rankings determined by ownership structure, the paper deals with analysis of year-to-year changes in rankings. Principal Component Analysis (PCA) is the method of choice for weights determination. Squared factor loadings indicate the percentage of variability of each of these performance measures explained by the determined component. The relative importance of criteria is calculated as additive normalized values of squared factor loadings. In order to determine the rankings, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is applied.

■ MB-07

Monday, 10:30-12:00 - Building CW, 1st floor, Room 123

Memorial Session - in honour of Rolfe Tomlinson and Maurice Shutler

Stream: Memorial Session
Chair: *Graham Rand*
Chair: *Jakob Krarup*

1 - Honouring Rolfe Tomlinson and Maurice Shutler
Graham Rand, Jakob Krarup, Jakob Krarup

A slogan from last year's conference was "People make Glasgow". The same could be said of EURO. In particular, EURO is what it is today because of the commitment and wisdom of its Presidents. Since the conference in Glasgow we have been saddened by the death of two former presidents, the first to have passed away. This session will honour the contributions to EURO, and OR more generally, of Rolfe Tomlinson (president 1981-82) and Maurice Shutler (president 1993-94). Rolfe Tomlinson's time at the OR group in the UK's National Coal Board will be covered by John Ranyard and George Mitchell, whilst Robert Dyson will reflect on his leadership of the OR group at the University of Warwick. Paul Shutler and Jakob Krarup will give personal reminiscences of Maurice Shutler's contributions to OR in the UK and Europe.

■ MB-08

Monday, 10:30-12:00 - Building CW, 1st floor, Room 9

Complex preference learning in MCDA 3

Stream: Multiple Criteria Decision Aiding
Chair: *Salvatore Corrente*

1 - Applying MCHP, ROR and the SMAA methodology to the ELECTRE III method with interaction between criteria
Salvatore Corrente, José Rui Figueira, Salvatore Greco, Roman Slowinski

A great majority of methods designed for Multiple Criteria Decision Aiding (MCDA) assume that all criteria are considered at the same level, however, it is often the case that a practical application is imposing a hierarchical structure of criteria. To handle the hierarchy of criteria in MCDA, the Multiple Criteria Hierarchy Process (MCHP) has been recently proposed. MCHP permits to consider preference relations with respect to a subset of criteria at any level of the hierarchy. Here we consider the application of MCHP to the outranking method ELECTRE III, taking into account the interaction between couples of criteria that, can be of three types: mutual-weakening effect, mutual-strengthening effect, or antagonistic effect. To explore the plurality of rankings and binary relations between alternatives, that result from compatibility of many sets of ELECTRE III parameters with the available preference information, we propose to apply the Stochastic Multi-objective Acceptability Analysis (SMAA) and the Robust Ordinal Regression (ROR). On one hand, ROR permits to obtain necessary and possible preference relations on the set of alternatives in each node of the hierarchy. On the other hand, SMAA permits to compute the probability that an alternative gets a particular position in the recommended ranking, or probability that an alternative is preferred to another one, in all nodes of the hierarchy of criteria. We apply the proposed methodology to the ranking of universities.

2 - The ranking of Polish research institutions based on the distance measure function in the value space
Piotr Zielniewicz

The paper presents a method combining the robust ordinal regression approach and the idea of ranking alternatives based on the distance measure function. In this method, the preference model is composed of a set of additive value functions compatible with the preference information provided by the decision maker in the form of pairwise comparisons of reference alternatives. From among many forms of an additive preference model, we consider the model having as simple form as possible, i.e., the model that is the "closest to linear". We define a function representing closeness to the reference point (the ideal solution), however not in the criteria space, but in the value space. A set of mix-integer linear programming problems is solved to determine the minimum distance scores of each alternative (in this case research institution) on the set of compatible value functions. Finally, the obtained distance scores are used to rank all research institutions.

3 - Multi-criteria repair/recovery solutions for territory assignment problem
Oumaima Khaled, Michel Minoux, Vincent Mousseau, Xavier Ceugniet

In this talk we investigate solution recovery/repair issues in the context of a territory assignment problem where a number of salespersons (SPs) have to be assigned to customers in a given geographical area. Each salesperson operates from a given base office. The customers are grouped into clusters, the characteristics of which are supposed to be known (location, type(s) of product(s), etc.) and a SP has to be assigned to each customer cluster(CC). The main objective of an assignment is the minimization of the sum (over all CC) of the distance between the center of the CC and the base office of the SP assigned to it. The recovery/repair scenarios addressed assume that a first (optimal) assignment has already been determined, but because of the dynamic structure of the market context, various unexpected events can occur requiring reconsideration of this initial assignment. The question of "best repair", i.e., determining a new solution to the perturbed problem in order to come up with both a reduced increase in the total distance criterion and limited changes to be carried out in the assignment, typically involves multiple criteria such as the number of CCs impacted by the change, the number of SPs impacted, etc. We show that this repair problem can be formalized as a multi-objective integer linear programming problem minimizing a specified function of the various repair criteria. Numerical results illustrating the relevance of the proposed model will be given and discussed.

4 - Dominance based Monte-Carlo algorithm for multi-criteria ordinal classification
Tom Denat, Meltem Ozturk

In this document we are studying a multi-criteria method for preference elicitation and ordinal classification. In literature there are several methods adapted to ordinal classification, such as ELECTRE TRI, rule based or additive-utility methods. Such methods use decision parameters (thresholds, weights ...) which must be elicitated (directly or indirectly) from the decision maker. The specificity of our approach is to be probabilistic, based on a Monte-Carlo principle and thus not requiring sophisticated decision parameters. Hence, we do not assume that the decision maker's reasoning follows some well-known and explicitly described rules or logic system. The only two assumptions that we made are that monotonicity should be respected as well as the classification examples given by the decision maker (learning set). Three variants of our methods will be presented. We proved that for all the variants the learning set is respected and the result converges a.s. and that for two variants monotonicity is respected. We saw practically that the convergence of the result is quite effective. We then compared our algorithm to three other MCDA elicitation methods (UTADIS, MR-Sort, DRSA) through a k-fold validation. This test was based on two sets of real data: judgment on the severity of potential accidental pollution (data from ecology specialists) and an ethic judgment on companies (from individuals). Our algorithm gets on these data sensibly better results than the others.

■ MB-09

Monday, 10:30-12:00 - Building CW, 1st floor, Room 12

OR Applications in Industry

Stream: OR Applications in Industry
Chair: *Geir Hasle*

1 - Flexibility value in Transmission Expansion Planning in Colombia using Real Options.
Alvin Henao Perez, Enzo Sauma, Angel Gonzalez

This paper presents an estimation of the the value of introducing flexibility in the Colombian Transmission Expansion Planning (TEP). This approach uses Real Options (RO) applied on a stylized version of Colombian electricity network. The transmission expansion process is split in a fixed expansion and a flexible expansion. The latter is used as an adapting mechanism to handle demand growth rates higher than expected. Results show the value that flexibility in Colombian TEP process has.

2 - Optimization for a Semi-Automated Warehouse
Ali Can Özcan, Bahar Yetis Kara, Ozlem Cavus, Tolga Dizdarer, Onur Altıntaş, Hakan Gultekin

This study focuses on the optimization of a Sorter system in a facility of Ekol Logistics. The system is composed of conveyors and automated baskets that handle product sorting, and manual labor that handles the product movement in between. Products are fed to the Sorter through conveyors and then manually transferred to automatic baskets that will drop them to their correct packages. The aim of this study is to create optimal feeding schedules to design a balanced flow of products to the system and to generate a continuous feeding capability that will eliminate the unnecessary idle time in between the waves of operation. Two models are proposed for optimal feeding schedule: a mixed integer optimization model and a simulation model. In addition to these models, a heuristic solution is also suggested. The models and the heuristic algorithm use company's operation data and product demands to find the hourly feeding schedule. They schedule workers for 3 shifts and assign the labor to required locations. The suggested models can be modified to be used in different environments with different sets of constraint.

3 - Applied OR at SINTEF
Geir Hasle

SINTEF is a Norwegian cross-disciplinary contract research institute that aims at bridging the gap between academia and industry. OR activities are found in many organizational units. In this talk, I will present examples of OR activities in the Group of Optimization, Department of Applied Mathematics. Examples include logistics simulation and optimization in railway and bus transportation, air traffic management, vehicle routing, and healthcare.

■ MB-10
Monday, 10:30-12:00 - Building CW, ground floor, Room 1

Meet the Editors of EJOR

Stream: EURO Awards and Journals
Chair: *Roman Slowinski*
Chair: *Immanuel Bomze*
Chair: *Robert Dyson*
Chair: *José Fernando Oliveira*
Chair: *Ruud Teunter*
Chair: *Emanuele Borgonovo*

1 - Some facts about the European Journal of Operational Research (EJOR)
Roman Slowinski, Immanuel Bomze, Emanuele Borgonovo, Robert Dyson, José Fernando Oliveira, Ruud Teunter

The editors of EJOR will give some characteristics of the journal, and will explain their approach to evaluation and selection of articles. They will point out topics of OR which recently raised the highest interest. Two other presentations in the session will be done by authors of representative and highly cited papers published recently in EJOR in two categories: theory & methodology, and innovative application of OR. In the last part of the session, the editors will answer some general questions from the audience.

2 - Competitive Food Supply Chain Networks with Application to Fresh Produce
Anna Nagurney, Min Yu

In this paper, we develop a network-based food supply chain model under oligopolistic competition and perishability, with a focus on fresh produce. The model incorporates food deterioration through the introduction of arc multipliers, with the inclusion of the discarding costs associated with the disposal of the spoiled food products. We allow for product differentiation due to product freshness and food safety concerns, as well as the evaluation of alternative technologies associated with various supply chain activities. We then propose an algorithm with elegant features for computation. A case study focused on the cantaloupe market is investigated within this modeling and computational framework, in which we analyze different scenarios prior/during/after a foodborne disease outbreak.

We relate the model to several other supply chain network models of perishable products, including medical nuclear ones, and demonstrate how the original model can also be adapted to capture quality issues over time in food supply chains.

3 - The Vessel Schedule Recovery Problem (VSRP) - A MIP model for handling disruptions in liner shipping
David Pisinger, Berit Dangaard Brouer, Jakob Dirksen, Christian Edinger Munk Plum, Bo Vaaben

Containerized transport by liner shipping companies is a multi billion dollar industry carrying a major part of the world trade between suppliers and customers. The liner shipping industry has come under stress in the last few years due to the economic crisis, increasing fuel costs, and capacity outgrowing demand. The push to reduce CO2 emissions and costs have increasingly committed liner shipping to slow-steaming policies. This increased focus on fuel consumption, has illuminated the huge impacts of operational disruptions in liner shipping on both costs and delayed cargo. Disruptions can occur due to adverse weather conditions, port contingencies, and many other issues. A common scenario for recovering a schedule is to either increase the speed at the cost of a significant increase in the fuel consumption or delaying cargo. Advanced recovery options might exist by swapping two port calls or even omitting one. We present the Vessel Schedule Recovery Problem (VSRP) to evaluate a given disruption scenario and to select a recovery action balancing the trade off between increased bunker consumption and the impact on cargo in the remaining network and the customer service level. It is proven that the VSRP is NPNP-hard. The model is applied to four real life cases from Maersk Line and results are achieved in less than 5 seconds with solutions comparable or superior to those chosen by operations managers in real life. Cost savings of up to 58% may be achieved by the suggested solutions compared to realized recoveries of the real life cases.

■ MB-11
Monday, 10:30-12:00 - Building CW, 1st floor, Room 127

Neural Networks and Applications

Stream: Fuzzy Optimization - Systems, Networks and Applications
Chair: *Kiran Anwar*
Chair: *Jun-Der Leu*

1 - An Empirical Comparison of Different RBF Neural Network Training Algorithms for Classification
Tiny Du Toit

Radial Basis Function Neural Networks (RBFNNs) use Radial Basis Functions as their activation functions. The final network output is a linear combination of the Radial Basis Functions of the neuron parameters and the inputs. RBFNNs are popular for time series prediction, curve fitting, control, function approximation, signal processing, and classification. A RBFNN has several distinctive features making it different from other types of neural networks. These features include a more compact architecture, faster learning, and universal approximation. Several RBFNN training algorithms have been proposed in the literature. Amongst them are the Genetic algorithm, Kalman filtering algorithm, the gradient descent algorithm, and the Artificial Bee Colony algorithm. In this research, a hybrid conjugate gradient descent method is compared to the above-mentioned algorithms. Well known classification problems from the UCI Machine Learning Repository are used in the experiments. Results indicate that the hybrid conjugate gradient descent method outperforms the other algorithms on simple RBFNN models based on the percentage of correctly classified samples (PCCS) metric as well as the standard deviations of the PCCS.

2 - Plantar Pressure Identification and Differentiation Using an Artificial Neuromolecular System
JongChen Chen

Inappropriate use of foot may result in diseases on foot. The aim of this study is to investigate the relation between plantar pressures and center of gravity (COG), from which we can use to differentiate various features of users, to analyze plantar pressure of users with different motions, and finally to investigate users' plantar pressure under different situations. Our ultimal goal is to develop a customerized plantar pressure system for different people, time, and needs. To collect the data of human plantar pressure data, for each foot, five piezoresistive force sensors were embedded into an insole (10 sensors for both feet). These sensors were linked with an Arduino, a family of single-board microcontrollers, was used to input, process, and output data between the piezoresistive force sensors and the computer. The floor-based device Model BP 5050 was used to measure gravity of center (GOC) while wearing the in-shoe sensor (device) fitted in a shoe on the force plate for collecting the data of GOC and plantar pressure. An artificial neuromolecular system earlier constructed in our lab was used to differentiate behavior modes of different users. A conclusive result was that the biometric features possessed by each user were quite different that allowed us to separate one from another. Based on the plantar pressure data of each individual, we were able to differentiate normal/abnormal behaviors.

3 - Predicting the Direction of a Stock Index Using Artificial Neural Networks and Evidential Reasoning
Dong-Ling Xu, Chen You

This paper focuses on the prediction of the direction, either up or down, of Shanghai Stock Exchange Composite Index using Artificial Neural Networks (ANNs) and Evidential Reasoning (ER) models. Factors affecting the movement of a stock index are first identified as the inputs to the models. After model building and optimal tuning of model parameters, it is shown that ANN models perform better in predicting the "seen" sample data, while the ER model perform more accurately for forecasting new observations.

A new concept, strength of predictions, is introduced in the paper. It is defined as |P(up) - P(down)| or the absolute difference between the predicted probabilities of a stock's price going up and down. It is shown that for those stocks having high prediction strengths, the models have high prediction accuracy. Such a finding leads to the derivation of a selective trading strategy which generates high monetary gains.

As ER is a probabilistic reasoning process which extends Bayesian reasoning by considering the reliabilities and weights of those factors affecting a stock market movement, the prediction performance of ER and Bayesian models are also compared. ER shows a better performance. The paper concludes with a discussion of the advantages and disadvantages of ANN and ER models, and future research directions in the area.

4 - Design and Development of a Heuristic Based Evaluation function for General Game Playing
Kiran Anwar, Sobia Khalid, Sana Yousuf

General Game Playing (GGP) refers to formation of artificial intelligent agent that can play several games if game rules are provided. In this paper a heuristic based evaluation function called Goal Seeking Dead End Avoidance (GOSEDA) designed for GGP player is presented. The emphasis is to make player's performance better such that it does not only play games but also win games. The algorithm GOSEDA focuses on avoidance of dead-end during match play. GOSEDA algorithm explores the game tree and allows the player to select only those nodes during game play that have maximum number of moves. GOSEDA algorithm is evaluated using four benchmark Game Description Language (GDL) games. Experiments have been performed by connecting the player with Game Controller provided by Stanford logic group of Stanford University. In each game the player plays a match against Random Player of the Game Controller provided by the Stanford University logic group of research. The basic parameter for measuring performance of the algorithm designed for the GGP player is score of the player. The algorithm takes more time to play or win the game than its rival player strategy but still shows remarkable performance for two of the benchmark games.

■ MB-12

Monday, 10:30-12:00 - Building CW, ground floor, Room 029

Complexity in supply chains

Stream: Sustainable Supply Chains
Chair: *Aleksander Banasik*

1 - Eco-efficient agri-food supply chains: dealing with uncertain model parameters
Aleksander Banasik, Argyris Kanellopoulos, G.D.H. (Frits) Claassen, Jacqueline Bloemhof, Jack van der Vorst

Until recently food production focused mainly on delivering high quality products at low costs and gave only secondary attention to environmental impact and depletion of natural resources. This trend is changing due to the growing awareness of climate change, shrinking resources, and increasing world population. Multi-objective optimization models have been proposed to quantify trade-offs between conflicting objectives and to derive eco-efficient solutions, i.e., solutions for which environmental performance can only be improved at higher costs. In practice, not all the required information is available in advance due to various sources of uncertainty in food production. In this research a Multi-Objective Optimization model is proposed to support decision making in mushroom production and to evaluate the impact of uncertainty on decision support. The advantages and disadvantages of using stochastic programming, robust optimization, and a deterministic variant of the model are analysed and discussed.

2 - Designing a sustainable reverse network for recovery of WEEE using multi-objective optimization
Dennis Stindt, Petra Hutner, Jan-Philipp Jarmer, Christian Nuss, Axel Tuma

Political and societal stakeholders perceive CLSC as an enabler for integrating sustainability into business operations. We set out to investigate this underlying assumption. This research is guided by the following question: How does the consideration of various environmental aspects impact the design and viability of a reverse network? Therefore, we develop a multi-objective mixed integer linear program that represents a European product take-back and recovery network for WEEE. This reverse network design problem comprises two echelons: Collection centers and reprocessing facilities, former in charge of accumulation and separation of backflows into fractions designated for disposal, recycling, or high value recovery.

The economic parameters as well as backflow forecasts are derived from action research conducted in cooperation with a global manufacturer of IT-equipment. For acquisition of the environmental data we implement life cycle assessment following ReCiPe. This way, we determine the ecological impacts of the CLSC within each endpoint category: Damage to human health, damage to ecosystem, damage to resource availability. We solve the mathematical problem focusing on the economic dimension and each of the endpoints independently. In this way, we detect potential conflicts between the objectives and pave the way for implementing various procedures for multi-objective optimization.

3 - Risk Analysis for a Synchro-modal Supply Chain
Denise Holfeld, Axel Simroth, Roberto Tadei

Inter-modality increases the complexity of supply chains. By linking of organizations risk effects within the chain be transferred to other members, knock-on effects are possible and the reliability of the whole supply chain depends on its weakest link. Therefore, risk management is becoming more and more important. Managing the supply chain reactively by reviewing risk indicators, such as delays in transit, is a negative way to manage and mitigate against risk. The EU project SYNCHRO-NET will demonstrate how powerful a SYNCHRO-modal supply chain eco-Net can catalyse the uptake of synchro-modality. A new holistic concept will enable active inclusion of risk assessments by cooperation of different modules. With help of a "Real-time Optimisation" module paths for a mission are evaluated and can be adapted to current situations during the realisation. Depending on the risk attitude of a specific user a "Supply Chain De-stressing" module modifies the paths with the aim to de-stress the supply chain. For each possible path different KPIs are provided as basis for the user's decision. Beside "classical" logistics KPIs (e.g., cost, time, etc.) a "Risk Analysis" module will provide an additional risk based KPI. To determine such novel risk measure a Monte-Carlo rollout approach is used. In particular, by running through numerous random scenarios future developments of a decision are considered. Finally, a decision for one path is done by the user itself.

■ MB-13

Monday, 10:30-12:00 - Building CW, ground floor, Room 3

VeRoLog: Rich VRPs - More than just routing vehicles

Stream: Vehicle Routing and Logistics Optimization
Chair: *Werner Heid*
Chair: *Nitin Ahuja*

1 - Workload Balancing in the Context of Multi-period Service Territory Design
Matthias Bender, Anne Meyer, Stefan Nickel

Many companies operate a field service workforce for providing recurring services at their customers' premises. Examples include salespersons who regularly visit their customers and service technicians who periodically carry out maintenance work.

In these applications, each field worker is responsible for a dedicated geographical region, the so-called service territory. At the tactical planning level, the visit schedules are determined for each service territory, i.e. customer visits are assigned to the days of the planning horizon subject to customer-specific visit requirements. The planning objective is twofold: On the one hand, all customer visits of a field worker that are scheduled for the same day should be geographically concentrated in order to obtain short travel times. On the other hand, the daily workload - consisting of service and travel time - should be balanced. This means that a TSP must be solved for each day to determine the expected travel time. The actual route for each day is planned by the field worker in the short term.

In this talk, we propose a MIP-based heuristic, which aims at improving the workload balance within a service territory. We incorporate an estimator for the change in travel time that results from moving a customer visit to another day. This allows our approach to search large neighborhoods. We evaluate our approach on real-world instances provided by our industry partner PTV Group.

2 - Long-Haul Routing in Hub Network
Olli Bräysy, Birger Raa, Wout Dullaert

Long-haul transportation often takes place in a large hub network and the planning is done over long planning horizon. The traditional solution approach has been to define the hub network and plan the full truckload transport between the hubs using flow-based network optimization. Once those decisions were taken, the pickup and delivery routes from the hubs are determined. This decomposition often leads to suboptimal operations in practice as the approach does not guarantee a good match with varying vehicle and hub capacities and daily vehicle schedules. We suggest a combined approach where the long haul pickup and delivery routes with given time windows are planned simultaneously with the optimal hub network design over a multi-day planning horizon. Given the high complexity of the problem, we introduce several model simplifications. The applicability of the model to practice and the savings potential are illustrated via real example, showing up to 11% savings potential compared to current practice.

3 - The (Over) Zealous Snow Remover Problem
Kaj Holmberg

Planning snow removal is a difficult, infrequently occurring optimization problem, concerning complicated routing of vehicles. Clearing a street includes several different activities, and the tours must be allowed to contain subtours. The streets are classified into different types, each type requiring different activities. We address the problem facing a single vehicle, including details such as precedence requirements and turning penalties. We describe a solution approach based on a reformulation to an asymmetric traveling salesman problem in an extended graph, plus a heuristic for finding feasible solutions. The method has been implemented and tested on real life examples, and the solution times are short enough to allow online usage. We compare two different principles for the number of sweeps on a normal street, encountered in discussions with snow removal contractors. A principle using a first sweep in the middle of the street around the block, in order to quickly allow usage of the streets, is found to yield interesting theoretical and practical difficulties.

■ MB-14

Monday, 10:30-12:00 - Building CW, 1st floor, Room 125

Heuristics for Combinatorial Problems

Stream: Mixed-Integer Linear and Nonlinear Programming
Chair: *Luis Moreno*

1 - An Adapted Tabu Search for the Mutually Exclusive Knapsack Sharing Problem
Abdelkader Sbihi

In this paper, we propose to tackle a new variant of the knapsack problem that we call the mutually exclusive knapsack sharing problem (MEKSP). MEKSP is a particular knapsack sharing with added disjunctive constraints for each family of items. Our method is a local search based reactive tabu. First, we describe a greey heuristic to build a feasible solution that we complement with an improving procedure. Later, we describe our reactive tabu search with special features for intensifying and diversifying strategies. The approach yields satisfactory results within reasonable computational time that show the effectiveness of the proposed approach.

2 - Approximation of TSP Tours with a Restricted Set of Edges on Regular Grids
Isabella Hoffmann

In the traveling salesman problem (TSP) with forbidden edges the objective is to minimize the length of a tour of a graph with a restricted set of edges. All edges whose lengths are shorter than a given minimum length may not be included in the tour. Restricting the graphs on regular grids, we found a linear-time algorithm Weave that creates an asymptotically optimal tour for the longest possible minimum edge length or a slightly shorter minimum length. Weave was originally designed to solve the Maximum Scatter TSP which maximizes the shortest edge appearing in a tour. The TSP with a minimum edge length yields an application in laser melting processes. Powder is melted in small rectangular regions called islands, which are arranged in a certain order. It is desired to reduce production time while preserving a certain level of quality of the samples, so a short tour with restricted shortest edges between consecutive islands is needed.

3 - An Efficient Algorithm Using the Combination of Three Sequential Heuristic Rules for Solving the Traveling Salesman Problem
Luis Moreno, Javier Diaz

Based initially on the known priority rule for the Traveling Salesman Problem (TSP) that searches the closest not visited neighbor for each location (myopic strategy), a deterministic algorithm is proposed that uses sequentially two additional heuristic rules to solve the TSP.

After a solution is obtained by the priority rule, a first improvement is made to the solution by using an "order n" heuristic rule that searches the longest distance in the solution circuit, removes it to obtain a chain and from the two resulting ends, the shortest distance to one of the other nodes in the chain is searched. Using these two edges the circuit is reconstructed in an iterative process until it is not possible to do more improvements.

With the solution of the previous step an additional heuristic rule is used that splits the solution in several chains by removing the longest edges, and then a linear programming problem is solved to link them again and form a new circuit, using a reduced set of constraints.

The solutions obtained in these tree steps are very close to the optimal or better known solution for several problems in the classical library http://comopt.ifi.uni-heidelberg.de/software/TSPLIB95/ and are obtained in a very efficient (short) time.

■ MB-15

Monday, 10:30-12:00 - Building CW, 1st floor, Room 126

Quantitative Methods for the Analysis of Gas Markets

Stream: Optimization of Gas Networks
Chair: *Gregor Zöttl*

1 - Endogenizing long-term contracts in gas markets models
Abada Ibrahim, Andreas Ehrenmann, Yves Smeers

Long-term contracts have been associated with the initial developments of the gas industry in all regions of the world. These contracts fixed a minimum volume to be exchanged (Take Or Pay) and indexed the price of gas using a formula that usually referred to oil product prices. These arrangements allowed market risk sharing between the producer (who takes the price risk) and the mid-streamer (who takes the volume risk). They also offered risk hedging since oil is considered as a trusted commodity. The fall of the European natural gas demand combined with the increase of the oil price favored the emergence of a gas volume bubble. As a result, the downstream part of the industry brought forward the idea of indexing contracts on gas spot prices. In this paper, we present an equilibrium model that endogenously captures the contracting behavior of both the producer and the mid-streamer who strive to hedge their profit-related risk. The players choose between gas forward and oil-indexed contracts. Using the model we show that i) contracting can reduce the trade risk of both the producer and mid-streamer, ii) oil-indexed contracts should be entered into only when oil and gas spot prices are well correlated, iii) contracts are best suited when the upstream cost structure is mainly driven by capital costs and iv) a high level of risk aversion from the mid-streamer might deprive upstream investments and the downstream consumer's surplus.

2 - A multilevel programming approach for gas market analysis
Lars Schewe, Veronika Grimm, Julia Grübel, Martin Schmidt, Gregor Zöttl

We propose a multilevel optimization model for booking-based entry-exist systems for the analysis of the German gas market. Our goals are to reflect the Status Quo and to identify inefficiencies of this system. We discuss these inefficiencies using computional results on a stylized model of the German gas transport network.

The market design of most European gas markets is the so-called entry-exit system. In entry-exist systems, the network users buy rights (bookings) from the transmission system operator to inject or to discharge gas up to a certain amount - constrained only by the restriction that the in- and outflows (a nomination) must balance. In turn, the TSO has to guarantee that all network users can exercise their rights. To determine maximal capacities that can be sold by the TSO is extremely difficult. This is one of the possible inefficiencies of the entry-exit-system.

We propose a multilevel optimization model for booking-based entry-exist systems. On the upper level, the TSO maximizes his profit while ensuring that all booking-compliant nominations are feasible. On the lower level, the customers decide on their bookings only guaranteeing balanced nominations. We compare this model to a welfare-maximation model that only considers nominations. We present preliminary computational results on a stylized representation of the German gas transport network with 12 nodes and 13 arcs using market data from 2014.

3 - What Short-term Market Design for Efficient Flexibility Management in Gas Systems?
Florian Perrotton

With the increase of electric intermittent renewables, often backed-up by CCGTs, variability has been transferred to the gas network. Balancing the network has become a technical and economic issue. Applied to gas systems, market designs similar to locational marginal pricing might improve the situation. However, in such markets, flexibility can be handled in different ways. Using a linearized transient model of the gas network, we analyze the efficiency of two different auction designs.

■ MB-16

Monday, 10:30-12:00 - Building CW, 1st floor, Room 128

Robust Combinatorial Optimization II

Stream: Discrete Optimization under Uncertainty
Chair: *Daniel Schmidt*

1 - Process Scheduling via Adjustable Robust Optimization under Decision-Dependent Uncertainty
Chrysanthos E. Gounaris, Nikolaos H. Lappas

Multipurpose batch processing facilities play a major role in the production of specialty chemicals and other low-demand, high-value products. Maintaining high levels of utilization in such plants calls for the careful coordination of the limited available resources (e.g., equipment, personnel, raw materials, utilities) so as to meet a number of concurrent - yet often incongruous - production targets. However, at the moment we have to commit to a manufacturing plan, a multitude of parameters (e.g., processing times, process yields, material costs, resource availabilities) may be uncertain.

We develop an adjustable robust optimization (ARO) framework to address uncertainty in this setting. Unlike the traditional RO approach, which results in a static, "here-and-now" solution, ARO results in a multi-stage solution policy that has a proper functional dependence on parameter realizations. We derive the ARO counterpart model and discuss how policies must be restricted so as to depend only on observable parameter realizations. We also incorporate the use of decision-dependent uncertainty sets to handle the endogenous nature of the applicable uncertain parameters. Finally, in order to enhance computational efficiency, we also explore procedural solution strategies that generalize the well-known robust constraint generation method for the case of decision-dependent uncertainty sets. A comprehensive computational study is presented across literature benchmark examples.

2 - Stochastic Adaptive Processes
Marek Adamczyk

In the stochastic bipartite matching problem, as in the classical version, we must find a maximum weight matching in a given weighted bipartite graph. However, in the stochastic variant we do not know exactly which edges are present in the input graph. Rather, we have a probability for each edge and must "probe" an edge to see if it is present; and if it is, then we are forced to take it into the matching. Additionally, each vertex has a "patience" parameter that tells how many edges adjacent to it can be probed. In this variation of the matching problem a concept of a solution is not just a subset of edges anymore. Now it is an exponentially-sized decision tree which describes which edges to probe given outcomes of the previous probes. The goal is to find a strategy that maximizes the expected size of the constructed matching.

In the talk, using the bipartite matching as an example, I will overview problems of this nature. I will highlight couple of interesting facts which make this setup different from other setups that incorporate uncertainty in the input. For example: even though an optimal strategy may require exponential space to describe — essentially meaning that the decision tree is the only way of representing it —, I will show how using linear programming one can derive efficient algorithms whose performance is only constant factor worse than the performance of an optimal strategy.

3 - The Multi-Objective Shortest Path Problem under Gamma-Uncertainty
Lisa Thom, Andrea Raith, Marie Schmidt, Anita Schöbel

In multi-objective optimization several objective functions are considered, e.g., searching for a route on which financial costs and travel time are minimized at the same time. Robust optimization is one possibility to handle uncertainties, that often occur in applications, e.g., travel times can depend on congestion. Only recently have concepts of those two fields been combined to multi-objective robust optimization, and minmax robust efficient solutions have been defined.

In our talk we consider a shortest path problem with several objective functions which are all uncertain in the following sense: The edge lengths may vary in intervals, but for each objective we suppose that only for a given number of edges the lengths differ from their minimal values. For one single objective this reduces to the well-known concept of Gamma-uncertainty introduced by Bertsimas and Sim (2003). They developed an algorithm to find minmax robust solutions (solutions with optimal value in the worst case) to combinatorial optimization problems under this kind of uncertainty.

We extend this algorithm to the uncertain multi-objective case and analyze in which cases it is able to find minmax robust efficient solutions. Based on this we develop an algorithm for a more general setting and show its performance within some shortest path application.

■ MB-17

Monday, 10:30-12:00 - Building CW, ground floor, Room 0210

Transportation 2

Stream: Transportation
Chair: *Corrinne Luteyn*

1 - A Study on Developing an Evaluation Model for Urban Logistics Providers
Chih-Feng Chou, Ying-Chin Ho

More and more people are living in the urban area as the world is becoming more urbanized. As a result, how to provide urban residents with good-quality livings has been an important issue to not only the government, but also the persons, organizations and companies providing goods or services to urban residents. Many persons, organizations and companies have found that due to many factors (e.g., living space, life styles, cultures, etc.) services and goods needed by people living in the urban area are not completely identical to those needed by people living in the rural area. For example, due to the lack of living space, urban residents may need more storage service from logistics providers than rural residents. In this study, we build an urban-logistics-provider evaluation model that can assist urban logistics providers in evaluating themselves and finding out what they can do to improve their performance. This model can also assist customers in evaluating their urban logistics providers and selecting the best one to serve them. The purposes of this study are as follows. First, we want to understand what services urban residents need from their urban logistics providers. Second, we want to understand what capabilities an urban logistics provider must possess to satisfy the needs of its customers. Finally, we want to find out what performance criteria need to be considered in the urban-logistics-provider evaluation model and understand the reasons behind them.

2 - Improving an Incomplete Road Network given a Budget Constraint
Corrinne Luteyn, Reginald Dewil, Pieter Vansteenwegen

The optimization problem, considered in this research, is about determining the best set of possible improvements of an incomplete road network such that the total travel time on the network is minimized. Three possible improvements are studied in this research: (re-)opening pedestrian zones for vehicles, widening existing roads and converting existing roads into one-way roads with a higher speed. The total costs of the selected set of improvements may not exceed a given budget. A Mixed Integer Programming formulation is presented to determine the best set of improvements. Due to the complexity of the problem, a heuristic is introduced to find near-optimal solutions for cases of realistic size. This heuristic iterates between a construction part and an analysis part. During the construction part, routes for the vehicles are constructed in the current network using a fast Variable Neighborhood Search. In the second part of the heuristic, the constructed routes are analyzed heuristically in order to determine a good set of improvements for the network. Since the selected improvements in the set can interfere with each other, this determined set is tested again in the construction part. The performance of our heuristic is evaluated on a set of benchmark instances based on a realistic road network with a varying number of customers and vehicles. Additionally, the solution quality is compared to that of solutions obtained using exact solution techniques.

3 - A model for Airline Operations Recovery with support for crew down-ranking
Grzegorz Siekaniec

Despite the very precisely established plan, the disruptions are everyday reality in the airline operations. They are caused by unforeseen factors such as weather disruptions, security alerts, crew sickness etc. Disruptions can vary in magnitude spanning from small ones to large scale events impacting the big part of airline network. Sabre Airline Solutions developed Recovery Manager Crew optimization engine aimed at recovering crews' operations of different size in nearly real-time by bringing them back to original schedule while minimizing cost and operational disturbances. The mathematical formulation of the model will be presented with the focus on the most recent enhancement - crew down-ranking. The importance of crew down-ranking lies in the fact that it expands set of possible recovery options, increasing chances of earlier time of recovery and/or lower costs.

4 - Is the optimal plan in airline operations planning really optimal in practice?
Aykan Akincilar, Ertan Güner

Even an airline operations planning problem could be solved to optimal, which is clearly a very hard task, the obtained plan is still highly vulnerable to internal and external factors. Thus, it becomes hard to implement those plans without any disruption. It means that recovery planning, which generally stirs up a significantly great challenge for every partner of an airline, e.g., AOCC staff, crews, passengers, etc., seems inevitable in practice. Or can it be completely or partly avoided? This fair question grows amazingly up in the field of airline operations also, like many other fields in the literature. Main goal of this presentation is to discuss this phenomenon. Additionally, in this frame, necessity and importance of robust planning in airline operations planning, strong and weak sides of the state-of-the-art robust planning attempts in this field are also discussed. After some gaps in the literature are indicated and, then, some suggestions are made for future works based on those gaps.

■ MB-18

Monday, 10:30-12:00 - Building CW, ground floor, Room 023

Inventory Management 1

Stream: Production and Operations Management
Chair: *Tim Lamballais Tessensohn*

1 - Planning inventory transshipments in retail networks
Thomas Archibald, Kevin Glazebrook, Sandra Rauscher

Models of transshipments in inventory systems generally assume that demand is observed. This research relaxes this assumption and proposes a model that can be used to plan reactive (i.e., to meet existing shortages) and proactive (i.e., to meet anticipated future shortages) transshipments in a general setting. Approximate dynamic programming is applied to develop a heuristic for the model. A numerical study shows that the proposed heuristic can lead to substantial cost savings compared to commonly used policies.

2 - Optimal inventory policy for items with price and time-dependent demand considering backlogged shortages
Joaquin Sicilia-Rodriguez, Luis A. San-José-Nieto, David Alcaide Lopez de Pablo

In this work we analyze an inventory model for items whose demand is a bivariate function of price and time. It is supposed that the demand rate multiplicatively combines the effects of a time-power function and a price-logit function. The aim consists of maximizing the profit per time unit, assuming that the inventory cost per time unit is the sum of the holding, shortage, ordering and purchasing costs. An algorithm to find the optimal price, the optimal lot size and the optimal replenishment cycle is developed. Several numerical examples are introduced to illustrate the solution procedure.

3 - A novel approach to analyze inventory allocation decisions in Robotic Mobile Fulfillment Systems
Tim Lamballais Tessensohn

E-commerce introduces challenges for warehouses as assortments are large and consist of small products with strongly fluctuating demand. The Robotic Mobile Fulfillment System (RMFS) is a new category of automated storage and part-to-picker order picking systems developed specifically with a focus on e-commerce. We develop a Semi-Open Queueing Network (SOQN) model to analyze inventory allocation decisions in an RMFS. The contributions are threefold. First, the paper shows the number of pods per product, the ratio of pick to replenishment stations and the replenishment point that optimize the order throughput time given a desired inventory level. Second, this work adds two modeling techniques to the modeler's toolbox by showing how a queueing model can be used to model robot movement and how classes can be used to model inventory levels. These techniques can be applied and generalized to other parts-to-picker systems. Lastly, this work contributes methodologically by introducing a new type of SOQN model.

■ MB-19

Monday, 10:30-12:00 - Building CW, ground floor, Room 021

Lot Sizing, Lot Scheduling and Related Problems 2

Stream: Lot Sizing, Lot Scheduling and Production Planning
Chair: *Stéphane Dauzere-Peres*

1 - Two-echelon supply chain coordination mechanism under information asymmetry for a general number of type profiles
Rutger Kerkkamp, Wilco van den Heuvel, Albert Wagelmans

We consider a principal-agent contracting model between a supplier and a retailer under the classical economic order quantity (EOQ) setting. This two-echelon supply chain must satisfy known constant demand without backlogging. The supplier and the retailer are characterised by their constant holding and ordering cost parameters. The goal of the supplier is to minimise his own costs by offering a contract to the retailer. Such a contract includes a side payment as an incentive mechanism.

Unfortunately, the retailer does not share her holding costs. This leads to a contracting model with asymmetric information. We assume that there are finitely many possible values for the retailer's holding cost, each corresponding to a so-called retailer type. Furthermore, each retailer type has its own outside option, i.e., its own participation threshold. To minimise his expected costs, the supplier presents a menu of contracts to the retailer: one contract for each retailer type. The optimisation problem at hand is to determine such an optimal menu of contracts.

We show how to solve this non-convex model efficiently for any number of retailer types. We also derive theoretical properties of the optimal menu of contracts. This research extends the current literature by simultaneously considering a general number of retailer types and type-dependent outside options.

2 - Worst-case analysis of relax-and-fix heuristics for some lot-sizing models
Wilco van den Heuvel, Nabil Absi

Relax-and-fix heuristics are regularly used to solve several types of lot-sizing problems. The main idea of a relax-and-fix heuristic is to find a solution for a MIP problem by iteratively fixing the integer variables through repeatedly (1) relaxing the integrality of a set of (unfixed) integer variables, and (2) fixing (part of) the remaining integer variables to the optimal values of the resulting MIP problem. Computational results in the literature show that these relax-and-fix based heuristics perform well on sets of randomly generated problem instances. To the best of our knowledge, no theoretical analysis has been performed on the performance ratio of such heuristics (i.e., the ratio between the heuristic and optimal objective value).

In this research, we analyze the worst case behavior of relax-and-fix heuristics for some basic lot-sizing models. Our theoretical analysis shows that for the single-item uncapacitated lot-sizing problem the performance ratio can be arbitrarily bad for a given number of variables that are fixed in each iteration of the relax-and-fix heuristic. Furthermore, computational experiments reveal that an increase in the number of variables or an increase in the amount of overlap in the variables being optimized over in each iteration, does not lead to a better performance of relax-and-fix heuristics in general.

3 - A Branch-and-Cut Algorithm Using Two-Period Relaxations for Big-Bucket Lot-Sizing
Kerem Akartunali, Mahdi Doostmohammadi, Ioannis Fragkos

In this paper, we investigate polyhedral structure of the two-period subproblems proposed for big-bucket lot-sizing problems by Akartunali et al. (2014). Based on two relaxations of the two-period subproblem, we propose various families of valid inequalities and present their facet-defining conditions. These inequalities are lifted to the original space of the two-period subproblems, and they also inspire the derivation of a new family of inequalities defined in the original space. Since the exact separation problems for all families of inequalities are NP-hard, we exploit the structural similarities of the different families in order to design an efficient separation algorithm, and utilize a procedure that identifies members of each family that exhibit large violations. This procedure is embedded in a modern branch-and-cut solver, and extensive computational tests indicate the detailed performance of these new cuts.

4 - Lot Sizing Models for Designing On-Line Electric Vehicle Systems
Stéphane Dauzere-Peres, Young Jae Jang

In this talk, we present an original application of lot-sizing models, that are usually applied to production planning or supply chain planning problems. A new type of transportation system based has been developed by Korea Advanced Institute of Science and Technology (KAIST), where electric vehicles (buses) are charged on line and wirelessly from power transmitters under the road. We will show that the design problem of a single bus line is equivalent to a single-item dynamic lot-sizing problem with production capacity, inventory capacity and setup carryover. We will also discuss possible extensions of the problem to the design of multiple bus lines that can potentially share the same power transmitters.

■ MB-20

Monday, 10:30-12:00 - Building CW, ground floor, Room 022

EWGLA: Location

Stream: Location
Chair: *Andreas Klose*

1 - Location Theory in the Phylogenetic Tree Space
Marco Botte, Anita Schöbel

The space of phylogenetic trees consists of all weighted trees with a fixed set of labeled leaves. It was introduced as a metric space by Billera, Holmes and Vogtmann (BHV) in 2001 and has some interesting properties. This space is investigated because of its applications in biology: The task is to determine a 'center point' for a given set of trees in this space. Those trees are, e.g., derived by samplings of different genes of humans and ape species. Each gene sampling results in a tree proposing a possible evolutionary tree for those species, where the tree may vary for different genes. The goal is to find one tree which represents the set of sampled gene trees.

We model the problem as a location problem: The sampled gene trees are the existing facilities and we search a new facility (the evolutionary tree) which is as close as possible to them. The challenge of the location problems is the complexity of the space, which consists of an exponential amount of different tree structures amongst other tricky features.

In the talk the BHV - tree space will be introduced, followed by some approaches to location theory within it. Those are either to work in a low dimension or to assume some structure on the existing facilities. Afterwards, first results for these location problems are presented. Thereby the methodology is shown, using existing knowledge of problems by carrying over some specifics of the tree space to a well-known environment.

2 - Application of tropical optimization techniques to the solution of location problems
Nikolai Krivulin

We consider minimax single-facility location problems in multidimensional spaces with Chebyshev and rectilinear distances. Both unconstrained problems and problems with constraints imposed on the feasible location area are under examination. We start with the description of the location problems in a standard form, and then represent them in the framework of tropical (idempotent) algebra as constrained tropical optimization problems. These problems involve the minimization of non-linear objective functions defined on vectors over an idempotent semifield, subject to vector inequality and equality constraints. We apply methods and results of tropical optimization to obtain direct, explicit solutions to the problems. To solve the problem, we introduce a variable to represent the minimum value of the objective function, and then reduce the optimization problem to an inequality with the new variable in the role of a parameter. The existence conditions for the solution of the inequality serve to evaluate the parameter, whereas the solutions of the inequality are taken as a complete solution to the problem. We use the results obtained to derive solutions of the location problems of interest in a closed form, which is ready for immediate computation. Extensions of the approach to solve other problems, including minimax multi-facility location problems, are discussed. Numerical solutions of example problems are given, and graphical illustrations are presented.

3 - A comparison of algorithms for solving the capacitated facility location problem with convex production costs
Andreas Klose

We consider the capacitated facility location problem with differentiable convex production cost functions. The problem arises in numerous real-world applications as queues in call-centres, server queueing or when production is pushed beyond normal capacity limits. For finding proven optimal solutions, we suggest a branch-and-bound method based on Lagrangian relaxation and subgradient optimization. This method is compared on a large number of test instances to three other exact solution methods: A cutting plane approach that uses supporting hyperplanes of the convex cost functions for generating lazy constraints as well as fractional cuts; in case of quadratic cost functions, the use of a commercial solver for quadratically constrained MIPs based on a perspective formulation of the problem as suggested in the literature; and, finally, a Benders decomposition approach.

■ MB-21

Monday, 10:30-12:00 - Building CW, ground floor, Room 025

Robustness in public transport

Stream: Public Transportation
Chair: *Pieter Vansteenwegen*

1 - Integrating robust timetabling in railway line planning
Sofie Burggraeve, Simon Bull, Richard Lusby, Pieter Vansteenwegen

We propose an algorithm to build from scratch a railway line plan that minimizes passenger travel time and operator cost and for which a feasible and robust timetable exists. A line planning module and a timetabling module work iteratively and interactively. The line planning module creates an initial line plan. The timetabling module evaluates the line plan and identifies a critical line based on minimum buffer times between train pairs. The line planning module proposes a new line plan in which the time length of the critical line is modified in order to provide more flexibility in the schedule. This flexibility is used to improve the robustness of the railway system. The algorithm is validated on a high frequency railway system with little shunt capacity. While the operator and passenger cost remain close to the initially built line plan, the timetable corresponding to the final line plan has the potential to significantly improve the minimal buffer time, and thus the robustness, in 8 out of 10 studied cases.

2 - Robust control strategy for minimising energy consumption of electric buses using cooperative ITS technology
Giulio Giorgione, Francesco Viti, Marcin Seredynski

The introduction of high capacity electric buses to public transport substantially reduces transportation externalities. One of the main drawbacks of electric buses is the limited range. It can be extended thanks to on-route opportunity charging. We propose a complementary approach based on Driving Assistance Systems (DASs). Specifically, we combine Green Light Optimal Speed Advisory (GLOSA) and Green Light Optimal Dwell Time Advisory (GLODTA) to reduce energy consumption of an electric bus. The former optimises the velocity of the bus, while the latter optimises battery-charging time at a bus stop so that the use of charging infrastructure is optimised without affecting service level of the bus. The proposed algorithm is robust to changes of traffic signal settings and the PT traffic thanks to continuous access to Signal

Phase and Timing (SPaT) from signal controllers as well as to information about charging requests from other buses, the algorithm adapts its approach to the difficulty of the underlying optimisation problem. We also identify the best positions to place recharging stations. The heuristic rules developed in this study are applied to a Bus Rapid Transit (BRT) system. We assume that bus dwell times at bus stops as well as traffic signal timings are known by our system. Provided example shows how adopting speed and dwell time strategies help achieving efficient BRT operations, i.e., energy consumption is reduced and scheduling constraints are satisfied.

3 - An efficient heuristic for real-time train rescheduling and local rerouting
Sofie Van Thielen, Francesco Corman, Pieter Vansteenwegen

In practice, unexpected events frequently cause delays, often leading to conflicts, since multiple trains simultaneously require the same infrastructure. Currently, such conflicts are manually resolved by dispatchers, although it is impossible for them to anticipate the impact of their actions on the entire network. Conflict detection and resolution tools can help dispatchers make informed decisions. This research introduces a new heuristic that uses rescheduling and rerouting in station areas and is innovative due to strong similarities with real-life situations. The algorithm for rescheduling is based on limiting the total delay caused by conflicts, through analyzing the predicted progress over the following hour. If the conflict arises in a station area, an optimization procedure checks first whether rerouting leads to a solution with (almost) no delays. Because some trains have a needless amount of alternative routes, a routing filter is applied before the rerouting procedure. This rerouting procedure is based on a flexible job shop problem aiming to minimize the actual travel time of passengers. This fast and effective method is experimentally tested using a close-to-practice simulation tool and compared to commonly used dispatching rules.

■ MB-22

Monday, 10:30-12:00 - Building CW, ground floor, Room 027

Topics in Combinatorial Optimization

Stream: Combinatorial Optimization
Chair: *Silvano Martello*
Chair: *Paolo Toth*

1 - Final point generalized intersection cuts
Egon Balas, Aleksandr Kazachkov, Francois Margot

We introduce a new class of generalized intersection cuts for mixed integer programming, called final point cuts, which define facets of the convex hull of the disjunctive set from which they are derived. We report on computational experiments that show these cuts to close on average more than twice the size of the integrality gap closed by standard intersection cuts, and roughly a third of that closed by the split closure.

2 - Power of Preemption for Minimizing Total Completion Time on Uniform Parallel Machines
Alan Soper, Leah Epstein, Asaf Levin, Vitaly Strusevich

For scheduling problems on parallel machines, the power of preemption is defined as the supremum ratio of the cost of an optimal non-preemptive schedule over the cost of an optimal preemptive schedule (for the same input), where the cost is defined by a fixed common cost function. We present a tight analysis of the power of preemption for the problem of minimizing the total completion time on any number of uniformly related machines, showing that its value for two machines is equal to 1.2, and its overall value is approximately 1.39795.

3 - Multi-Depot Fleet Dimensioning for Seasonal Stochastic Demand
Marcus Poggi, Rafael Martinelli

We address the problem of multiple depot fleet dimensioning for delivery of a seasonal stochastic demand along a given period. Static and dynamic rules for the allocation of demands to depots are discussed. Given a predicted demand behavior represented by a generation function over time and space, distances between clients and the depots, cost to lease one vehicle for the period, unity cost for traveling a distance for leased and for short time hired vehicles and a demand allocation rule, find the (possibly heterogenous) fleet size at each depot that minimizes the expected operation cost for the period. We propose a decomposition approach based on Stochastic Dual Dynamic Programming that allows dealing with the integrality of the subproblems. The resulting solution is then evaluated through simulation of the operation along the period via a Monte-Carlo method. The sensitivity to the quality of demand prediction and to the demand allocation rule is analyzed. Finally, we discuss implementation issues and the limits of the proposed method.

■ MB-23

Monday, 10:30-12:00 - Building CW, ground floor, Room 028

Wireless Sensor Networks

Stream: Graphs and Networks
Chair: *Reinhardt Euler*
Chair: *Ahcene Bounceur*

1 - Composition of Graphs and the Weakly Connected Independent Set Polytope
Fatiha Bendali, Jean Mailfert

Modelling topologies in Wireless Sensor Networks (WSN) principally uses domination and connectivity from graph theory. An undirected communication graph G is naturally associated to the sensors located in the region they monitor. Indeed, a sensor corresponds to a node of G, and whenever two sensors can directly communicate, this virtual link is associated to an edge of G. In G, we define a Weakly Connected Independent Set as a subset W of the set of nodes such that W is an independent set (no two sensors of W can directly communicate) and the partial graph with the subset of edges having exactly one end node in W, is connected. Furthermore, W allows us to classify the nodes into three classes: the masters (nodes of W) which collect data of their neighbourhood, the slaves which only depend of a master and conduct detection activities, and the bridges that are linked to at least two masters and that ensure communication between them. The minimum weakly connected independent set problem is formulated as an integer linear program. In particular, we present some composition operations on graphs (1-sum, adding vertices or edges, corona and join of graphs) which enable us to obtain the corresponding weakly connected independent set polytopes from pieces.

2 - A New Polyhedral Approach for the Minimum Energy Symmetric Network Connectivity Problem
Jean Mailfert, Mourad Baiou, Fatiha Bendali, Salsabil Grouche

A wireless sensor is a standalone device, powered by a battery, making measurements in its immediate environment. It emits by radio the collected data to a base station directly if it can, or to its neighbouring sensors for indirect sensing transmission to the station. The battery providing the necessary energy for communicating has a limited lifespan. One of the current problems in wireless sensor networks is to assign a transmit power for each sensor so that the communication network would be still connected and that the allocated global power is minimal. Our work addresses the problem of minimum power allocation by integer linear programming. We propose first a formulation that can treat specific graphs as cycles or cactus. Finally we give a more general formulation.

3 - Finding the Boundary Nodes of a Wireless Sensor Network Without Conditions on the Starting Node
Ahcene Bounceur, Madani Bezoui, Reinhardt Euler, Marc Sevaux

Finding the boundary nodes of a Euclidean connected graph can be done using the LPCN algorithm. In each iteration, this algorithm calculates the minimum angle formed by the current node and its neighbor found in the previous iteration with its other neighbors. The node that gives the minimum angle will be considered as the current boundary node of the next iteration. This algorithm works only if the starting node is a boundary node. In general, we start from a node having the minimum x-coordinate. The drawback of this condition is that the boundary nodes cannot be determined in the case where it is not possible to determine the starting boundary node. In this presentation, we propose a new technique called "Reset and Restart" that allows to start from any node of the graph and to run the LPCN algorithm normally by assuming that the starting node is the one having the minimum x-coordinate xmin. If the next found boundary node has an x-coordinate smaller than xmin than this one will be considered as a starting node with the smallest x-coordinate, the xmin will be updated by this coordinate and all the previously found boundary nodes will be cancelled and considered as ordinary nodes (Reset step). The algorithm will be executed again (Restart step) starting from this node. This procedure will be repeated as soon as a node having an x-coordinate smaller than xmin is found. Otherwise, the algorithm stops if the next node selected from the starting node is selected twice.

4 - Novel Approach for Routing in Wireless Sensor Networks
Abdelmalek Boudries, Amad Mourad, Rabah Kassa

Minimizing the energy consumption of sensor nodes due to the delivery of the data towards the base station, and sharing of energy needed to accomplish this task, is a good way to delay the node failure due to lack of energy of their battery, and to extend the lifetime of the entire network. Our goal is to share the total energy consumed and to route data towards the base station from multiple nodes to minimize the individual energy consumption. In this work, we propose a generic solution for routing, taking into account connectivity maintenance in wireless sensor networks. The solution can be used in any routing protocol. The weight of a node is defined in a way that it changes according to the percentage of the remaining energy rate, and the weight of a path is equal to the average weight of the component nodes. Once the routing path is chosen and the delivery of data has begun, the data source can change the routing path if it receives an update message from the routing path component node by comparing the new weight of the path to the weight of the checked routing paths. An update message is sent by a participant node routing and its remaining energy is critical. The simulation showed the effectiveness of the proposed solution.

■ MB-24

Monday, 10:30-12:00 - Building BM, 1st floor, Room 119

Defence and Security 2

Stream: Defence and Security
Chair: *Ana Isabel Barros*

1 - ISR Security Planning
Axel Bloemen, Ana Isabel Barros, Dennis Huisman, Martin van Meerkerk

In Intelligence, Surveillance and Reconnaissance mission planning, it is necessary to assign the scarce available ISR resources to an extensive number of information collection tasks. In practice, the planning has to deal with a limited availability of ISR resources and their operational constraints and capabilities. Moreover, tasks often have a limited time window in which they can be addressed and cannot be performed by all the ISR resources. Therefore, often only a subset of the available tasks can be performed. In order to tackle this we introduce the multi-constrained stochastic team orienteering problem with heterogeneous resources problem and propose an heuristic to develop a robust assignment and routing plans that explicitly take uncertainty in travel and handling times into account, and discuss its performance.

2 - Flight Planning for Unmanned Aerial Vehicles
Armin Fügenschuh

The mission planning problem for an unmanned aerial vehicle (UAV) asks for an optimal trajectory that visits a largest possible subsets from a list of desired targets. When selected, each target must be traversed in a certain maximal distance and within a certain time interval. In a further variant of this problem, a fleet of potentially inhomogeneous UAVs is given. Before actually planning the trajectories, a vehicle-to-target assignment has to be carried out. If the targets are surrounded by radar surveillance, then the vehicle's trajectory should be chosen to minimize the risk of detection. This planning problem is similar to classical vehicle routing problems with time windows. We adapt such models from vehicles driving on street networks to freely floating UAVs. Different to classical vehicle routing, the fuel consumption rates during cruise (at various speed and altitude levels) need to be considered within the model. Also certain areas can be restricted for an entrance of the UAV. We formulate the mission planning problem for UAVs as mixed-integer second-order cone programming problem. The cone constraints are linearized thereafter, so that mixed-integer linear solvers can be applyed for a numerical solution.

3 - Simultaneously Determining Ingress/Egress Points and Time Allocations for UAV Grid Routing
Rajan Batta, Michael Moskal II

In this work we propose a method for simultaneously determining the best ingress and egress points and the time allocations for a series of linked Unmanned Aerial Vehicle (UAV) routing instances to maximize global information gain across all routes within an Area of Operation (AO). The area of operation is decomposed into a network of grids based on geographic location and then partitioned into a series of zones called macrogrids which each contain a set of grids representing numerically-valued areas of surveillance interest, or microgrids, which effectively become potential waypoints for the UAV. Given a sequence of macrogrids for an Intelligence, Surveillance, and Reconnaissance (ISR) mission, a series of heuristics are used to generate and score potential ingress and egress points which serve as in input to a mathematical allocation model to determine a set of parameters that improves global information collection.

4 - Optimal Path Planning with Minimum Number of UAVs by Using Genetic Algorithm
Ali Seyis, Yusuf Karacin, Omer Ozkan

Unmanned systems as a result of evolution have been replacing the manned systems especially in pioneer fields like aviation. Unmanned Aerial Vehicles (UAVs) are used for operations both in military and civilian usage. The major interest fields in designing UAVs are interoperability, reliability, autonomy, engine systems and payload. Path planning is directly related with these fields; hence it has prime importance for UAVs. In this work, the defined UAV path planning problem is based on multi-Travelling Salesman Problem (m-TSP). In m-TSP, the "n" number of target nodes should be visited only one time by "m" number of vehicles and the vehicles should return to the same starting node. The objective function of m-TSP is to find the subtours for all UAVs that the total travelling cost is minimized. Additionally in the solved problem, the number of UAVs is also minimized simultaneously. m-TSP is an NP-hard problem, therefore a Genetic Algorithm (GA) is generated to solve the path planning problem with minimum number of UAVs. The flying ranges of the UAVs are also used as constraints. The designed GA has problem specific representation and operators. Seven different problem sets are selected from literature. The number of target nodes is varying from 22 to 150 and the flying ranges of the UAVs are differentiated from 50 to 2500 unit distances. The proposed GA is compared with an algorithm and performed well in dealing with the problem in reasonable CPU times.

■ MB-25

Monday, 10:30-12:00 - Building BM, ground floor, Room 19

Behavioural Issues in Decision Analysis

Stream: Behavioural Operational Research
Chair: *Gilberto Montibeller*
Chair: *Detlof von Winterfeldt*

1 - Innovative public decision making assisted by design theory: is it possible?
Irene Pluchinotta, Akin Kazakci, Alexis Tsoukias, Giovanna Fancello

In complex and uncertain environments, it is very difficult to determine how effective a policy will be. Part of the difficulty resides in the fact that even when a policy is targeted to regulate the behavior of specific actors, actors are interdependent in performing their tasks, individually and collectively. Each decision is commensurate with their perspectives and frames and will influence and be influenced by the actions choices of the other actors. We should be aware that a deep understanding of the relationship between knowledge, behavior and actions is required. Among the new demand for supporting the policy cycle the issue of assisting the design of policies has been identified as critical. Design theory, originally conceived for assisting practitioners in "designing", has evolved in a more formal version aiming at assisting and organizing any process of creating "objects", possibly immaterial and abstract such as a strategy or a policy. These "objects" do not exist within our knowledge, but can be designed out of it. The talk addresses the problem of how to support innovation in policy design using formal analytic tools. It explores how design theory can be matched with constructive decision analysis in order to assist the design of policies and how these can be used for innovative public decision-making.

2 - Debiasing Overconfidence
Valentina Ferretti, Sule Guney, Gilberto Montibeller, Detlof von Winterfeldt

Decision problems often involve alternatives that have uncertain impacts, particularly in the appraisal of complex policies, such as in health, counter-terrorism, or urban planning. Furthermore, many of these impacts are hard to estimate, because of the lack of conclusive data, few reliable predictive models, or conflicting evidence. In these cases, decision and risks analysts often use expert judgment to quantify uncertain impacts. Behavioral decision researchers have identified numerous biases that affect experts in such estimates and therefore impact the quality of a decision analysis. A recent review of cognitive and motivational biases in decision analysis, conducted by Montibeller and von Winterfeldt, identified overconfidence as a relevant bias in this elicitation task, both in terms of its prevalence and its persistence against attempts to reduce it (such as warning the experts about the bias). They also listed a series of debiasing strategies employed in practice by decision analysts, noting the limited evidence about their effectiveness in more controlled experimental settings. The aim of the talk is to report on our early findings from two experiments we recently conducted to test the effectiveness of several of these debiasing strategies to reduce overconfidence when eliciting continuous probability distributions.

3 - Combining Methods for Problem Structuring and Multicriteria Decision Analysis - a review of practice and reflections on behavioural implications
Valerie Belton, Mika Marttunen, Judit Lienert

The past 20 years has seen growing attention to problem structuring for MCDA and in particular an increased use of a range of formal approaches, developed outwith the MCDA community, to support that process. We will report on the findings of a recent literature review covering applications of range of MCDA methods for discrete choice (MAVT/MAUT, AHP/ANP, outranking methods and TOPSIS) together with both generic problem structuring methods (SODA, SSM and SCA) and more focused approaches (SWOT, stakeholder analysis, scenario analysis and DPSIR) during the period 2000-2015. The review revealed a significant growth in papers describing the use of such combinations in practice since 2000, from a total of 16 papers in in the first five years to more than 30 papers per year in each of the past five years. Following a brief overview of the findings of the general review we will focus on the outcomes of a more in depth analysis of 69 selected papers, covering the range of potential combinations. We describe and reflect in more detail on the benefits and challenges of specific combinations of the selected methods and the extent to which these can address the identified biases that can occur in problem structuring for MCDA, concluding with recommendations for future research and practice.

4 - Bayes and Prejudice
Detlof von Winterfeldt

When judging probabilities, people ignore statistical base rates. For example, when judging the likelihood of fatal pitbull attacks, they think of dramatic examples, ignoring the fact that fatal dog attacks are very rare, by pitbulls or other breeds. Ignoring base rates explains prejudice against minorities among dogs and humans.

■ MB-26

Monday, 10:30-12:00 - Building BM, 1st floor, Room 109D

Dynamical models in sustainable development 2

Stream: Dynamical Models in Sustainable Development
Chair: *Naoum Tsolakis*

1 - Using Systems Thinking Methodology to Support SME Transition to Circular Economy
Toni Burrowes-Cromwell, Alberto Paucar-Caceres

Designing out waste and decarbonizing business are among key action areas towards a UK Circular Economy and sustainable development (CE). They are essentially 'learning by doing' principles, with the potential for innovative changes in business planning, processes and delivery. This paper investigates how Systems Thinking Methodology in management science and operational research might enable adoption of these action principles. It aims to support business transition to Circular Economy among SME manufacturers in the UK. Using a systems thinking approach (and PSM developed in the field of 'Soft' Operational Research/Management Science), the paper will highlight how 'Soft' Systems Operational Research might connect with CE principles. This alliance could be strategic by helping to inform operational 're-design' of SME business processes. This is the first stage of a 'work in progress' project. In a second stage, we will explore systemic frameworks to improve resource management and, to promote waste to resource approaches among a sample of Manchester/ NW manufacturers. We aim to provide systemic skills and methodological guidance to: business leaders, staff teams, policy makers, environmental consultants and other specialists, Thus, this project will help in cascading wider awareness of CE activity that links SME manufacturing to Waste to Resource Business.

2 - Monte-Carlo Simulations for Risk Analysis Systems using Bowtie Models
Ionut Iacob, Alex Apostolou, Stephan Bettermann

Risk assessment and analysis, originally a standard process in drilling and mining industries, has recently gained popularity in a variety of domains: health industry, transportation, handling hazardous materials, environment, etc. Quantitative risk assessment of a critical event (accident) is essentially the relationship (often modeled as the product) between the probability of the event and the severity of its consequences. While the mathematical model may look straightforward, in practice, risk analysis is a very complicated process that includes making decisions based on uncertain events. An exact risk analysis is, in general, not possible due to the large number of the parameters in the model. We use Monte-Carlo simulation to perform risk analysis in a bowtie model. For different probability distributions of event's causes and different severities of consequences in the model we perform all computations and produce different outcomes of risk assessment values. The Monte-Carlo simulation in a bowtie model can assist risk analysts in their decision-making process over a range of possibilities. It shows the sensitivity of the outcome to input changes, the extreme situations, and all intermediate control values along the ways from the critical event's causes to its consequences.

3 - The impact on the taxi industry of improved access to a city airport
John Hearne, Solmaz Jahed Shiran

Many cities around the world experience congested road access to airports. Adding extra lanes to access roads or building a new rail link between the central city and the airport are strategies used to alleviate this problem. But is this a good solution for all? A system dynamics model to understand the impact of such a strategy on the taxi industry will be presented. In particular we look at the possible effect on income of taxi drivers. We also consider the investment in vehicles and show the negative transient effects that can result depending on the staging of improvements to airport access. Proposals to expand access to the airport in Melbourne (Australia) is used to illustrate the work.

4 - Food Security, Smallholdings and Short Food Supply Chains in the Developed World: A System Dynamics Framework for a Sustainable Future
Naoum Tsolakis

Food security is a major concern mainly stemming from the projected global population growth to 9.1 billion in 2050 and the corresponding increase in food demand by 70%. Specifically, a plethora of external forces challenge the global food supply resilience, namely: (i) food price volatility due to climate change and extreme weather conditions, (ii) oil shortages, (iii) increased use of feed and biofuels, (iv) trade embargos and political instability cases, (v) rapidly growing food demand in China and India, and (vi) expansion of the western dietary norms which are characterized by food consumption beyond physical needs. To that end, smallholdings could enhance the adaptive capacity of local and regional food systems towards modern challenges. However, smallholding farming has received only limited attention by stakeholders in developed countries, despite the prevalence of food-related non-communicable diseases. Meanwhile, an integrated framework that could enable the effective assessment of smallholdings' impact upon food security and the related economic, environmental and social ramifications does not yet exist. Therefore, the objective of this study is to provide a policy-making support tool based on System Dynamics in order to foster the development of smallholdings and ensure food security in a sustainable context. The derived managerial insights could be of great value towards the development of short food supply chains and local food systems in the developed world.

■ MB-27

Monday, 10:30-12:00 - Building BM, ground floor, Room 20

Markov Decision Processes and Game Theory

Stream: Dynamical Systems and Mathematical Modelling in OR
Chair: *Masayuki Horiguchi*
Chair: *Katsunori Ano*

1 - Impulse control of piecewise deterministic processes
Alizée Geeraert, Benoîte de Saporta, Francois Dufour

Piecewise deterministic Markov processes (PDMPs) have been introduced by M.H.A. Davis as a general class of stochastic hybrid models. The path of a PDMP consists of deterministic trajectories punctuated by random jumps. These jumps occur either spontaneously in a Poisson like fashion or deterministically when the process hits the boundary of the state space. We consider the infinite horizon expected discounted impulse control problem where the controller instantaneously moves the process to a new point of the state space at some specified time. There exists an extensive literature related to the study of the optimality equation associated to such control problems but few works are devoted to the characterization of (quasi)optimal strategy. Our objective is to propose an approach to explicitly construct such strategies consisting of a sequence of intervention times and locations of the process after intervention. An attempt in this direction has been proposed by O.L.V. Costa and M.H.A. Davis. Roughly speaking, one step of their approach consists in solving an optimal stopping problem which makes this technique quite difficult to implement. Our method has the advantage of being constructive and is loosely speaking based on the iteration of a single-jump-or-intervention operator associated to an auxiliary PDMP. Moreover, it is important to emphasize that we do not require the knowledge of the optimal value function as in other works of the literature.

2 - Optimal stopping model with unknown transition probabilities
Masayuki Horiguchi, Alexei Piunovskiy

In this talk, we consider the optimal stopping problem for a discrete-time Markov chain with observable states, but with unknown transition probabilities. The objective is to stop the process with an stopping policy which minimize the total expected running costs and terminal cost. Using the Dynamic Programming approach, combined with Bayesian statistical method, we show that optimal stopping rule is of a threshold type. Also, meaningful explicitly solved examples are shown.

3 - Mutually Dependent One-stage Decision Processes
Toshiharu Fujita

Recently, we have introduced and discussed mutually dependent decision process (MDDP) models. The models have a recursive combination of decision processes through reward functions at each stage and transitions between state spaces. In order to show its applicability, we consider an MDDP model which comprises two one-stage deterministic decision processes and apply the model to a problem of finding the shortest guaranteed strategy for winning a certain two-player combinatorial games of perfect knowledge.

4 - Comparing Performance Based and Warranty Contract
Yasushi Masuda, Haruhiko Miho

The benefit from a durable product is influenced by the actions taken by the supplier and the customer. We see the following three actions as relevant: the quality of the product produced by the supplier, the level of care extended by the customer, and the quality of after-sales service provided by the supplier. We are interested in a self-enforcing mechanism to coordinate the actions of the two agents. The supplier uses warranties as signals of the product quality since the supplier of reliable products can offer an extensive warranty coverage. On the other hand, in the presence of warranties the customer may not extend care to the product. Under a performance based contract (PBC), the customer's payment to the supplier is tied to the performance of the product such as the cumulative uptime of the product. Thus the PBC provides an incentive to the supplier to maintain the product quality and the after-sales service quality. The purpose of this paper is to compare the PBC and the warranty contract (WC) as mechanisms for aligning incentives between the supplier and the customer. In the first part of the analysis, we explore how the PBC competes against the WC in terms of the supplier's profit in the setting where the product quality is unobservable and the customer may not extend proper care to the product. In the second part, we extend the analysis by incorporating a supplier who sets both the product quality and the after-sales service quality.

■ MB-29

Monday, 10:30-12:00 - Building BM, ground floor, Room 7

Health Care Emergency Management

Stream: Health Care Emergency Management
Chair: *Patrick Soriano*
Chair: *Vahid Eghbal Akhlaghi*
Chair: *Gerhard-Wilhelm Weber*

1 - Using Simulation to Analyze Patient Flow at a Hospital Emergency Department
Yong-Hong Kuo, Janny Leung, Colin Graham

We present a case study which uses simulation to analyze the patient flow at a hospital emergency department in Hong Kong. We first analyze the impact of the enhancements made to the system after the relocation of the emergency department. We developed a simulation model to capture all the key relevant processes of the department. When developing the simulation model, we faced the challenge that the data kept by the emergency Department were incomplete so that the service-time distributions were not directly obtainable. We propose a simulation-optimization approach (integrating simulation with meta-heuristics) to obtain a good set of estimate of input parameters of our simulation model. Using the simulation model, we evaluated the impact of missing patients and physician heterogeneity on the efficiency of the emergency department.

2 - Predicting Patient Flow in a Paediatric Intensive Care Unit
Sally Brailsford

The US healthcare industry has been facing rising costs for many years. The Children's Hospital of Wisconsin (CHW) in Milwaukee wished to know whether savings could be made if an observation unit were set up as an intermediate unit between the Paediatric Intensive Care Unit (PICU) and the Acute Care Unit. This arose from a concern that in future, insurance companies might refuse to pay for PICU level of care if the patient could have been safely treated elsewhere. This paper describes an Excel-based analytic tool which enables clinicians to identify patients who might be eligible for treatment outside the PICU, and then estimate the financial impact of relocating them. Data mining techniques were used to identify and group the patients/disease types selected for placement outside of the PICU, as well as key resources and tasks involved in patient care and outcomes.

The study focused on one specific reason for admission, ingestion (accidental or deliberate) of toxic substances. A list of procedures requiring PICU level of care was established through discussion with the PICU physicians, and these were used to classify patients into two groups, those who should stay in the PICU and those who could be safely treated in the observation unit. The cost analysis showed that a predicted 87% savings could be made between the current situation and the best scenario, i.e., if CHW were able to identify and relocate all eligible patients.

3 - Data Mining-Optimization Model Improves Efficiency in Emergency Department
Kalyan Pasupathy, Mustafa Sir, David Nestler, Thomas Hellmich

Traditional optimization models take a top-down approach in framing the objective and constraints and identifying decisions leading to optimal solutions. While such an approach works perfectly well for theoretical solutions, often they become quite complex when dealing with practical applications. In this research, we propose a combined data mining-optimization approach to understand patterns in the data to inform optimization models and determine optimal decisions. A specific application of this approach to staffing decisions in emergency departments is described. Emergency departments are at the mercy of patient demand levels, which has inherent patterns. They are faced with making ideal staffing levels and coordination of shifts across various professions (e.g., physicians, nurses, residents, etc.) to reduce patient wait times. Classification and regression tree analysis was used on historical data to determine significant differences in length of stay variables for adult and pediatric patient pods and determine ideal workload distribution. Optimization was then used to match the required ideal staffing level to patient demand. The new staffing level was implemented starting fourth quarter in the year 2015 in a large academic medical center. A pre- post- comparison of results showed a significant reduction in wait time and length of stay in the emergency department. The new model continues to be used for staffing levels on an ongoing basis.

■ MB-30

Monday, 10:30-12:00 - Building BM, 1st floor, Room 110

System Dynamics Session 2

Stream: System Dynamics Modeling and Simulation
Chair: *David Wheat*

1 - The Dynamics of Global Offshore Oil Production
Onur Özgün, Bent Erik Bakken

Offshore oil has represented most of global oil production growth the 1970s. Despite its relatively high cost, high oil prices has provided conditions for the growth of offshore oil. However, depletion of offshore reserves, dropping oil prices and emerging unconventional extraction technologies, the future of offshore oil may not be as bright. We present a system dynamics model that given a scenario for global oil demand, endogenously creates production capacities of conventional onshore, unconventional onshore and offshore oil as a result of short-term and long-term dynamics. The short-term imbalance between supply and delay is compensated by adjustments in capacity utilization. In the longer term, any sustained rise in oil prices creates investments, which increases capacity after a delay. Differences in the behaviours of three types of oil are created as a result of differences in costs, investment responses and initial conditions. The model also considers the effects of learning and reserve depletion on the costs of oil production for three categories of oil. The effects of strategic policies of OPEC countries and political conflicts on capacity utilization can also be directly introduced as an external input. Validation runs closely mimics historical mix between the three oil sectors. This model is used for strategic planning in the oil sector to analyse the effects of different cost, reserve and strategy scenarios on the future of oil production.

2 - Mutual Impact of Monetary and Fiscal Policies: A System Dynamics Model
Pervin Dadashova

The paper presents the application of the system dynamics approach to the analysis of monetary and fiscal policies mutual impact in Ukraine with the aim of achieving efficiency and consistency To reach this purpose, the basic model of the Ukrainian economy that consists of 7 blocks representing production, consumption, price calculation, income distribution, international trade, banking sector, and budget formation has to be strengthened by including the refinancing and liquidity mobilization monetary instruments of the Central bank, by-currencies public debt accumulation and restructuring representation, and complex mechanism of price level establishing. Listed changes make the model more realistic regarding the current socio-economic changes in Ukraine, while complex structural representation of the economy allows for the illustration of both the direct effects monetary and fiscal regulatory actions make on the economy, and multistage indirect influence that the policies realization can have on each other. Hence, being evaluated based on the historical data and with numerous policies instruments built-in, the model enables scenario testing for the definition of regulative actions that are the most efficient in specific goal achievement and avoiding interference between each other leading to the long term stabilization. Therefore, the use of the system dynamics method to model monetary and fiscal policies realization and interaction in Ukraine is useful for the analysis and

3 - Combining System Dynamics and Machine Learning for Crisis Management in Insurance Companies
Anton Lytvyn

This paper expands the previous work dedicated to the development of a crisis management system for Ukrainian insurance companies (Lytvyn & Dadashova, Paper presented at 33rd International Conference of the System Dynamics Society, 2015) by incorporating financial crisis prediction models based on logistic regression and decision trees into the system dynamics model of insurer business activities. The initial model has been adapted to contain the elements of the designed logistic regression and decision tree models in order to integrate crisis forecasting and crisis response processes, as well as support management learning from crisis. The aim of the model is to provide the means of crisis phenomena anticipation and testing of the alternative paths of addressing them from the management perspective with concentration mainly on the financial aspects of insurer operations. The incorporation of machine learning classifiers into the system dynamics model enables effective exploitation of the most valued features of both modelling paradigms - precision of machine learning and flexibility of system dynamics. The model should allow the management of Ukrainian insurance companies to devise timely and efficient decisions directed at preventing and overcoming crises with the help of the scenario analysis tools included.

4 - Dynamic Input-Output Modeling of North Dakota's Economy: A System Dynamics Approach
David Wheat

Building on previous work (Wheat & Pawluczuk, Economics and Management, 4, 2014), this paper extends the integration of two approaches to economic modeling—input-output tables and system dynamics - to develop a multi-industry dynamic model of the economy of North Dakota in the United States. The original model's structure has been modified to achieve a more robust representation of production constraints originating in inter-industry supply chains and in interstate labor markets. The model is being developed for policy planning by state government officials in a shale-oil-based regional economy shaken by the collapse of world oil prices. Integration of the two modeling methods extends the applicability and value of input-output analysis by eliminating static assumptions of fixed technology, fixed combinations of labor and capital, fixed prices, and infinite supplies of factors of production. Moreover, integration provides a disciplined way to disaggregate system dynamics models to a level of inter-industry detail that is needed for economic impact studies of regions and small nations. In North Dakota, the model will be useful for modeling oil price scenarios and projecting workforce supply and demand, interstate labor migration, social infrastructure requirements, and other economic development issues. Later versions of the model will include structured representations of policy options to address state officials' concerns.

■ MB-31

Monday, 10:30-12:00 - Building BM, 1st floor, Room 111

Balance and Fairness in Tournaments

Stream: OR in Sports
Chair: *Frits Spieksma*

1 - Competitive Intensity and Quality Maximizing Seedings in Knock-out Tournaments
Dmitry Dagaev, Alex Suzdaltsev

Before a knock-out tournament starts, the participants are assigned to positions in the tournament bracket through a process known as seeding. There are many ways to seed a tournament. We solve a discrete optimization problem of finding a seeding that maximizes spectator interest in a tournament when spectators are interested in matches with high competitive intensity (i.e., matches that involve teams comparable in strength) and high quality (i.e., matches that involve strong teams). We find a solution to the problem under two assumptions: the objective function is linear in quality and competitive intensity and a stronger team beats a weaker one with sufficiently high probability. It turns out that, depending on parameters, only two special classes of seedings can be optimal. While one of the classes includes a seeding that is often used in practice, the seedings in the other class are very different. When we relax the assumption of linearity, we find that these classes of seedings are in fact optimal in a sizable number of cases. In contrast to existing literature on optimal seedings, our results are valid for an arbitrarily large number of participants in a tournament.

2 - Assigning Youth Football Teams to Leagues
Túlio Toffolo, Jan Christiaens, Frits Spieksma, Greet Vanden Berghe

The football leagues grouping problem (FLGP) consists of the assignment of teams to round-robin tournaments. Leagues sizes are constrained by both lower and upper bounds and each team must be assigned to exactly one league while simultaneously respecting fairness constraints. The primary objective is to minimize the total travel distance of teams. The problem is a generalization of the classic clique partitioning problem with minimum clique size requirement. The main difference is that the FLGP imposes a limit on the number of teams from the same club in a league (or clique). Three integer programming formulations are presented: two compact and one with an exponential number of variables. The first two formulations are solved by CPLEX, while the last is solved by a tailor-made branch-and-price algorithm. CPLEX is employed to solve the master problem, whereas a heuristic algorithm solves the column generation's pricing problem. Whenever the heuristic fails to produce a solution for the pricing problem, a mixed integer programming formulation is solved. Experiments reveal that the branch-and-price is able to solve most instances. Larger instances are addressed via meta-heuristic methods aimed at the generation of feasible, high-quality solutions.

3 - The Circle Method Generates Schedules with Maximum Carry-over
Dries Goossens, Erik Lambrechts, Annette Ficker, Frits Spieksma

In 1847, Reverend T. Kirkman published a method that can be used for constructing a schedule for round-robin competitions. This method, here called the circle method (aka the polygon method, or the canonical procedure), has been used abundantly in practice for many sports leagues around the world to construct schedules in round robin competitions. The so-called carry-over effect value is a number that can be associated to each round robin schedule; it represents a degree of balance of a schedule. In this contribution, we prove that, for an even number of teams, the circle method generates a schedule with maximum carry-over effect value, answering an open question.

■ MB-33

Monday, 10:30-12:00 - Building BM, 1st floor, Room 113

Emerging Applications of Data Mining and Computational Statistics 2

Stream: Computational Statistics
Chair: *Pakize Taylan*
Chair: *Gerhard-Wilhelm Weber*
Chair: *Olga Kurasova*

1 - An Application Study to Nonparametric Logistic Regression Based on GAM
Pakize Taylan

The most widely used statistical method for analyzing and modeling a dataset in medical research is nonparametric logistic regression. It models the expectation of a dichotomous response variable with the model log[p(x)/(1-p(x))], where p(x) is conditional probability of dichotomous response variable given one or more independent variables. Logistic regression models are usually fit by linear regression and Generalized Additive (GAM). In this study, it is proposed conditional probability p(x) modeling by generalized additive model using B-splines as smooth functions. The method is illustrated with different simulating data, and they are compared to existing techniques such as linear logistic regression.

2 - Artificial Neural Networks for Massive Data Visualization
Olga Kurasova, Viktor Medvedev, Gintautas Dzemyda

The amount of data collected from various devices, sensors, networks, etc. has been constantly increasing. Data are usually massive and high-dimensional, where data items are described by a lot of features. It is difficult to understand the data without additional processing. A series of dimensionality reduction and visualization has been developed. Self-organizing neural networks and their combination with multidimensional scaling can be applied to visualize massive data. A self-organizing neural network is trained by an unsupervised strategy, where in each step of training, a data item is passed to the network and elements of the network are changed according to a training rule. We confront with computational difficulties, as the network training is a time consuming problem when large amount of data are processed. With a view to cope with this problem a new training strategy of the self-organizing neural network has been proposed to decrease the number of data passes herewith the number of the training steps. It is based on the assumption that a large amount of data includes many similar items, thus even in one pass, the network can "see" a lot of similar data. As the change of the network elements depends not only on a data item passed to the network in that time, but also on the order number of the training steps, the training rule is modified and adapted for massive data analysis. The proposed strategy allows to visualize sufficiently large amounts of data effectively.

3 - Decision Optimization: Combinatorial Optimization for Business Analysts
Sebastien Lannez, Susanne Heipcke, Zsolt Csizmadia

It is appealing for business analysts to implement decision problems using a simple graphical workflow. By designing interactions between decisions and equations, business analysts can easily create models to optimize assignment of actions to items, like optimizing investment options, taking into account global constraints across (subgroups of) the whole customer portfolio. FICO Decision Optimizer, an industry leading optimization software used by the banking industry, supports such paradigm and allows for solving large-scale general assignment problems. Challenging optimization problems like nation-wide credit authorization, debt collection or marketing campaigns are then automatically solved via advanced mathematical decomposition algorithms using a distributed calculation framework, and relying on mainstream analytics technology integration with PMML and R. These technologies, coupled with an innovative Tree Aware Optimization algorithm allow for the generalization of the results into Decision Trees which are in their turn used as policies in decision rules engines. The standard Decision Modeling Notation framework which supports the workflow and its use to generate combinatorial optimization problems for FICO Xpress Optimization Suite will be presented in this talk.

4 - Region-based image retrieval and analysis with use of scalable boundary-skeleton model
Ivan Reyer, Ksenia Zhukova

An approach to region-based image retrieval and analysis is suggested. A continuous model of a segmented image consisting of a set of nonoverlapping polygonal figures is constructed. Each polygon from the set approximates a homogeneous raster region within the image, with polygons of two neighbour regions having common fragments of boundary. To obtain the set of polygons a modified algorithm for approximation of a binary image with polygons of minimal perimeter is used. The model also includes marked skeletons of polygons describing changes of skeletal representation and significance estimations for boundary convexities corresponding to polygon vertices. The estimations are calculated with use of a family of boundary-skeleton shape models generated by a polygonal figure. Obtained image models are compared by shape and color of polygons. To estimate the shape similarity, the change of significant convexities' number at increase of the approximation accuracy value is compared. The applications of the presented approach to retrieval and analysis of raster and vector images are described.

■ MB-34

Monday, 10:30-12:00 - Building BM, 1st floor, Room 116

Stochastic Optimisation in Supply Chain Management 2

Stream: Supply Chain Scheduling and Logistics
Chair: *Roberto Rossi*

1 - Dealing with Uncertainty in Vessel Crew Scheduling
Seda Sucu, Kerem Akartunali, Robert van der Meer

Assignment of crew members in transportation settings is a quite popular area due to the characteristics of complex rules and regulations that require long solution times to reach optimal for real life problems. The crew scheduling problem is widely studied in airline settings with deterministic data; however, it is very limited in maritime settings. Additionally, most of the studies in vessel crew scheduling problems focused on deterministic data. However uncertainties are inevitable in maritime settings and these uncertain conditions lead changes in crew schedule and these changes results with high costs to companies. Therefore, it is important to have more robust schedules from the beginning of the planning horizon. In this study, we work on the crew scheduling problem for Offshore Service Vessels on a global scale. We propose a simplified model for the sources of uncertainty in vessels, and suggest robust approaches to deal with uncertainty.

2 - An Approximate Dynamic Programming Approach for Stochastic Time-Dependent Capacitated Vehicle Routing Problems
Mustafa Cimen, Mehmet Soysal

This study addresses a time-dependent capacitated vehicle routing problem with stochastic travel times and environmental concerns. Deterministic vehicle routing problems are well-known to be NP-Hard. Incorporating stochastic travel times render classical optimization approaches such as Dynamic Programming or Mixed-Integer Programming infeasible for even fairly small-sized problems. We propose an Approximate Dynamic Programming based algorithm as a solution approach for a time-dependent capacitated vehicle routing problem with stochastic travel times. The studied problem manages key performance indicators of total travel time, total energy use (emissions) and total routing cost.

3 - Hierarchical Control Model for Several Stochastic Network Projects
Aharon Gonik

Almost every company is handling simultaneously several projects, in different stages of progress. The common practice is to supervise each project independently, neglecting levelling company overall Cash-Flow, optimization of Limited Resources and supporting projects that are "Legging-behind". A hierarchical control model is suggested which at any dynamic control point determines: 1. Optimal central and leveled budget values which are reassigned from the company to each project. 2. Optimal resource delivery (manpower & equipment) schedules from a central control source for all the projects activities. In order to - maximize the probability of meeting the due date of the slowest project. A Critical-Path, flowing across all projects (as an unified system), which collects the calculated confidence probabilities of each project to meet it's Due-Dates on time, will be established via the On-Line simulated control model

4 - An MILP model for computing (s, S) policies with stochastic demand
Mengyuan Xiang, Roberto Rossi, Belen Martin-Barragan

In this paper, we present mixed integer linear programming (MILP) models to compute near optimal parameters for the non-stationary stochastic lot sizing problem under the (s, S) control policy. Our models are built based on piecewise linearization of first order loss functions. We discuss different variants of the stochastic lot sizing problem which include penalty cost scheme, α service level constraints, β service level constraints and βcyc service level constraints. These models also operate under lost sale settings. Our new MILP models favourably compare to existing approximation heuristics and exact methods in the literature: they are the first MILP heuristics to approximate (s, S) policy parameters, they perform efficiently under four measures of service quality, they work for generically distributed demand patterns as well , and they handle problems under lost sale settings. Our computational experiments demonstrate the effectiveness and versatility of our models.

■ MB-35

Monday, 10:30-12:00 - Building BM, ground floor, Room 17

RNA 2D structure

Stream: Computational Biology, Bioinformatics and Medicine
Chair: *Piotr Lukasiak*
Chair: *Maciej Antczak*

1 - Algorithms for Predicting RNA Secondary Structure: Making the Most of an Ill-Conditioned Problem
Michael Zuker

With a simplified model of the three dimensional structure of single-stranded RNA, it is possible to assign free energies to arbitrary conformations using parameters derived by physical chemists. Practical algorithms can be formulated to predict minimum and close to minimum free energy conformations as well as ensemble properties such as base pair probabilities and melting profiles. Given the model, these computations are exact. However, the problem itself is ill-conditioned in the sense that solutions are sensitive to small fluctuations in energy parameters and slight changes in nucleic acid composition. These problems can be mitigated by computing average properties, by adding auxiliary information to constrain solutions and by accepting that some of the uncertainty might be genuine. For over 25 years, visual inspection of "energy dot plots" has been used to assign a subjective measure to the reliability of predictions. More recently, the entropy of the Boltzmann distribution of all possible secondary structures assigns a numerical value to the propensity of an RNA to fold in a "well-defined" manner. Low entropy is associated with better predictions, whereas high entropy indicates either structural plasticity or the failure of the thermodynamic model to be useful for certain RNAs. Systematic in silico mutations of an RNA have shown that particular single base changes can cause a large change in entropy together with a significant change in secondary structure.

2 - Non-canonical RNA Base Pair Predictor for Even Imperfect and Incomplete Models
Jacek Smietanski

RNA secondary structure is defined as a set of canonical base pairs similar to those observed in DNA helix. However RNA can form much more different base pairs types. According to Leontis-Westhof classification we can distinguish 12 basic families of base pairs that can be specified simply by indicating the interacting edges and the relative orientations of the glycosidic bonds of the two bases. All families plays crucial role in three-dimensional structure formation, however they are hard to predict and are not recognized by most of prediction software. The aim of presented work is to implement a method able to predict both canonical and non-canonical base pairs even for imperfect and incomplete RNA structure models. This can be used in optimization or validation of proposed structural conformation for given molecule, resulting in more reliable 3D RNA predictions. The main advantages of this predictor are: 1) the ability to work with incomplete structures 2) the ability to correctly predict base pair family even for imperfect initial atoms coordinates. The predictor is based on the set of SVM multi-class classifiers and is able to decide to which of recognized pair families a given base pair belongs to. The predictor was trained on the experimental high quality data set and tested on different, not used for training, imperfect and incomplete structures. The average quality of predictor for tested fuzzy nucleotide pairs is at about 96% of correct recognition.

3 - Integrating Probing Data in RNA Secondary Structure Definition Using Pareto Optimization
Cedric Saule, Stefan Janssen, Robert Giegerich

Pareto optimization combines independent objectives by computing the Pareto front of its search space, defined as the set of all solutions for which no other candidate solution scores better under all objectives. This gives, in a precise sense, better information than an artificial amalgamation of different scores into a single objective, but is more costly to compute. Pareto optimization naturally occurs with genetic algorithms, albeit in a heuristic fashion. Non-heuristic Pareto optimization so far has been used only with a few applications in bioinformatics. We study exact Pareto optimization for two objectives in a dynamic programming framework. We define a Pareto product operator on arbitrary scoring schemes. Independent of a particular algorithm, we prove that for two scoring schemes A and B used in dynamic programming, the scoring scheme AB correctly performs Pareto optimization over the same search space. We apply this technic to RNA structure determination by optimizing scores based on a folding model and on probing data as two independent objectives. We embark on a comprehensive evaluation of coupling folding model and probing data. We also investigate whether extending this approach by adding more than one probing method improves predictive power. We demonstrate that the Pareto front computation finds ghost solutions, ie biologically plausible structures which cannot be detected by state of the art linear combinations of folding model and probing data.

■ MB-36

Monday, 10:30-12:00 - Building BM, ground floor, Room 18

Scheduling in Healthcare 1

Stream: Scheduling in Healthcare
Chair: *Maria Eugénia Captivo*

1 - Integrated Surgery and Recovery Ward Planning with Surgical Teams Timetabling
Edilson Arruda, Cecília Siqueira, Laura Bahiense

The National Institute of Traumatology and Orthopedics (INTO) is a Brazilian reference center for high complexity Orthopedic surgeries and serves most of these surgeries in the state of Rio de Janeiro. Their services are currently divided into thirteen distinct specialties, each of which can be served in any of the 18 surgery rooms they have available for nine hours each business day, and employ any of the 273 beds made available for post-surgery care. Due to high demand and long surgery recovery times, INTO typically features a long waiting list for surgeries. This paper proposes an integrated planning and operation framework, which has two phases. In phase one it finds a feasible weekly surgery allocation policy by means of integer programming that maximizes the allocation of the surgical center while ensuring that the output rate of patients exceeds the input rate for each specialty. For each specialty, we then employ a clustering technique to group the surgery types, taking into account the similarities in their surgery and recovery times. Finally, in the second phase we make use of the obtained clusters to allocate individual surgery types of each specialty to surgeons, according to their weekday availability, by means of a timetabling model. The latter model is built to minimize the changes in the schedule of the first phase, while maintaining the number of weekly schedules assigned to each specialty.

2 - Sharing Operating Rooms Between Elective and Non-elective Surgeries: An Online Optimization Approach
Davide Duma, Roberto Aringhieri

At the operational decision level, the problem arising in the Operating Room (OR) planning is also called "surgery process scheduling", which usually consists in (i) selecting elective patients from an usually long waiting list and assigning them to a specific OR session over a planning horizon, (ii) determining the precise sequence of surgical procedures and the allocation of resources for each OR session, and (iii) dealing with the arrival of non-elective patients requiring a surgery within a given time threshold. The Real Time Management (RTM) of ORs is the decision problem arising during the fullfilment of the surgery process scheduling of elective and non-elective patients, that is the problem of supervising the execution of such a schedule and to take the more rational decision regarding the surgery cancellation or the overtime assignment. The RTM is characterized by the uncertainty of the duration of a surgery and the arrivals of non-elective patients. In this work we propose an online optimization approach dealing with the RTM of ORs, which takes into account both elective and non-elective patients. We evaluate the competitiveness of such an approach providing a mixed-integer programming model to compute the optimal offline solution, that is the optimal solution assuming to know in advance all the information that are acquired over time by the online solution. Further, we assess the effectiveness of the RTM on a simulated clinical pathway under several scenarios.

3 - Operating Room Scheduling Models: Where Does the Shoe Pinch?
Carla Van Riet, Michael Samudra, Erik Demeulemeester

We determined the common pitfalls in researching operating room (OR) scheduling problems by looking at different research aspects such as the patient type, the used performance measures, the decisions made, the OR supporting units, the inclusion of uncertainty, the research methodology and the set-up of the testing phase.

Our findings indicate, among others, that it is often unclear whether an article mainly targets researchers and thus contributes advanced methods or targets practitioners and consequently provides managerial insights. Moreover, many performance measures (e.g., overtime) are not always used in the correct context. Furthermore, we see that important modelling assumptions that would allow both researchers and practitioners to determine whether the research results are relevant to them are often missing. In this talk, we discuss the common pitfalls when researching OR scheduling and highlight ways to overcome them.

4 - Heuristics for Different Perspectives of a Surgical Case Assignment Problem
Maria Eugénia Captivo, Catarina Mateus, Inês Marques

The surgical suite has multiple and powerful stakeholders. In a public hospital, the government wants to achieve some social measures like: number of patients in the waiting list, number of days in the waiting list, or percentage of patients treated after the clinically acceptable period (maximum response time). The administration of the hospital wants to achieve those goals in order to avoid high contractual penalties; they also desire a high efficiency level of the surgical suite, not only because this is a highly costly service with big influence in many other services in the hospital (e.g., wards) but also because the number and complexity of the surgeries performed represent a significant hospital funding source. At the same time, the surgeries are often scheduled by the surgeons depending on their agenda and on their capacity to remember all of their patients. When a systematic system to select and schedule the patients to be operated in a given week is not available, the surgeons will tend to select the patients they remember the best (e.g. those patients more recently consulted or those patients that pressure the surgeon). This can bring a sort of LIFO strategy to manage the waiting list for surgery which may undermine the government guidelines. In this work, heuristics were developed intending to mimic the different stakeholders' perspectives for a surgical case assignment problem. Results, using data from a Portuguese hospital, will be presented and discussed.

■ MB-38

Monday, 10:30-12:00 - Building BM, 1st floor, Room 109M

Optimization for Sustainable Development Related to Industries 2

Stream: Optimization for Sustainable Development
Chair: *Herman Mawengkang*
Chair: *Gerhard-Wilhelm Weber*
Chair: *Sadia Samar Ali*

1 - Modeling a Vehicle Routing Problem for Catering Service Delivery with Heterogeneous Fleet
Devy Mathelinea

The heterogeneous vehicle routing problem (HVRP) is a variant of classical VRP problem which describes a heterogeneous set of vehicles with different capacity, in which each vehicle starts from a central depot and traverses along a route in order to serve a set of customers with known geographical locations. This paper proposes a model for the optimal management of service deliveries of meals of a catering company located in Medan City, Indonesia. The HVRP incorporates time windows, service choice deliveries, fleet scheduling in the scheduled time planning. The objective is to minimize the sum of the costs of traveling and elapsed time over the planning horizon. We model the problem as a linear mixed integer program and we propose a feasible neighbourhood direct search approach to solve the problem.

2 - A Deterministic Optimization Model for Integrated Production - Distribution Planning of Fish Processed Products
Intan Syahrini, Herman Mawengkang

Due to the rapid development in technologies, most companies have faced the big global changes in the business environment. Therefore these companies have been urged to improve their global supply chain systems. Production and distribution as two main areas in the system needs to be integrated in order to get more economics advantages. This paper addresses a multi-product fish production-distribution planning which produces simultaneously multi fish products from several plant facilities. The research under investigation is located at Eastern coast of North Sumatra Province, Indonesia. The production-distribution planning performs processing fish into several seafood products and distributes them to a set of distribution centers. The objective is to meet customer demand subject to perishable nature of raw fish material and the finished products. A mixed integer linear programming model is developed for tackling the integrated problem. Direct search is used for solving the model.

3 - A Decision Model of Hospital Capacity Management Problem under Uncertainty
Suryati Sitepu

Nowadays the needs to get health services is rapidly growing. This situation occur due to the increasing number of populations. For inpatient hospital care, capacity management systems requires information on beds and nursing staff capacity. This paper presents a capacity model under uncertainty that gives insight into required nursing staff capacity and opportunities to improve capacity utilization on a ward level. A capacity model is developed to calculate required nursing staff capacity. The uncertainty turns up on the availability schedule of staff and the number of patient. A stochastic combinatorial optimization is formulated to describe the problem.

■ MB-39

Monday, 10:30-12:00 - Building WE, 1st floor, Room 107

Risk measurement and management

Stream: Financial and Commodities Modeling
Chair: *Roy Cerqueti*

1 - Allocation of risk capital in a cost cooperative game induced by a modified Expected Shortfall

Arsen Palestini, Roy Cerqueti, Mauro Bernardi

Coherent risk measures have been widely studied in the latest years (Acerbi, Csoka et al.) as a crucial instrument to assess individual institutions' risk. Those measures fail to consider individual institutions as part of a system which might itself experience instability and spreads new sources of risk to the market participants. We take into account a multiple institutions framework where some of them jointly experience distress events in order to evaluate their individual and collective impact on the remaining institutions in the market. To carry out this analysis, we define a new risk measure (SCoES), generalising the Expected Shortfall (Acerbi) and we characterise the riskiness profile as the outcome of a cost cooperative game played by institutions in distress (a similar approach was adopted by Denault). Each institution's marginal contribution to the spread of riskiness towards the safe institutions in then evaluated by calculating suitable solution concepts of the game such as the Banzhaf-Coleman and the Shapley-Shubik values.

2 - Risk Seeking or Risk aversion? Phenomenology and Perception

Mario Maggi, Caterina Lucarelli, Pierpaolo Uberti

We remove assumptions on individual risk preference, and set two theoretical rules for portfolio choices: either minimize or maximize risk, for any return. Risk is modeled by four alternative measures. We empirically test these rules by observing 690 individuals (bank customers and financial professionals, aged 18-88), while making risky decisions, with measurement of Skin Conductance Response. Two perspectives are assumed to evaluate portfolio efficiency: individuals uniquely consider 'money'; or they experience a 'subjective' perception of money. We find a large dominance of risk-seeking behaviors, if observed through the phenomenology of money, independently from the risk measure used. Conversely, the same individuals appear risk averter, when values include the subjective experiences, and risk is assumed to be mentally projected with standard deviation formula. These results are consistent for sub-groups of individuals, by gender, age, education and profession. Implications are severe, as a sign of unawareness of behavior under risk.

3 - A nonlinear dynamic model for credit risk

Viviana Fanelli, Lucia Maddalena, Silvana Musti

A great deal of recent literature discusses the role of credit risk transfer and contagion in financial markets. Credit risk transfer, on the one hand, is used in order to improve the diversification of risk, on the other hand, it could contribute to increase the risk of financial crises. In this paper, we investigate the interaction between the internal nonlinear factors and external disturbance of credit risk contagion that has effects on financial markets. These effects are observable from theoretical and practical points of view. We use a nonlinear dynamics model to study the credit risk transfer and contagion. We simulate numerically the model in order to describe the characteristics of credit risk contagion dynamics.

4 - Bayesian Portfolio Management in a Skew Student-t Dynamic Semi-Parametric Environment

Mauro Bernardi

The increasing complexity of financial market dynamics asks for more flexible models that approximate the predictive distributions over horizons of one to several trading days. In this paper we propose a new time series model that generalizes Gaussian hidden Markov models through the introduction of a Dirichlet Skew-Student process as component density. Model parameters as well as latent factors are estimated by means of a new Metropolis–within–Gibbs sampling algorithm. The article uses the model to perform portfolio optimization under Value–at–Risk (VaR) and Expected Shortfall (ES) budget constraints. To this aim, we show that linear combinations of the multivariate Skew Student-t mixtures, which arise as predictive distribution of the proposed model, can be represented as finite mixtures of univariate Skew Student-t mixtures and we provide an analytical formulas for the VaR and ES.

■ MB-40

Monday, 10:30-12:00 - Building WE, 1st floor, Room 108

Pricing under incomplete markets

Stream: Financial Engineering and Optimization
Chair: *Firdevs Ulus*

1 - How Fundamental is the Trinomial Model for European Option Pricing. A New Methodological Approach

Yann Braouezec

We consider the simplest non-probabilistic framework to price European options using the no-arbitrage principle in an incomplete market setting. Our approach only requires to consider a one-period model with three states of the world and does not make any use of a stochastic process. We show how to compute the range of the arbitrage-free prices and we also show that this computation naturally leads to the emergence of a pricing measure equivalent to the statistical one, which is unknown in our framework. Using the quoted bid and ask prices of liquid European options, we suggest how to imply the parameters of the trinomial model, used in turn to estimate the volatility.

2 - Utility Indifference Pricing Under Incomplete Preferences

Firdevs Ulus

Utility indifference pricing theory is well studied for complete preferences that can be represented by a single utility function. Moreover, it is known that under some assumptions incomplete preferences can be represented by a single-utility multi-prior or multi-utility single-prior representations under some assumptions. Under both representations, it is possible to see the utility maximization problem as a convex vector optimization problem. We allow utility functions to be multivariate and we define the utility buy and sell prices as set valued functions of the claim. Utility indifference price bound is defined accordingly. It has been shown that the buy and sell prices recover the complete preference case where the utility function is univariate. Moreover, buy and sell prices satisfy some monotonicity and convexity properties as expected. It is possible to compute these set valued prices by solving two convex vector optimization problems.

3 - Diversification of Portfolio Tail Risk

Qi Wu

We quantify the behavior of portfolio tail risk under different tail assumptions of asset return joint distribution. We develop explicit asymptotic expansions of portfolio Value-at-Risk (VaR) and portfolio Expected Shortfall (ES) for a parameterized family of multivariate elliptical distribution, where the joint tail behavior can be of either the exponential type such as the Kotz distribution, or the power type such as the Student t-distribution. For any fixed portfolio composition, our results show that the difference between portfolio ES and VaR is asymptotically zero, up to the sub-leading order for assets exhibiting exponential tail decay, whereas for assets exhibiting power type tail decay, portfolio ES is proportionally larger than VaR starting at the leading order. When such portfolios are margined jointly rather than separately, the amount of risk reduction depends very much on the portfolio dispersion, up to the tail heaviness of asset return distribution.

4 - Interest Rate Modelling with Stochastic Basis Spread
Cheuk Hang Leung, Qi Wu

Since the financial crisis of 2007-2008, the spread between OIS and LIBOR becomes non-negligible and stochastic. Traditional models used for pricing interest rate derivatives, assuming LIBOR discounting, are no longer adequate. In the work, we construct a general dual short rate model with stochastic spread between LIBOR and OIS, all in the presence of stochastic volatilities. We provide a set of no-arbitrage conditions when the basis spread is stochastic. We further provide relevant asymptotic formulas for pricing vanilla interest rate derivatives. Through calibration, we finally report the effect of stochastic basis between LIBOR and OIS in the dual curve setting.

■ MB-41

Monday, 10:30-12:00 - Building WE, 2nd floor, Room 209

Financial Mathematics 2

Stream: Financial Mathematics and OR
Chair: *Masamitsu Ohnishi*
Chair: *Katsunori Ano*

1 - Generalized Multilevel Monte-Carlo method using a few discretization techniques
Hitoshi Inui, Katsunori Ano

The Milstein scheme is known as the discretization technique which can be used in order to improve the convergence of multilevel Monte-Carlo method (MLMC). MLMC was proposed in Giles (2008) and has been known as the computational complexity reduction (variance reduction) method for standard Monte-Carlo method using only one type of time step interval generating simulation paths. In this talk, we test generalized multilevel Monte-Carlo method (GMLMC), which has many types of estimators and becomes MLMC in a special case, using a few discretization techniques (the Milstein scheme etc.) in the context of financial option pricing.

2 - Optimal stopping boundary for American put option on Jump diffusion process by Multilevel Monte-Carlo method
Yuto Shimizu, Kengo Sumimoto, Katsunori Ano

Multilevel Monte-Carlo (MLMC) pass simulation has been applied to the pricing of the derivative such as American put option and Game option. By our simulation for the price, MLMC indeed decrease the variance of the estimator of the price than the one by standard Monte-Carlo method. By the way, our simulation for the optimal stopping boundary shows that MLMC does not decrease the variance of the estimator, which is derived by the dynamic programming equation for American put option on jump diffusion process, than the one by standard Monte-Carlo method. We try to study this phenomena.

3 - The Dynamic Valuation of Callable Contingent Claims with Partially Observable Regime Switch
Kimitoshi Sato, Katsushige Sawaki

In this paper, we consider a model of valuing callable financial securities when the underlying asset price dynamic is unobservable but partially observable by receiving a signal stochastically related to the state of the real economy. The callable securities enable both an issuer and an investor to exercise their rights to call. We formulate this problem as a coupled stochastic game for the optimal stopping problem within the partially observable Markov decision process. Then, we show that there exists a unique optimal value of the callable contingent claim which is a unique fixed point of a contraction mapping. We derive analytical properties of optimal stopping rules for the issuer and the investor under two types of general payoff functions: put-type and call-type. Furthermore, we provide a numerical example to illustrate specific stopping boundaries for the both players by specifying the payoff function of callable securities.

4 - Equilibrium point on standard normal distribution between expected growth return and its risk
Shingo Nakanishi

When we consider the expected growth return, we also estimate the risk as its standard deviation. At the same time, we can confirm that the risk is a loss like the lower difference between the expected growth return and its standard deviation multiplied by a probabilistic point to ensure the quantification of the loss. We can evaluate that the loss is the combination of both the line of expected growth return based on the time and the parabolic curve which consists of the standard deviation and the square root of the time. If we investigate that a maximal loss from its combination based on the time, we can show you the equilibrium point on a standard normal distribution as the probabilistic point. We admit various relations when we focus on combinations of expected returns and these standard deviations. However, if we associate that the time is equal to 1 when the maximal loss can be estimated by the probabilistic point on standard normal distribution, we can understand that the equilibrium point is unique. We can confirm that the probabilistic point is based on the 27 percent rule or the grouping of normal distribution such as "good", "normal" or "bad". Moreover, we can propose that the equilibrium point shown probabilistic point on a standard normal distribution makes a square shape composed of the equilibrium point on the standard normal distribution if we think of the truncated normal distribution transformed from the standard normal distribution.

■ MB-42

Monday, 10:30-12:00 - Building WE, 1st floor, Room 120

Game Solutions and Structures

Stream: Game Theory, Solutions and Structures
Chair: *Marcin Malawski*

1 - On the Axiomatization of Stability in Organizations
Stéphane Gonzalez

The notion of pairwise stability is a central notion in social network theory, particularly to model the strategic formation of links among agents. This concept is based on the idea that interactions among two agents are stable as soon as 1) there is no member of formed pairs who can improve his situation by severing a relationship; 2) we cannot find two individuals who benefit from adding a link between them. We propose a generalization of this graph-concept through a new notion of solution under hypergraphs that we call F-stability. After showing some economic applications, we propose an axiomatization of the F-stability, one which provides the first axiomatization of pairwise stability.

2 - Discounted Tree Solutions
Philippe Solal, Sylvain Béal, Eric Rémila

This article introduces a discount parameter and a weight function in Myerson's (1977) classical model of cooperative games with restrictions on cooperation. The discount parameter aims to reflect the time preference of the agents while the weight function aims to reflect the importance of each node of a graph. We provide axiomatic characterizations of two types of solution that are inspired by the hierarchical outcomes (Demange, 2004).

3 - The SD-prenucleolus and the SD-prekernel
Ilya Katsev, Javier Arin

The SD-prenucleolus was defined in 2014 by J. Arin and I. Katsev. This is a new TU-game solution with many interesting properties. For present moment the SD-prenucleolus is the only known continuous solution which satisfies core stability for balanced games and coalition monotonicity for two important classes: convex games and veto-monotone games. The SD-prekernel is an analogue of prekernel, but based on the the same definition of excess function as the SD-prenucleolus. We will give an axiomatization of the SD-prekernel, proving some facts about it and discussing the question "when the SD-prekernel is single-valued?".

4 - Associations of Players in Graph-Restricted Games
Marcin Malawski

As observed by van den Brink [1], "neutrality" of a specific form of collusion between players in a cooperative game is, in general, incompatible with efficiency and null player property, but becomes compatible when the collusion possibilities are restricted to coalitions of players which are connected in a tree imposed on the player set. In that case, all three properties are fulfilled by hierarchical solutions as defined by Demange [2] and by their convex combinations. We prove analogous results for another form of players' collusion, namely association (Haller [3]) under which all players in a colluding group are treated as members of a coalition as soon as anyone of them enters that coalition. Moreover, we characterize the sets of all solutions satisfying neutrality of association together with some additional properties. One such interesting property is "external neutrality" under which forming an association by a group of players does not influence the payoffs to other players. More general consequences of external neutrality are also drawn, and possibilities of replacing neutrality by profitability of association are discussed.

[1] R. van den Brink, Efficiency and collusion neutrality in cooperative games and networks, Games Econ. Beh 76 (2012). [2] G. Demange, On group stability in hierarchies and networks, J. Polit. Econ. 112 (2004). [3] H. Haller, Collusion properties of values, Int. J. Game Theory 23 (1994).

■ MB-43

Monday, 10:30-12:00 - Building WE, ground floor, Room 18

Energy Storage and Renewables

Stream: Stochastic Models in Renewably Generated Electricity
Chair: *Benjamin Böcker*
Chair: *Christoph Weber*

1 - Stochastic Storage Valuation Considering Aging Processes (Lithium-ion)
Benjamin Böcker

In future energy systems with a high share of renewables matching electricity demand and supply becomes increasingly challenging. Storage systems can provide an important flexibility option, but have to compete with other technologies in an uncertain environment. The presentation focuses on the impact of battery aging on storage operation and valuation. The developed model is based on the Least-Square Monte Carlo method and allows to determine the value of storage from an investor point of view for different applications. Technical characteristics of storage systems and the application are usually well-known, but in the case of batteries nevertheless challenging. Aging of a battery is a very complex underlying electrochemical process, highly dependent on an uncountable number of different cell configurations. Here a simplified aging model is derived from existing studies and both calendar and cyclic aging effects are considered. The advantage of this model is shown in a selected application.

2 - Uncertainties in Optimized Scheduling of Electric Vehicle Charging
Zongfei Wang, Patrick Jochem, Wolf Fichtner

With increasing market penetration of electric vehicles (EV), capacity bottlenecks in distribution grids seem unavoidable for uncontrolled EV charging. One key issue about the integration of EV is how to optimally schedule the charging behavior. This paper tries to solve the problem while considering uncertainties in EV arrival time, battery state of charge upon arrival and leaving time. Driving behaviors are described in an inhomogeneous Markov process. We use real EV usage data from a field test with about 30 EV with three recorded EV states (driving, charging and only parking) for 6 months. EV driving patterns are simulated to consider uncertainties in EV charging availability. Simulated EV driving data from the Markov process is used in a mixed-integer linear programming model to optimize EV charging schedules. Battery and inverter characteristics such as minimum charging power and non-linear charging pattern are also considered. The optimization is conducted from a system operator's view and also considers dynamic electricity tariffs. With the uncertainty of arrival and leaving time and the required energy demand, our approach will not lead to a global optimum. So a global optimum is given for a perfect foresight scenario as a benchmark. Both results and the underlying reasons for differences are discussed comprehensively. Monte Carlo method is applied by randomly generating driving patterns from the Markov process in order to see the average of charging curves.

3 - An Agent-based Model for Investment Decision in Electricity Markets under Uncertainty
Andreas Bublitz, Dogan Keles, Wolf Fichtner

Investments decisions in electricity markets are complex problems. With technical lifetimes of power plants that extend over 30 years, long time periods have to be regarded when determining the value of an investment. Naturally, this value is subject to uncertainty — which is one of the characteristics of a real investment. Besides uncertainty, two other aspects characterize real investments: investments are not or only partially reversible and the time for an investment decision is to some extent flexible. Literature suggests treating real investments like American-style call options, whose value can be determined via the Black-Scholes model. In the field of energy economics there exists a broad application of real-option models. While many models focus on stochastic processes such as Brownian motions to model the electricity prices, here an approach is presented where hourly prices are forecasted based on existing power plants and expected future investments. To analyze investments in electricity markets an agent-based model for the German market area is chosen, where the generation companies represented by supply agents, determine individually if and when to build a new power plant. Each supply agent forecasts fundamental based hourly day-ahead market prices for the year a new power plant could be operated for the first time. To account for uncertainties underlying the investment such as fuel prices, a recombining tree for each investment option is created.

■ MB-47

Monday, 10:30-12:00 - Building WE, 1st floor, Room 115

Stochastic Modeling and Simulation in Engineering, Management and Science 1

Stream: Stochastic Modeling and Simulation in Engineering, Management and Science
Chair: *Semih Kuter*

1 - Analysis of Automated Transfer Line with Discrete Phase Type Distribution of Repair Time and Its Application
Yang Woo Shin, Dug Hee Moon

A transfer line that consists of finite number of machines separated by buffers of finite capacity is considered. All machines have equal constant unit time. Each machine can contain a part. So each machine can work while the upstream buffer is empty or downstream buffer is full. Machine is said to be starved if its upstream buffer is empty when it completes its process. The blocking after service (BAS) mechanism is considered. The first machine is never starved and that the last machine is never blocked. Machines are unreliable and operation dependent failures (ODF) rules are adopted. The time to failure and time to repair are assumed to have geometric distribution and discrete phase type distribution, respectively. In this talk, we present an approximation method for the system based on decomposition method and show that the approach can be applied to the various systems such as the no buffer asynchronous system, the systems with multiple failure modes and/or imperfect production and the system that contains the no buffer synchronous subline.

2 - Mixed Logit-based Stochastic Dynamic User Equilibrium
Hanns de la Fuente-Mella, Alexander Paz, Daniel Emaasit

Traditional stochastic user equilibrium methods are either probit-based or logit-based models. Both approaches have certain weaknesses which have limited their usefulness. This research proposes a mixed logit-based Stochastic Dynamic User Equilibrium (SDUE) model which does not suffer from traditional weaknesses and which does not require path enumeration. The capabilities of the mixed logit model enable the development of a robust SDUE assignment model that can be applied to general networks while maintaining correct flow propagation. In this sense, the flexibility in error terms specification provided by the mixed logit model enables the propose SDUE model to explicitly capture spatial and temporal correlations in unobserved factors in a single framework. The SDUE problem is expressed as a mathematical programming problem and its solution is found by an iterative mixed logit-based network loading procedure. The method is made practicable / deployable because link flows calculated during the stochastic network loading process make the SDUE process to converge.

3 - Discounted Semi-Markov Decision Processes with Possibly Accumulation Points: A Service Rate Control Problem with Impatient Customers
Bora Cekyay

We start considering an M/M/1 queue with impatient customers, where the service rate is controlled by a decision maker. The system can operate under two different service rates, namely, low and high service rates. Whenever a new customer arrives or a customer already in the system leaves the system, the decision maker chooses the service rate which will be used till the next arrival or departure. Service costs, holding costs for the waiting customers, and abandonment costs for the customers leaving the system without taking any service are included in the model. The objective is to find the optimal service rate policy minimizing the expected total discounted cost. This problem is modeled as a semi-Markov decision process (SMDP) with exponential sojourn times. Due to the impatient customers, the transition rates of the decision process are unbounded. This is why the standard assumption in the discounted SMDP literature, which guarantees that there is no accumulation point, cannot be satisfied for this problem. Moreover, the well-known technique uniformization cannot be used for this problem. We propose some conditions for such a SMDP, possibly not satisfying the standard assumption, under which the value iteration algorithm converges, and the existence of an optimal deterministic stationary policy is guaranteed. Then, it is proved that the optimal policy has a control-limit structure under some monotonicity assumptions by using a new device, called customization.

■ MB-48
Monday, 10:30-12:00 - Building WE, 1st floor, Room 116

Simulation

Stream: Simulation in Management Accounting and Management Control
Chair: *Stephan Leitner*
Chair: *Friederike Wall*

1 - Effects of forecasting abilities in a transfer pricing model
Arno Karrer

In this paper we analyse the impact of heterogeneous agents and forecasting abilities on negotiated transfer prices and the consolidated profit resulting at firm level. An agent-based simulation is employed to show potential results implied by different forecasting abilities of negotiating profit centers. In particular, intra-company profit centers are free to trade with each other or independent parties on an external market, which is technologically as well as demand independent. Profit centers use an estimated market price as basis for their negotiations. Since their estimations are limited to their forecasting ability, they are involved in a bargaining process with outside options. The negotiation process is modelled as ultimatum game and, subsequently, as bilateral negotiation. To achieve a maximized comprehensive income it may be favourable for the profit centers to choose the outside option over the intracompany deal. On the long run the intracompany option should be favourable, as it excludes the profit orientated external market. We investigate our agent's behaviour under different parameter settings regarding their forecasting ability and furthermore regarding the negotiation process. Results show how different forecasting abilities and different forms of negotiation affect the comprehensive income and also the income of each profit center.

2 - Biased Innovation Investment
Jingbin He, Bo Liu

We propose a model of dynamic investment, financing and risk management for innovative firms. The model highlights the important role of the endogenous marginal value of liquidity (cash and credit line) for innovative firms' corporate decisions. Our four main results are: (1) The innovative firm will overinvest when cash holding is higher and underinvest when it is close to liquidation boundary, while the innovative firm will overinvest when it holds more cash; (2) The innovation investment is concave and tends to maintain a positive stable level when the cash-capital ratio is high; (3) The average and marginal q of non-innovation firm are both below the q value of innovative firm, and the higher average q of innovative firm reflects the value of future possible new production technology; (4) The firm tends to invest more in the capital stock to offset the refinancing cost, and the firm's innovation investment trigger is lower when it is allowed to use hedging strategy.

■ MB-51
Monday, 10:30-12:00 - Building PA, Room D

Advances in Multi-Objective Programming Methods and Applications

Stream: Mathematical Programming
Chair: *Tunjo Perić*

1 - Vendor Selection and Supply Quotas Determination by using Analytic Hierarchy Process (AHP) and a new Multi-Objective Programming Method
Tunjo Perić, Zoran Babic

In this paper a new methodology for vendor selection and supply quotas determination is proposed. The proposed methodology combines Analytic Hierarchy Process for determining the coefficients of the objective functions and a new multiple objective programming method based on cooperative game theory for vendor selection and supply quotas determination. The proposed methodology is tested on the problem of flour purchase by a company that manufactures bakery products. Three criteria are used for vendor selection and quantities supplied determination: (1) purchasing costs, (2) product quality, and (3) vendor reliability.

2 - An Application of Multiple-Objective Linear Programming Method for the the Distribution Problem Solving
Jadranka Kraljevic

In this paper an application of a multi objective programming method introduced in Matejas, J., Perić, T., (2014) has been presented. This method is used to solve the cost/profit allocation problem. The method is based on the principles of cooperative games and linear programming. Two cases are considered, the standard case with proportional distribution and the generalized one in which the basic ideas of coalitions are incorporated. The presented theory is applied on an investment model for economic recovery problem solving.

3 - Three Different Approaches for Multiple Objective Fractional Linear Programming Problem Solving
Maid Omerović, Tunjo Perić

In this paper, three different approaches to solve multiple objective linear fractional programming problems have been investigated: (1) the goals satisfactory method, (2) the goal programming method, and (3) the fuzzy multiple objective linear programming method. For the goal programming method we propose a new linearization approach of the linear fractional objective functions. The efficiency of the presented approaches has been tested on the production plan optimization problem by solving multiple objective linear fractional programming problems from the point of view of decision makers and analysts. The obtained results indicate the advantages of the goal programming approach in comparison to the other two methods.

4 - A New Linearization Approach for Solving Multi-Objective Linear Fractional Programming Problems by Goal Programming
Sead Resic

In this paper, we propose a new linearization approach for solving multi objective linear fractional programming problems by using goal programming methods. The applicability of the proposed methodology has been tested on the example of financial structure optimization of a company. The obtained results show advantages of the proposed methodology compared to the existing methods. The proposed methodology is simple for both the analyst and the decision maker. Determination of the objective function weights by the decision maker, reflects the decision maker's preferences in the obtained solution.

■ MB-52

Monday, 10:30-12:00 - Building PA, Room C

Continuous Optimization, Convexity and Robustness

Stream: Convex, Semi-Infinite and Semidefinite Optimization
Chair: *Cesar Beltran-Royo*

1 - Two-Stage Stochastic Linear Programming: The Conditional Scenario Approach
Cesar Beltran-Royo

In this talk, we consider the Two-stage Stochastic Linear Programming (TSLP) problem with continuous random parameters. A common way to approximate the TSLP problem, generally intractable, is to discretize the random parameters into scenarios. Another common approximation only considers the expectation of the parameters, that is, the expected scenario. In this paper we introduce the conditional scenario concept which represents a midpoint between the scenario and the expected scenario concepts. The message of this talk is twofold: a) The use of scenarios gives a good approximation to the TSLP problem. b) However, if the computational effort of using scenarios results too high, our suggestion is to use conditional scenarios instead because they require a moderate computational effort and favorably compare to the expected scenario in order to model the parameter uncertainty.

2 - Adjustable Robust Optimization approach to optimize discounts for a multi-period supply chain problem under demand uncertainty
Viktoryia Buhayenko, Dick den Hertog

In this research a problem of supply chain coordination with discounts under demand uncertainty is studied. To solve the problem, an affinely adjustable robust optimization model is developed. At the time when decisions about order periods, ordering quantities and discounts to offer are made, only a forecasted value of demand is available to a decision maker, which is never accurate. The proposed model produces a discount schedule, which is robust against the demand uncertainty. The model is also able to utilize the information about the realized demand from the previous periods in order to make decisions for future stages in an adjustable way. We both consider box and budgeted uncertainty sets. Computational results show the necessity of accounting for uncertainty, as the total costs of the nominal solution increase significantly when only a small percentage of uncertainty is in place. It is testified that the affinely adjustable model produces solutions which perform significantly better than the nominal solutions not only on average but also in the worst case. The trade-off between reduction of the conservatism of the model and uncertainty protection is investigated as well.

3 - Piecewise Linear Multicriteria Programs
Xiaoqi Yang

In this talk we study multicriteria programs with piecewise linear objective functions and a polyhedron set constraint. Here a piecewise linear function may be continuous or discontinuous. In the discontinuous case, the domain is the union of some closed polyhedra and some semi-closed polyhedra, where the later are defined as the intersection of some closed and/or open half spaces. We obtain an algebraic representation of a semi-closed polyhedron. We establish that the (weak) Pareto solution/point set of a piecewise linear multicriteria program is the union of finitely many semi-closed polyhedra. This is a generalization of the well-known Arrow, Barankin and Blackwell theorem, which says that the (weak) Pareto solution/point set of a linear multicriteria program are the unions of nitely many polyhedra. We will investigate their weak sharp minimum property. We propose an algorithm for finding the Pareto point set of a continuous piecewise linear bi-criteria program and generalize it to the discontinuous case. We apply our algorithm to solve the discontinuous bi-criteria portfolio selection problem with an l risk measure and transaction costs and show that this algorithm can be improved by using an ideal point strategy.

■ MB-53

Monday, 10:30-12:00 - Building PA, Room A

OR in Regular Study Programs

Stream: Initiatives for OR Education
Chair: *Kseniia Ilchenko*

1 - Implementing Croatian Business Best Practices into OR Education Process
Kristina Soric

Zagreb school of economics and management launched in this academic year the new four year undergraduate program Business mathematics and economics (www.zsem.hr). We start with the classical topics such as mathematical analysis and linear algebra, but then continue immediately with the applications in economics, business and finance, using software while solving real problems from the practice, both from the field of process optimization and finance. In these activities, we got a great support from the Croatian business practice who is ready to share with us their problems in order to teach students. We organized the workshop and consultations with some of them, and in this work we present the main conclusions and suggestions that we got as their feedback.

2 - Integration of OR-based courses in Bach. and MSc. Management programs
Joao Miranda

The integration of three OR-based courses in Bachelor and Msc. Management programs is described. In the Technology and Management College at Portalegre Polytechnics (ESTG/IPP, Portugal), the course on Quantitative Methods occurs in the first term of the Management program: it and introduces Linear Programming (LP), after addressing selected topics of Linear Algebra, Integral Calculus and Differential Calculus. In the fourth term of the same Management program, the Operations Research course advances the LP studies, includes special topics of Transportation Problem and initiates Forecasting methods. The Multivariate Analysis and Decision Making course is included in the first term of the MSc. program in Management of Small and Medium-Sized Enterprises (SME): univariate statistics is enlarged to multivariate analysis and directed to multicriteria decision making, also addressing Decision Theory and Game Theory. Courses syllabuses and their main attributes are described, the learning methodology using a Problem/Project Based Learning approach and the associated evaluation are also analysed. In addition, illustrative examples that both show the specificities of each course and the courses interconnections are addressed. Finally, the students' general results, the impact of such integration approach, and future developments are discussed.

3 - OR Courses for the Interdisciplinary Master Program in Project Management
Kseniia Ilchenko, Olga Nazarenko

The OR study in Ukraine is formally limited only by linear and nonlinear optimization problems. However, all other issues are widely presented in other courses and can be included to different fields of science. But the common tendency is that OR usually is not studied by current/future managers and authorities. The complexity of modern systems and processes, and the value of information for their description caused the necessity of a new specialization called "Data mining in decision-making" in Project Management program. It requires interdisciplinary education that combines knowledge of information technology, mathematical methods and approaches to the analysis of complex systems, such as social and economic. The main attention is paid for verification, quantitative and qualitative analysis in decision-making, and forecast of impacts consequences, that are prerequisites for minimization of the deviations from planned results. The OR methods are included as separate courses or modules to increase the analytical competence of students and their ability to process information and create conditions for decision-making at different levels of management.

4 - The process and value of a mixed method design in exploring assessment in the EFL writing at university level in the Libya context
Imad Waragh

Mixed methods research is the use of quantitative and qualitative methods in a single study. It is becoming an increasingly popular technique used by social researchers. Explanatory design was carried out by collecting quantitative data first followed by qualitative data. Mixed research collection devices were the appropriate design to apply valid and reliable procedures to address the research questions. The central purpose of this paper is to provide an accessible introduction to mixed methods used in this study because it delivers rich and comprehensive data. The use of quantitative and qualitative approaches in combination provides a better understanding of research problems than either technique in isolation. This enables the researcher to look at the investigated phenomena from different angles which enhances full understanding. Using mixed-methods fills the gap that could occur if quantitative or qualitative methods are used on their own with the added bonus that using both methods could increase the validity of the research findings. The choice of selecting research methods is driven by the research questions. This study involves the questionnaire and semi-structured interviews which offer the strength of confirmatory results drawn from both methods. The integration of instruments can generate insights into a research question, resulting in enriched understanding of the study.

■ MB-54

Monday, 10:30-12:00 - Building PA, Room B

Projection methods in optimization problems 2

Stream: Convex Optimization
Chair: *Simeon Reich*
Chair: *Rafal Zalas*

1 - Zero-convexity, perturbation resilience, and subgradient projections for feasibility-seeking methods
Daniel Reem, Yair Censor

The convex feasibility problem (CFP) is at the core of the modeling of many problems in various areas of science. Subgradient projection methods are important tools for solving the CFP because they enable the use of subgradient calculations instead of orthogonal projections onto the individual sets of the problem. Working in a real Hilbert space, we show that the sequential subgradient projection method is perturbation resilient. By this we mean that under appropriate conditions the sequence generated by the method converges weakly, and sometimes also strongly, to a point in the intersection of the given subsets of the feasibility problem, despite certain perturbations which are allowed in each iterative step. Unlike previous works on solving the convex feasibility problem, the involved functions, which induce the feasibility problem's subsets, need not be convex. Instead, we allow them to belong to a wider and richer class of functions satisfying a weaker condition, that we call zero-convexity. This class, which is introduced and discussed here, holds a promise to solve optimization problems in various areas, especially in non-smooth and non-convex optimization. The relevance of this study to approximate minimization and to the recent superiorization methodology for constrained optimization is explained.

Ref: [Math. Prog. (Ser. A) 152 (2015), 339-380, arXiv:1405.1501].

2 - Projection Methods and Constraint Shape
John Chinneck

Projection methods are commonly applied to sets of constraints defining a convex feasible region where their favorable properties are well understood. Under the name of "constraint consensus methods" they are also applied as heuristics when the convexity properties of the feasible region are unknown, which is frequently the case in practice. Suppose that the "shape" (linear, convex, concave, both) of each nonlinear constraint could be discovered (and hence the convexity properties of the feasible region could be deduced). Could this information be used to accelerate projection methods seeking a feasible point for the set of constraints? We develop methods for estimating the shape of nonlinear functions as the constraint consensus solution proceeds and show how to use this information to increase speed by adjusting the algorithms as they run, primarily by inserting linear or quadratic correction steps to the updates.

3 - The variable metric forward-backward splitting algorithm under mild differentiability assumptions and line searches
Saverio Salzo

We study the variable metric forward-backward splitting algorithm for convex minimization problems without the standard assumption of the Lipschitz continuity of the gradient. In this setting, we prove that, by requiring only mild assumptions on the smooth part of the objective function and using several types of backtracking line search procedures for determining the step lengths or the relaxation parameters, one still obtains weak convergence of the iterates and convergence in the objective function values. Moreover, the o(1/k) convergence rate in the function values is obtained if slightly stronger differentiability assumptions are added. Our results extend and unify several studies on variable metric proximal/projected gradient methods under different hypotheses. We finally address applications and eventually show that, using the proposed line search procedures, the scope of applicability of the variable metric forward-backward splitting algorithm can be considerably enlarged, up to include problems that involves Banach spaces and smooth functions of divergent type.

4 - **Weak, strong and linear convergence of a double-layer fixed point algorithm**
Rafal Zalas

In this talk we consider consistent convex feasibility problems in a real Hilbert space defined by a finite family of sets Ci. In particular, we are interested in the case where Ci=Fix Ui=z: pi(z)=0, Ui is a cutter and pi is a proximity function. Moreover, we make the following state-of-the-art assumption: the computation of pi is at most as difficult as the evaluation of Ui and this is at most as difficult as projecting onto Ci.

The considered double-layer fixed point algorithm, for every step k, applies two types of controls. The first one - the outer control - is assumed to be almost cyclic. The second one - the inner control - determines the most important sets from those offered by the first one. The selection is made in terms of proximity functions.

The convergence results presented in this talk depend on the conditions which first, bind together sets, operators and proximity functions and second, connect inner and outer controls. In particular, a demi-closedness principle, bounded regularity and bounded linear regularity imply weak, strong and linear convergence of our algorithm, respectively. The framework presented in this talk covers many known (sub-gradient) projection algorithms already existing in the literature; see, for example, those applied with (almost) cyclic, remotest set, maximum displacement, most violated constraint, parallel and block iterative controls.

Monday, 12:30-14:00

■ MC-01

Monday, 12:30-14:00 - Building CW, AULA MAGNA

Keynote Alexander Shapiro

Stream: Plenary, Keynote and Tutorial Sessions
Chair: *Mustafa Pinar*

1 - **Risk Averse and Distributionally Robust Multistage Stochastic Optimization**
Alexander Shapiro

In many practical situations one has to make decisions sequentially based on data available at the time of the decision and facing uncertainty of the future. This leads to optimization problems which can be formulated in a framework of multistage stochastic optimization. In this talk we consider risk averse and distributionally robust approaches to multistage stochastic programming. We discuss conceptual and computational issues involved in formulation and solving such problems. As an example we give numerical results based on the Stochastic Dual Dynamic Programming method applied to planning of the Brazilian interconnected power system.

■ MC-02

Monday, 12:30-14:00 - Building CW, 1st floor, Room 7

Algorithmic Components of Evolutionary Multi-objective Optimization

Stream: Evolutionary Multiobjective Optimization
Chair: *Manuel López-Ibáñez*

1 - **Evolutionary Multi-objective Optimization with the Shark Library**
Tobias Glasmachers

Shark is an open source C++ library for machine learning and optimization. Its direct search component implements a number of state-of-the-art evolutionary algorithms for single- und multi-objective optimization. In the last five years the library has undergone a major redesign resulting in the recently released version 3.0. In this transition the interfaces of all optimization methods were unified, covering 0th to 2nd order methods for single- and multi-objective optimization.

This talk is dedicated to the interface and software design of Shark's evolutionary multi-objective optimization methods. The library currently implements real-coded NSGA-II, SMS-EMOA, and multiple variants of MO-CMA-ES. The algorithms are composed of flexible and reusable components (evolutionary operators). They fit into Shark's generic optimization interface, which allows to change the algorithm and/or problem under consideration with ease.

2 - **10 years of experience developing the jMetal framework: current status and future perspective**
Antonio J. Nebro, Juan J. Durillo

Multi-objective optimization with metaheuristics has become an active research field in the last 15 years. During this time, many algorithms have been proposed and a number of software frameworks have been developed for implementing them. jMetal is a project that started in 2006 and has become a popular framework in the field. We describe the conceptual design of jMetal and how it is currently evolving. We comment our experiences in using jMetal in the design and implementation of multi-objective algorithms and in its application to solve real-world problems from the civil engineering and bioinformatics domains. Finally, we give our vision of future perspectives around jMetal in the context of multi-objective optimization.

3 - PaGMO: Parallel Global Multiobjective Optimizer
Marcus Märtens, Krzysztof Nowak, Dario Izzo

We present PaGMO, a framework designed to tackle a variety of optimization problems from science or real-world application domains. The extensible design of PaGMO allows for easy implementation of new algorithms, evaluation on a vast number of benchmarks, and comparison with the included and well-established state of the art solvers. The framework comes with a rich collection of bio-inspired evolutionary algorithms for unconstrained, constrained, mixed-integer, continuous, single-objective and multi-objective problems that can be applied and customized for both local and global optimization. The core feature of PaGMO is a transparent implementation of the asynchronous island model - a coarse-grained parallelization scheme of the optimization process. Using the island model, PaGMO can utilize both, multicore architectures and cluster environments, to achieve a significant boost in computational performance. Combining different solvers and migration strategies allows for the design of new parallel optimization heuristics. The focus of this work is the design and utilization of PaGMO's features for multi-objective optimization by showcasing how advanced concepts like the hypervolume indicator, migration and decomposition can be adapted to make use of parallel computational resources.

4 - How to Design a New State-of-the-Art Multi-objective Evolutionary Algorithm Every Weekend
Manuel López-Ibáñez

There are new multi-objective evolutionary algorithms (MOEAs) proposed every year, all of them claiming to improve over previous proposals. Most MOEAs are proposed as monolithic blocks with a few parameters that need to be set. Few researchers concern themselves with the study of the similarities between the algorithmic components that make up the design of MOEAs. The large number of MOEA proposals combined with the lack of a clear classification of their components makes difficult to judge what is actually novel in a newly proposed MOEA and what makes it perform better than its predecessors. Imagine if one could take all MOEAs already proposed in the literature, break them into components, then automatically recombine those components for specific problem scenarios and, finally, be able to propose new state-of-the-art MOEAs by the mere application of computational power. Our own recent work has shown that such an automatic design of MOEAs is feasible today, even for the most well-studied scenarios in the MOEA literature. Once such a possibility becomes reality, some fundamental questions become urgent: What is a novel algorithm? What makes a particular combination of components useful? What is the most informative and unbiased manner of evaluating new MOEA proposals?

■ MC-03
Monday, 12:30-14:00 - Building CW, 1st floor, Room 13

MADM Application 3

Stream: Multiple Criteria Decision Analysis
Chair: *Pin-Ju Juan*

1 - Applying AHP Model for Selecting the Optimal Business Manager of Integrated Marketing Communications Companies
Pi-Fang Hsu, En-Ping Lin

This study intends to develop a model to assist IMC companies with selecting the optimal business manager. First, the proposed model adopts the modified Delphi method to identify suitable criteria for evaluating business managers of IMC companies. Next, the model applies the analytic hierarchy process (AHP) to determine the relative weights of evaluation criteria, ranks the alternatives and selects the optimal business manager. Additionally, a famous Taiwanese IMC company is used as an example to prove how a business manager is selected by applying this model. The results show the emphasis on the criteria of professional competence, personal qualities, creative thinking, social skills and self-regulation. This model could help IMC companies effectively select a business manager, making the results highly applicable in academia and commerce.

2 - The Novel Blue Ocean in Perspective of Tourism: Assessment regarding the Strategic Alliance of International Cruise Supplier and Cross-strait Travel Agency
Wen-Yu Chen

The cruise industry has experienced rapid growth in recent years; it also demonstrates great potential with respect to global economic development. Meanwhile, Asia is a fast-emerging market, and many cruise lines are very keen at expanding into this region. Therefore, how to evaluate the strategic alliance regarding the international cruise suppliers and the cross-strait travel agencies has become an exceedingly significant research issue. In previous studies, the concept concerning the strategic alliance partners' selection is mainly discussed amid the tangible commodities or non-service industry. Nevertheless, they did not examine the specific issues addressed in the present research. The present research combined qualitative (literature review, in-depth interviews, and modified Delphi method) and quantitative (analytic hierarchy process, AHP) methods to explore the selection criteria of strategic alliance partner; secondly, it implements the AHP approach to calculate the overall weights. The results of this study bilaterally contributed to Taiwanese and Mainland China governments in addition to the cross-strait travel agencies and international cruise suppliers, specifically when it comes to enhancing the overall service quality in cruise tourism. Simultaneously, it provides some references as regard to how to select a suitable strategic alliance partner.

3 - Development key performance indicators of Hostels
Pin-Ju Juan, Peng-Yu Juan

The purpose of this study is to develop indicators of key performance for hostels with a sustainable framework. In order to develop such objective indicators, this study employed a modified Delphi technique. A panel of 16 academic researchers in tourism provided input into developing the indicators. After three rounds of discussion, the panel members reached consensus on the set of indicators. Passing the result of studies, this research will construct an evaluating pattern of the key performance of the competitive advantage to evaluate the standard operational procedure (sop) of the hostels.

4 - Developing the data envelopment analysis model with incorporating the workplace injury to measure the safety performance of business operations
Li-Ting Yeh

Safety performance is becoming increasingly important. Workplace injury can be employed as a comparative measure of safety performance. The nature of the workplace injury is usually undesirable output in the business operations and economic activities. With incorporating the three workplace injury rates (including wounded or illness, disability and death), the data envelopment analysis model will be developed to evaluate the safety performance of business operations. This paper illustrates the study's methodology, which involves using an empirical application to evaluate the safety performance of 11 industrial sectors in Taiwan. The finding will useful to the government for amend the industry safety regulation with sustainability.

■ MC-04
Monday, 12:30-14:00 - Building CW, ground floor, Room 6

OR and CO in Web Engineering 1

Stream: Operations Research and Combinatorial Optimization in Web Engineering
Chair: *Maciej Drozdowski*

1 - Analyzing Web-Apps in Evolving Environments
Joaquim Gabarro, Jorge Castro, Maria Serna, Alan Stewart

The behaviour of short-duration Web-Apps in stable, but uncertain, environments can be assessed using short-duration uncertainty profiles [2]. Over longer periods user-demand for shared resources fluctuates and computational environments evolve. Long-duration repetitive Apps in uncertain evolving environments can be assessed using angel/daemon stochastic games [1]. Environmental evolution is modelled by long-duration uncertainty profiles. This allows the robustness of a Web App in a dynamic environment to be assessed using the value of a stochastic game. Here two extreme types of long-duration Apps are analysed: "Inert" Apps cannot affect environmental behaviour whereas "intrusive" Apps may influence overall operating conditions. Partial orders are derived for long-duration profiles; this allows the robustness of different environments to be assessed indirectly, without having to compute game values.

[1] Castro, J. et al.: The Robustness of Periodic Orchestrations in Uncertain Evolving Environments. ECSQARU 2015: LNCS 9161, 129-140, Springer. [2] Gabarro, J. et al.: Analysing Web-Orchestrations Under Stress Using Uncertainty Profiles. Comput. J.57(11): 1591-1615 (2014).

Acknowledgements: Gabarro, Serna and Stewart are supported by MINECO FEDER TIN2013-46181-C2-1-R and by 2014:SGR:1034 from AGAUR. Castro is supported by MINECO FEDER TIN2011-27479-C04-03 and TIN2014-57226-P and by 2014:SGR:890.

2 - Scheduling Web Data Gathering to Minimize Memory Usage
Joanna Berlińska

This work considers a focused web crawler that periodically gathers data from a set of frequently updated web pages. Each page is downloaded to a server and a data set it contains is extracted and processed for further usage. As soon as downloading a page starts, the appropriate amount of memory is allocated. The memory is released when computations on the corresponding data set finish. Gathering and processing data from all considered pages has to be completed in given time, bounded both by data gathering length cycle and the need to quickly react to new data. The scheduling problem is to organize page downloads so that the memory usage is as small as possible. We prove that this problem is computationally hard. Heuristic algorithms are proposed and tested in a series of computational experiments.

3 - Algorithms for Budgeted Internet Shopping Optimization Problem (B-ISOP)
Jakub Marszałkowski, Mateusz Ledzianowski

The Internet Shopping Optimization Problem is being researched for several years now. It models and solves a problem of buying a set of products available from many suppliers, paying costs of products, but also all necessary delivery costs. In the new budgeted version of this problem, the user wants to receive a maximal number of items or maximal combined perceived value of the items within limited budget. This way, an incomplete order realization is allowed. In the talk, a mathematical formulation of the problem will be presented. Next, its computational complexity will be analyzed and relations with some known problems will be discussed. Finally, algorithms solving the problem will be proposed including greedy as well as more heuristic approaches.

4 - A note how to enhance and optimize Cloud Brokers
Jedrzej Musial

Cloud Service Broker (CSB) should be perceived as a link between Cloud Service Provider (CSP) and Cloud Service Customer CSC). The link which plays a role of a negotiator. This complicated role is successful when both sides are happy. According to The International Organization for Standardization CSB is a "cloud service partner that negotiates relationships between cloud service customers and cloud service providers". Using CSB can be more advantageous than basic CSP since it can create a new frontend, new channels, new possibilities for using cloud services and many more. CSB can offer much better possibilities that link many different programs and services into new bundles. CSB may be defined as a big Internet cloud supermarket. We can treat services as products, CSP as shops and CSC as clients. Of course there are many ways of optimization, regarding from which point of view we tackle the problem. Optimization goal from the customer perspective is to pay the lowest possible price for a bundle of desired products. The optimization goal for the CSB is to sell all the necessary products for the highest possible price. One should notice that there are numerous additional requirements and variables such as realization time, uptime factor, trust, reliability, and many more. CSB problem is somehow similar to the Internet Shopping Optimization Problem. The author would like to show the similarities and discuss ideas how to enhance and optimize Cloud Brokering Problem.

■ MC-05
Monday, 12:30-14:00 - Building CW, 1st floor, Room 8

Preferences and Problem Formulation in Multicriteria Optimization 1

Stream: Multiobjective Optimization
Chair: *Iryna Yevseyeva*
Chair: *Michael Emmerich*

1 - A Co-evolutionary Algorithm for Green Inventory Routing Problem
Zhiwei Yang, Kaifeng Yang, Michael Emmerich, Thomas Bäck

With the increasing attention paid to global warming and more tax fee paid for the greenhouse gas emission, there is a growing need for the enterprises to take the environment influences into account in the decision making process of supply chain management. The inventory routing problem is a combinatorial problem which combines the inventory management and vehicle routing problem. In classical inventory management, the decision makers need to decide when and how much of goods should be delivered to the clients in each delivery period. Then the clients running out of stock are selected to be served and a capacitated VRP is generated. Each client has a demand and each vehicle has a capacity. Here the green inventory routing problem integrated the tax cost of the greenhouse gas emission, which means not only the inventory cost, the routing cost and the stockout cost should be minimized, but also the tax cost of the greenhouse gas emission should be minimized. In this paper, we proposed a co-evolutionary algorithm for this many objective problem. The concept of co-evolving subpopulations is applied. It enables to increase the diversity, adaption and stability of the algorithm. The populations in the algorithm correspond with species in nature. The change of one species would affect the situation of other species. All these species evolve together to search for a well-distributed Pareto front. Results show that the performance of our algorithm is better than other classical multi

2 - Objective Functions in Earth Observing Satellite Mission Planning and their Interdependence
Longmei Li, Feng Yao, Michael Emmerich, Ning Jing

The mission of Earth Observing Satellite (EOS) is to acquire photographs of specified areas on earth surface at the requests of users. With the high development of remote sensing technology, EOSes are widely used in environmental protection, national defense, agriculture, meteorology and other fields. The process of EOS mission planning aims at selecting and timetabling the observation activities to acquire the requested images, in order to maximize certain objectives while satisfying operational constraints. It plays an important role in the management of satellites. Traditionally, the objective function of EOS mission planning is a weighted sum of different objectives, but it is difficult to assign a meaningful weighting and the influence of the weights on the ranking can be counter-intuitive. In this paper, we focus on the scheduling of agile EOS constellations and formulate the problem as a multi-objective optimization, analyze interdependence of the five main objectives, i.e., profit, quantity of satisfied requests, quality of satisfied requests, energy consumption, and resource equilibrium. To do so we calculate the approximate Pareto-fronts using simulated instances. The objective functions are ordered in a hierarchy and scatter plot matrix is used to show correlations between each pair. Based on this we give suggestions on designing aggregation objective functions and incorporating preferences into multi-objective problem solving.

3 - Computing Pareto Fronts of Implicitly Defined Functions

Michael Emmerich, Michal Sklyar

In scientific and engineering optimization an objective function might be defined only implicitly by means of an equality equation. In such cases it would be desirable to use the analytical equation to compute optimal points or, in case of multicriterion optimization, a set of evenly spread Pareto optimal points, using the analytical expression. We present theory and methods of how to find Pareto fronts of implicitly defined objective functions. To achieve these results we use the implicit function theorem. Moreover, we discuss potential applications of this new approach.

4 - An Interactive Evolutionary Approach to Multi-objective Feature Selection

Murat Koksalan, Muberra Ozmen, Gulsah Karakaya

In feature selection problems, the aim is to select a subset of features to characterize an output of interest. In characterizing an output, we may want to consider multiple objectives such as maximizing classification performance, minimizing number of selected features or cost, etc. We develop a preference-based approach for multi-objective feature selection problems. Finding all Pareto optimal subsets may turn out to be a combinatorially-demanding problem and we still would need to select a solution eventually. Therefore, we develop an interactive evolutionary approach that aims to converge to a subset that is preferred by the decision maker. We test our approach on several instances simulating decision-maker preferences by underlying preference functions and demonstrate that it works well.

■ MC-06

Monday, 12:30-14:00 - Building CW, ground floor, Room 2

Urban and territorial planning in MCDA 1

Stream: Multiple Criteria Decision Aiding
Chair: *Isabella Lami*
Chair: *Marta Bottero*

1 - Supporting the Definition of Sustainable Smart District using a MACBETH approach

Patrizia Lombardi, Francesca Abastante, Isabella Lami, Jacopo Toniolo

Lowering energy intensity and environmental impacts of buildings is becoming a priority in Europe, considering that cities produce about 80% of all GHG (Greenhouse gas) emissions and consume 75% of energy globally. The big challenge is to improve the energy performances of existing housing stock representing the majority of the urban fabrics in European cities. This paper illustrates a research result of the European project DIMMER (District Information Modelling and Management for Energy Reduction), which aims to promote energy efficient behaviours integrating Building Information Modelling and district level 3D models with real-time data from sensors and user feedback. The methodology here applied is the multicriteria method MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique), an Additive Value Model method requiring a non-numerical approach to build a quantitative value model. The authors applied the MACBETH assessment model to two urban districts, in Turin (Italy) and in Manchester (UK) with the aim to discuss the main criteria to evaluate heating systems' policies at district level and to rank energy development scenarios of the specific districts analysed. Results from the case studies show how the economic aspects of the transformation are still overwhelming compared to the environmental issues.

2 - An application of the NAROR for the management of a real estate portfolio

Isabella Lami, Silvia Angilella, Marta Bottero, Salvatore Corrente, Valentina Ferretti, Salvatore Greco

We propose an application of the Non Additive Robust Ordinal Regression (NAROR) for the assessment and management of a real estate portfolio. NAROR aggregates the evaluations of the alternatives using the Choquet integral taking into account the possible interactions among criteria by means of non-additive weights (fuzzy measures). Using NAROR, the DM can supply preference information in terms of pairwise preference comparisons between reference alternatives, intensity of preferences, pairwise comparisons on the importance of criteria and sign and intensity of interaction among pairs of criteria. In this paper, the objective of the evaluation is the selection of the best performing building in terms of valorization in the real estate market. The buildings are analyzed and compared through the use of the NAROR on the basis of different criteria, such as location, destination, age, flexibility and surface. The evaluation has been based on a focus group with experts providing preference information to be used in the NAROR model. The use of NAROR has been particularly useful because it allowed the analysis of the possible interactions among the considered criteria requiring a limited cognitive effort from the DM. These interactions characterise inevitably a real estate operation and cannot be neglected in a moment of economic crisis, where the profitability of the assets is far to be sure.

3 - Urban processes assessment for the Metropolitan Area of Naples (Italy)

Pasquale De Toro, Alfredo Franciosa

The aim of the paper is to provide a support to the elaboration of the new instrument of government related to the Metropolitan Area of Naples (Italy), through the activation of processes of territorial governance, starting from the promotion of human health that contributes to the city productivity and to its sustainable development. Health and wellbeing can be considered some of the drivers through which it is possible to identify the urban areas of weakness, selecting actions and programs to improve the city resilience. Analyzing the environmental, social and economic determinants that influence human health in a hierarchic process, it has been analyzed the Metropolitan city of Naples according to all the factors that are able to influence synergistically the health of its population, meant in a multidimensional perspective of complete physical, mental and social wellbeing associated to the variables of the urban context. This process has lead to the identification of the territorial distribution of the health and wellbeing of the inhabitants, elaborating a division of the territory in different zones specifically involved in complex urban processes. The evaluation has been carried out in GIS environment with the elaboration of statistical spatial analyses and the integration with the Analytic Hierarchy Process multicriteria method.

4 - Multi-criteria Analysis as a Tool to Cope with Asymmetric Information. An Application to the Hospitality Sector

Klaas De Brucker, Inge Meesters

The hospitality sector is a typical example of market actors being confronted by asymmetric information. Rating systems have been developed to cope with this type of market failure. These categorise hotels, often using a star system (i.e. a sorting or 'beta' problem formulation). Such systems have evolved (initially through private initiative and today also through government agencies) rather spontaneously, without being grounded in the theory of multi-criteria analysis (MCA). This paper looks at the different rating systems through a MCA lens. We unravel the main characteristics of the systems (viz. the underlying aggregation procedure) used in a number of countries and identify some caveats. The main problems are that (1) the underlying criteria and

(2) aggregation procedure are unfamiliar to clients, (3) they differ between countries, (4) do not address the heterogeneity of customer preferences and (5) often only measure the availability of specific services and infrastructure, rather than their intrinsic quality. To remedy the problems, we propose a novel approach which consists of presenting the information relevant for all customers in a disaggregated but structured way, using a MCA evaluation matrix (i.e. a description, or in Roy's terms, a 'delta' problem formulation). The MCA matrix is designed so that customers can zoom in on those criteria they find most relevant. Finally, we test the implementation potential of our novel approach through stakeholder interviews.

■ MC-07

Monday, 12:30-14:00 - Building CW, 1st floor, Room 123

EURO Excellence in Practice, part I

Stream: EURO Awards and Journals
Chair: *Ton de Kok*

1 - Scheduling Scientific Experiments for Comet Exploration on the Rosetta/Philae Mission

Christian Artigues, Emmanuel Hebrard, Pierre Lopez, Gilles Simonin

On November 12th 2014, the robot-lab Philae was released from the spacecraft Rosetta and landed on the ground of the comet 67P/Churyumov-Gerasimenko. Philae is fitted with ten instruments to conduct the experiments elaborated by as many research teams across Europe. These experiments, should they be imaging, sampling or other types of signal analysis, correspond to sequences of activities constrained by two extremely scarce resources: the energy supplied by a single battery, and the storage memory of its CPU. The CNES, the French space agency that was in charge of designing the plans executed by Philae, acquired to that purpose from an industrial subcontractor a toolkit called MOST (Mission Operation Scheduling Tool). This toolkit modeled the problem of scheduling Philae's experiments as a complex Resource-constrained project scheduling problem using a commercial software embedding dedicated scheduling, constraint programming and operations research techniques. Limitations of this first version were identified as the solution procedure was way too slow for large scale scenarios. We thus present our contributions to solving the problem of scheduling Philae's activities. In particular, we focus on the design of polynomial-time complexity algorithms for efficiently reasoning about data transfers within Philae and between Philae and Rosetta. These algorithms made it possible to solve in a few seconds long term sequences of activities that otherwise required hours with the previous approach, or in some case could not be solved. Moreover, they also give a more accurate prediction of the memory usage, thus giving better guarantees against data loss. Moreover, as Philae bounced right after touch down due to a malfunction of its harpoons, recourse schedules had to be rebuilt in a nearly real-time basis, which was made possible by the reactivity of the new algorithms. Despite this unexpected event, most of the experiments could be carried out and allowed to obtain significant scientific discoveries.

2 - Duty and Workstation Rostering Considering Preferences and Fairness: A Case Study at a Department of Anaesthesiology

Jens Brunner, Andreas Fügener, Armin Podtschaske

This research addresses a personnel scheduling problem at hospitals. We present two mixed integer linear programming models - a duty-roster and a workstation-roster model. The duty-roster model determines the assignment of physicians to 24h- and late-duties whereas the workstations-roster model assigns physicians to actual workstations as operating rooms. The former serves as an input for the latter. In both models we maximize the number of assignments subject to labor regulations and internal department specific scheduling rules. Furthermore, we consider experience levels and qualifications in our models. To promote for job satisfaction we take into account fairness aspects as well as individual physician preferences. We implemented both models at a large German university hospital for the department of anesthesiology with approximately 150 physicians. We could demonstrate the superior quality compared to manual scheduling previously in use at our cooperation hospital with regards to granted requests, shortage of coverage, and fair distribution of weekend duties.

3 - A Novel Framework of Simulation and Optimisation for Offshore Wind Farm Installation Logistics at SSE and SPR

Kerem Akartunali, Euan Barlow, Matthew Revie, Diclehan Tezcaner Ozturk, Evangelos Boulougouris, Sandy Day

The development of an offshore wind farm involves a relatively complex sequence of activities in order to install electrical cabling, offshore electrical systems, turbine foundations, masts and turbine generators, typically spread through multiple years with budgets often significantly exceeding '100 million for each project. Complexities arise from various aspects including range of vessel types, their capabilities and availabilities, significant uncertainties apparent in weather and costs, and operational limitations and requirements. Motivated by an almost non-existent literature in the area and the urgent need expressed by our industrial partners Scottish Power Renewables and Scottish Southern Energy to improve current installation logistics operations and realize substantial cost savings, we started our project with an extensive period of data collection and data analysis, followed by an iterative process of model building in close collaboration with engineers and project managers. We have designed and developed several stand-alone and integrated simulation and optimisation modules in order to address the needs of our partners, where novel approaches exploiting Monte Carlo simulation, rolling horizon scheduling, and robust optimization were required to solve challenging massive-size industrial problems. All models were implemented in a multi-stage validation and verification process that resulted in custom-built software ready to use by the end users and decision makers.

■ MC-08

Monday, 12:30-14:00 - Building CW, 1st floor, Room 9

Complex preference learning in MCDA 4

Stream: Multiple Criteria Decision Aiding
Chair: *Andrej Bregar*

1 - Indirect derivation of criteria weights from veto related information: a generalised approach, its characteristics and applications

Andrej Bregar

In decision analysis, the importance of criteria may be determined either directly by compensatory criteria weights, or indirectly based on the selective characteristics of criteria. Within the scope of our previous research work, the correlation between the noncompensatory influence of veto and criteria weights was discussed. Several methods/operators exhibiting various levels of relativeness were introduced for the automatic derivation of criteria weights according to the selective effects of veto. The presented study builds on these methods for automatic derivation of criteria weights from the veto related preferential information that is modelled in the special case of dichotomic sorting analysis. It formally adapts and extends the methods to the general problematics of sorting and ranking, and to different types of preference models. It also determines the characteristics of the proposed generalised weight derivation approach, and measures its efficiency by applying a common framework for the evaluation of decision-making methods and systems. It considers various factors, such as cognitive load, correctness and relevance of judgments, accuracy and validity of weights, richness of cardinal discriminating information, robustness, breadth and depth of decision analysis, thoroughness of domain analysis, focus on problem solving, and methodological foundations. It additionally describes several use cases in the context of preference elicitation and aggregation procedures.

2 - On the normalization of interval weights and fuzzy weights
Ondřej Pavlačka

In many multiple criteria decision making methods, general weights of criteria need to be normalized for the purpose of elimination of their dimension. In applications, the weights can be uncertain and expressed by intervals or fuzzy numbers. Therefore, we will deal with the problem of fuzzy extension of the procedure of the normalization of weights. We will establish some properties of normalization that are important from the point of view of real applications and review the existing methods for normalization of interval weights and fuzzy weights. We will show that it is not sufficient to express the result of normalization only by a tuple of normalized interval weights or fuzzy weights together with the constraint that the sum of the weights is equal to 1, since it can cause a false increase of uncertainty in the model. This fact will be illustrated by an example. A consequence of this finding is that in multiple criteria decision making based on fuzzy weighted averages, like, e.g., fuzzy AHP, constraining fuzzy normalized weights and normalizing fuzzy weights will give different results.

3 - A Hybrid Linear Programming and Minimax Reference Point Approach for Weight Assignment in MADM
Jian-Bo Yang, Guoliang Yang, Dong-Ling Xu, Mohammad Khoveyni

How to determine weights for attributes is one of the key issues in the multiple attribute decision making (MADM) problems. This paper aims to investigate a new three-stage approach for determining the weights of attributes based on linear programming (LP) model and minimax reference point optimisation. This new approach first considers preliminary weights for attributes and considers the most favourite set of weights for each alternative or decision making unit (DMU). These weight sets are then aggregated to find the best compromise weights for attributes with the interests of all DMUs taken into account fairly and simultaneously. This approach is intended to support the solution of such MADM problems as performance assessment and policy analysis where (a) the preferences of decision makers (DMs) are either unclear and partial or difficult to acquire or (b) there is a need to consider the best "will" of each DMU. Two case studies are conducted to show the features of this new proposed approach and how to use it to determine weights for attributes in practice. The first case is about the assessment of research strengths of 24 selected countries under certain measures and the second is for analysing the performances of Chinese Project 985 universities, where the weights of the attributes need to be assigned in a fair and unbiased manner by following a general policy.

4 - PROMETHEE-GAIA Approaches for Multi-Criteria Inventory Classification and Warehouse Management
Birol Elevli, Ali Dinler

Multi-Criteria Inventory Classification (MCIC) methods classify inventory items with respect to several criteria in order to allocate storage locations within the limited storage area. This paper presents the applicability of PROMETHEE-GAIA method to inventory classification and warehouse management problems in a textile production plant. The number of inventory items varies with season (summer, winter and all-season), and the storage area is limited. Therefore, allocation of dedicated storage area for all products is not possible. In order to effectively manage the warehouse, the items need to be classified as seasonal so that warehouse can be arranged as dedicated area and temporary storage area. The items are first defined as either all-season, winter and summer on the basis of previous years order dates and order amount. There are 36 items for all-season, 30 items for summer and 45 items for winter season. Then, each group items are ranked according to criteria of total order, number of order, the number of month order received and the item price by using PROMETHEE-GAIA software. The results show that classification of items is very beneficial in terms of warehouse utilization and management.

■ MC-09

Monday, 12:30-14:00 - Building CW, 1st floor, Room 12

Application of OR for Embedded Systems

Stream: OR Applications in Industry
Chair: *Lilia Zaourar*

1 - Manufacturing of vias using DSA Technology: an integer programming approach
Dehia Ait-Ferhat, J. Andres Torres, Vincent Juliard, Gautier Stauffer

An integrated circuit is composed of several electrical components etched over multiple layers. We focus in this study on the manufacturing of a set of vias that connect components from two consecutive layers. One of the basic steps in this process is Lithography. Lithography imposes a certain minimum distance for two vias to be printed simultaneously. Hence dense layouts are decomposed into feasible sub layouts (a.k.a. masks) that are printed sequentially to produce the original arrangement: this is called Multiple Patterning (MP). Each lithography step is costly and the goal is thus to minimize the number of masks in this decomposition. This problem can readily be modeled as a standard graph coloring problem in unit disk graphs (a NP-hard problem). Directed self-assembly (DSA) is a promising solution to reduce further the number of masks. The idea is to group vias that have to be assigned to different masks in MP to a same mask combining DSA and Lithography. The main challenge of our study is to find the best way of grouping vias (following imposed rules) in order to minimize the number of 'hybrid' masks. This problem reduces to an improper coloring problem in unit disk graphs. We are interested in exact algorithms for this problem. We will present several integer programming formulation and we will compare those formulations on true instances. Standard MP being a special case, we will also show the potential benefits of using DSA over pure MP on those real instances.

2 - Application management on a heterogeneous microserver system
Lilia Zaourar, Jean Marc Philippe

Nowadays, we all use services provided by the execution of complex applications, such as weather forecasting, search engines, big data medical analyzes or intelligent transportation systems. These applications are studied, tested and simulated on massively parallel supercomputers. However, the energy consumption to maintain these systems and perform calculations becomes increasingly high. In fact, 15% of our total electrical energy is required to power computers at home, at work, in data centers and it is growing rapidly. In response to this evolution, a new server form factor, compact and energy-efficient, recently appeared: the micro-server. It concentrates all components of a conventional server integrating a large number of processors in the same volume. Meanwhile, the availability of accelerators (GPUs and FPGAs) enables the design of machines adapted to applications. Nevertheless, the exploitation of these heterogeneous platforms raises new challenges in terms of application management optimization on available resources. The aim of our work is to determine effective algorithms to exploit these heterogeneous platforms by finding the best allocation of an application to optimize the execution time and energy consumption with respect to various constraints. We propose a mathematical model for mapping and scheduling parallel applications in heterogeneous architecture with communication delays. We implemented it and have some preliminary numerical results.

■ MC-10

Monday, 12:30-14:00 - Building CW, ground floor, Room 1

EthOR Award - Applicants' Presentations and Award Ceremony

Stream: OR and Ethics

Chair: *Pierre Kunsch*
Chair: *Erik Kropat*
Chair: *Dorien DeTombe*
Chair: *Gerhard-Wilhelm Weber*
Chair: *Cathal Brugha*

1 - Development of a Markovian Decision Model (MDM) for Collection Centers for disaster relief operations
Irais Mora-Ochomogo

Statistics show that natural disasters have been increasing considerably in recent years, not only in number of events, but also in intensity and in the impact they have in the communities they strike. Mexico due to its geographical location, is very susceptible to present different types of disasters each year. When a disaster strikes in Mexico, around 80% of the donations made are in-kind, this arises the need to have an efficient donations' handling from the beginning of the supply chain, considering the logistical and ethical implications. This document presents the general description of the research carried on by the author and her thesis advisors about Markov Decision Model for Collection Points or Collection Centers, as well as the ethical issues faced in the development of this research.

2 - A New Contribution to Ethics and OR: Towards a More Ethical Journalism
Duygu Onay-Coker

My dissertation identifies the main problems of journalism ethics and proposes a new perspective by French Philosopher Paul Ricoeur for daily routines of journalism. Ricoeur's ethical thoughts postulate an ethical life with the main idea of "living together with and for others". In a globally connected world, media acts the main role for knowing and accepting each other and living with harmoniously. Therefore media itself should transform its linguistic into more peaceful structure.

In my dissertation I argue that media needs more ethical perspective to carry out its ethical assignment and the theory of linguistic hospitality by Ricoeur is valuable for journalistic daily routines. I believe my dissertation is relevant for the EthOR Award since my dissertation presents a new perspective of living with and for others through ethical media for creating a more peaceful society.

The presentation ends with a conclusion, a discussion and outlook to future studies related to this pioneering research, to Ethics and to OR with its classical, quantitative fields, their variety and scientific responses to the many challenges of tomorrow's world.

3 - Exploring "cultural corruption" in financial organizations: A hybrid modelling approach
Penka Petrova, Ross Kazakov

Organizations are complex social systems or "organisms" made out of agents, which socioeconomic status is dependent on the degree of their cultural health, i.e., the level of the unity of their ethical values and believes. A hybrid system dynamics and agent-based modelling experiment is conducted to explore the phenomenon of "cultural corruption" in a financial credit department and related effects on the department work flow, employee turnover and productivity. A metaphorical perspective is taken in relation to the organization as being a living organism which "cultural health" is being attacked by culturally corrupted "bacteria", i.e., new employees with corrupted moral and ethical values. The aim of the experiment is to explore the effect of the above on the organizational culture in the credit department, i.e., its degree of cultural corruption, on the working quality and efficiency, on employee turnover influenced by the "bacteria" employee infiltration and on the department organizational health. Key questions which we try to find answer to are "When organizations and their cultural health become vulnerable to "bacteria" employee?", "What is the role of the organization hiring and reward policy" when linked to the "personified cultural replication" agency phenomena, and "What "antimicrobial" policy an organization needs to undertake in order to protect its cultural health and to strengthen its cultural "immune" system".

4 - On the emergence of fairness norm via social networks: an experimental study
Omar Rifki, Hirotaka Ono

Recently there has been an increased interest in adopting game-theoretic models to social norms. Most of these approaches are generally lacking a structure linking the local level of 'norm' interactions to the global 'social' nature. Although numerous studies examined local interaction games, which deal extensively with neighborhood structures, regarding social network as a whole entity is quite limited. In this paper, we conduct a series of simulation experiments to examine the effects that a network topology could have on the speed of emergence of social norm. The emphasis is placed on the fairness norm in the ultimatum game context (Bicchieri 2006), by considering three network type models (Erdos-Reny, Barabasi-Albert and Watts-Strogatz) and several intrinsic topological properties, such as network diameter and density.

■ MC-11

Monday, 12:30-14:00 - Building CW, 1st floor, Room 127

Discrete and Global Optimization 1

Stream: Discrete and Global Optimization
Chair: *Jan van Vuuren*

1 - Optimisation of radio transmitter locations in mobile telecommunication networks
Thorsten Schmidt-Dumont, Jan van Vuuren

Mobile telecommunication has become an essential communication channel in the modern world. Network providers are faced with the challenge of providing as many people in as many different areas as possible with communication network access. Multiple factors have to be taken into account when radio transmitter placement decisions are made. Generally, maximum area coverage and the average signal level provided to the demand region are of prime importance in these decisions. These criteria give rise to a bi-objective facility location problem with the goal of achieving an acceptable trade-off between maximising the total area coverage and maximising the average signal level provided to the demand region by a network of radio transmitters. A bi-criterion framework for evaluating the effectiveness of a given set of placement locations for a network of radio transmitters is presented. This framework is used to formulate a novel bi-objective facility location model which may form the basis for decision support with a view to identifying high-quality trade-offs between maximising total area coverage and maximising the average signal level provided. This model is finally applied to a case study involving an area around Stellenbosch so as to demonstrate its practical use and flexibility. The suitability of transmitter placement suggestions provided is discussed in the context of this special case by comparing them to actual placements that have been made by a network provider.

2 - Decision support for the selection of water release strategies at open-air irrigation reservoirs
Christiaan van der Walt, Jan van Vuuren

Water earmarked for irrigation purposes in the agricultural sector is typically stored in open-air reservoirs. The availability of irrigation water greatly impacts the profitability of this sector and this availability is largely determined by prudent decisions related to water release strategies at open-air reservoirs. The selection of such a strategy is difficult, since the objectives which should be pursued are not generally agreed upon and unpredictable weather patterns cause reservoir inflows to vary substantially between hydrological years. A mathematical model is proposed which may form the basis of a decision support system for the selection of beneficial water release strategies. The proposed model generates a probability distribution of the reservoir volume at the end of a hydrological year for a given initial water release strategy, based on historical reservoir inflows. This strategy is then adjusted iteratively, with the aim of centring the minimum expected hydrological year end volume on some target value. The proposed model is implemented in a computerised decision support system which is validated in a special case study involving Keerom Dam, a large open-air reservoir in the South African Western Cape. Its strategy suggestions are compared to historically employed strategies and the suggested strategies are found to fare better in maintaining reservoir storage levels whilst still fulfilling irrigation demands.

3 - Simulating the Oviposition Site Selection Process of Eldana Saccharina Walker
Brian van Vuuren, Linke Potgieter, Jan van Vuuren

Eldana saccharina Walker (Lepidoptera: Pyralidae) continues to plague the sugarcane industry in South Africa. In an attempt to advance understanding of the pest and assist in the ongoing development of an integrated pest management (IPM) system to combat its infestation, an agent-based simulation model has been designed which simulates the individual members' behaviour within a population. This is in contrast to previously developed models which were founded upon approximations on a population level without taking in to account the local interactions between individual moths. In particular, two novel algorithms are proposed for simulating the process followed by female E. saccharina moths when selecting suitable oviposition sites. This is deemed important as there exists limited knowledge pertaining to this process and a means for generating a spread of eggs consistent with that which is observed in nature is paramount to predicting resulting dispersal and dynamics of an E. saccharina population. The manner in which this process is simulated, as well as incorporated into the rest of the agent-based model, is discussed in this paper.

4 - Integer Programming Models for the Mid-term Production Planning of High-tech Low-volume Industries
Joost de Kruijff, Cor Hurkens, Ton de Kok

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

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

■ MC-12

Monday, 12:30-14:00 - Building CW, ground floor, Room 029

VeRoLog: Selected transportation problems

Stream: Vehicle Routing and Logistics Optimization
Chair: *Frédéric Quesnel*

1 - A new branching heuristic for the air crew pairing problem
Frédéric Quesnel, Francois Soumis, Guy Desaulniers

The airline crew scheduling problem is studied by many researchers. Usually, the problem is divided in two steps : the crew pairing and the crew rostering problems. Most real-world crew pairing solvers must include restrictions on the total number of time (credit) that can be woked at each base. However, these constraints have not been often studied academically.

We first formulate the pairing problem as an original Danzig-Wolfe decomposition formulation that includes additional constraints limiting the total credit for each base. We present how this effects negatively the objective values of the solutions obtained as well as the computing time on some instances, when using a column generation algorithm to solve them. The causes of these unwanted outcomes are then analysed. Finally, we propose a new branching schemes designed to improve both the computing time and the objective value of our instances.

2 - The locomotive assignment problem with periodic inspections: a case study
Pawel Hanczar

With the promotion of the environmental friendly transportation modes, (the European Commission supports the freight transport operations in the rail sector) the increase of demand's diversification is observed. While most rail freight companies tend to apply fixed schedules, meeting the customer's specific requirements causes that this approach is not effective. The scope of this paper is to present a new method for the assignment of locomotives to trains with the need of periodic inspections in the context of freight rail transportation. Based on our experience this issue plays very important role in tactical planning process. Despite a thorough review of the literature the presented extensions were not yet considered in this area. The proposed formulation is based on a space-time network. In order to consider the need of periodic inspection this formulation was extended by a set of constraints which are similar to Miller-Tucker-Zemlin subtour elimination. To investigate the efficiency of the method, computational experiments were performed using data from one of the biggest polish rail freight company.

3 - A Biased Random-Key Genetic Algorithm for vehicle-reservation assignment in a car rental company
José Fernando Oliveira, Beatriz Brito Oliveira, Ana Ribeiro, Maria Antónia Carravilla

Car rental companies aim to maximize their profit by improving their rental schedule, i.e. the assignment of reservations to specific vehicles. With a heterogeneous fleet with partial substitution between car types and unbalanced demand on different stations at different time periods, empty transfers (repositions of cars between stations) are critical, especially for those vehicles that exist in small quantities, such as luxury cars. It is therefore fundamental to include these empty transfers in the planning process, in order to fulfill as many reservations as possible. In this work, a BRKGA is used to assign reservations to specific vehicles, in order to handle large amounts of data with reduced computer processing time, thus allowing for higher system availability for allocating reservations. Different decoders and solution representations are presented and tested, aiming to obtain high-quality solutions for real-world instances within a reasonable time-frame.

■ MC-13

Monday, 12:30-14:00 - Building CW, ground floor, Room 3

VeRoLog: Green Routing

Stream: Vehicle Routing and Logistics Optimization
Chair: *Jorge E. Mendoza*

1 - Solving the Multi-Objective Shortest Path Problem
Antoine Giret, Yannick Kergosien, Emmanuel Néron, Gaël Sauvanet

Multi-objective Shortest Path problem consists in finding Pareto-optimal paths between two given nodes in a graph where each edge has several associated costs, while minimizing several objectives. To solve this multi-objective problem, we develop a new exact method called Label Setting algorithm with Dynamic update of Pareto Front (LSDPF), which aims to find all non-dominated solutions of the problem. Different exploration strategies and improvements techniques have been proposed and tested. Numerical experiments on real data sets and on instances of the literature were conducted. Comparison with recent benchmarks algorithms solving Bi-Objective Shortest Path Problem - the bounded Label Setting algorithm by (Raith, 2010) and the pulse algorithm by (Duque et al., 2015) - shows that our method outperforms these benchmarks algorithms. This work is in collaboration with an enterprise who provide a web platform called Géovélo that aims to propose routes for cycling by solving a Bi-Objective Shortest Path Problem that takes into account both distance and insecurity criteria.

2 - A matheuristic approach for solving the electric vehicle routing problem with time windows and fast recharges

Merve Keskin, Bülent Çatay

The Electric Vehicle Routing Problem with Time Windows (EVRPTW) is an extension of the well-known VRPTW where electric vehicles (EVs) are used instead of internal combustion engine vehicles. An EV has a limited driving range due to its battery capacity and may need recharging to complete its route. Recharging may take place at any battery level and may be at any quantity up to the battery capacity. Furthermore, the stations may be equipped with chargers with different power supply, power voltage, maximum current options which affect the recharge duration. In this study, we model the EVRPTW by allowing partial recharges with two recharging configurations which can be referred to as normal recharge and fast recharge (FR). In FR, the battery is charged with the same energy in a shorter time but at a higher cost. Our objective is to minimize the total recharging cost while operating minimum number of vehicles. We formulated this problem as a mixed integer linear program and solved the small instances using CPLEX. To solve the larger problems we develop a matheuristic approach which couples the Adaptive Large Neighborhood Search (ALNS) approach with an exact method. Our ALNS is equipped with various destroy-repair algorithms to efficiently explore the neighborhoods and uses CPLEX to strengthen the routes obtained. We carried out extensive experiments to investigate the benefits of FR and test the performance of the proposed approach using benchmark instances from the literature.

3 - Electric Traveling Salesman Problem with Time Windows

Min Wen, Roberto Roberti

To minimize greenhouse gas emissions, the logistic field has seen an increasing usage of electric vehicles. The resulting distribution planning problems present new computational challenges. We address a problem, called Electric Traveling Salesman Problem with Time Windows. We propose a mixed integer linear formulation that can solve 20-customer instances in short computing times and a Three-Phase Heuristic algorithm based on General Variable Neighborhood Search and Dynamic Programming. Computational results show that the heuristic algorithm can find the optimal solution in most small-size instances within a tenth of a second and achieves goods solutions in instances with up to 200 customers.

4 - A comparative study of charging assumptions in electric vehicle routing problems

Jorge E. Mendoza, Alejandro Montoya, Christelle Guéret, Juan G. Villegas

Electric vehicle routing problems (eVRPs) extend classical routing problems to consider the limited driving range of electric vehicles. In general, this limitation is overcome by introducing planned detours to battery charging stations. Most existing eVRP models rely on one (or both) of the following assumptions: (i) the vehicles fully charge their batteries every time they reach a charging station, and (ii) the battery charge level is a linear function of the charging time. In practical situations, however, the amount of charge is a decision variable, and the battery charge level is a concave function of the charging time. In this research we extend current eVRP models to consider partial charging and nonlinear charging functions. We present a computational study comparing our assumptions with those commonly made in the literature. Our results suggest that neglecting partial and nonlinear charging may lead to infeasible or overly expensive solutions.

■ MC-14

Monday, 12:30-14:00 - Building CW, 1st floor, Room 125

Valid inequalities and formulations

Stream: Mixed-Integer Linear and Nonlinear Programming
Chair: *Fabrizio Rossi*

1 - Valid Inequalities for SDP-Optimal Power Flow with Integer Variables

Bartosz Filipecki

The optimal power flow (OPF) is an important problem in planning of electricity production and distribution with high potential savings worldwide. However, it is a nonconvex quadratically-constrained problem, which is in general challenging to solve. In recent years, approaches based on convex relaxation gained popularity due to availability of efficient algorithms and higher accuracy than simple linear approximation. We consider a version of the OPF problem which, in addition to the standard description, includes binary variables for modelling power plant (generator) operation. We use a semidefinite programming (SDP) relaxation approach for this problem and analyse polyhedral structure of feasible regions of several small instances. Hence, we propose to use some valid inequalities that have been successfully used to improve computation performance in mixed-integer (linear) problems of similar structure. We present a comparison of results between the original problem and the one using valid inequalities based on IEEE test instances.

2 - Time-indexed formulations for airport runway scheduling

Pasquale Avella, Maurizio Boccia, Carlo Mannino, Igor Vasiliev

Air traffic management typically consists of the coordinated solution of three distinct problems: The Departure Management Problem (DMAN), the Arrival Management Problem (AMAN) and the Surface Management Problem (SMAN). The DMAN problem decides take-off times for each departing flight, whereas AMAN focuses on landing times of arrival flights. Finally, the SMAN Problem decides how arriving and departing airplanes move in the airdrome. Even though in principle the three problems are tightly connected and should be solved jointly, it is common practice of the airport management to handle them independently. In this work we present a time-indexed formulation for AMAN, DMAN and their integration, ADMAN (Arrival and Departure MANagement), exploiting the relation with a classical scheduling problem, namely, the single machine problem with sequence dependent setup times. Starting from a time-indexed formulation recently proposed for single machine scheduling problems with sequence dependent setup times and release dates, we present a compact reformulation based on new families of clique inequalities, leading to significantly better lower hounds. We report on preliminary computational results on real and realistic instances, validating the effectiveness of the proposed approach.

3 - Use of 0,1/2 Chvàtal-Gomory cuts in the closest 0-1 string problem

Claudio Arbib, Mara Servilio, Paolo Ventura

The Closest (or Centre) String Problem, CSP, calls for finding an n-string (centre) that minimizes its maximum distance from m given n-strings. Recently, integer linear programming has been successfully applied within heuristics to solve the problem under the Hamming distance, a popular metric in code theory applications. In this perspective, the authors demostrated that the binary case (0-1 CSP) can efficiently be addressed by branch-and-cut using 0,1/2 Chvàtal-Gomory cuts. Separating a fractional solution by cuts of this sort can be done in polynomial time. However, their existence depends upon the parity of the right-hand side: in particular, no such cuts can be found if all the right-hand side coefficients have the same parity. We discuss the issue of parity-breaking and describe a projective method to overcome the inconvenience.

4 - Analysis of compact formulations for the stable set problem
Stefano Smriglio, Adam Letchford, Fabrizio Rossi

There are several different ways to formulate the stable set problem on a graph G=(V,E) as a 0-1 LP. We are interested in "compact" formulations, in which the number of constraints is bounded by a polynomial in |V|. The simplest such formulation is the so-called "edge" formulation, which has |E| constraints and 2|E| non-zero constraint coefficients. One can simultaneously strengthen the formulation and reduce the number of constraints and non-zeroes, by replacing some or all of the edge constraints with clique inequalities, i.e., inequalities associated to maximal cliques in G. The cliques can be generated, e.g., via a greedy heuristic or cutting-plane algorithm.

Murray and Church (1997) considered an alternative compact formulation, with 2|V| constraints and O(|V|2) non-zeroes. This formulation has |V| clique inequalities and |V| so-called "nodal" inequalities. We show how to construct several other compact formulations, by mixing clique and nodal inequalities in various ways. Most of our formulations have only O(|E|) constraints and O(|E|) non-zeroes, like the edge formulation. Extensive computational experiments, on the DIMACS test bed, show that some of the new formulations work remarkably well on certain instances.

■ MC-15

Monday, 12:30-14:00 - Building CW, 1st floor, Room 126

Engineering Optimization 1

Stream: Engineering Optimization
Chair: *Wolfgang Achtziger*

1 - Modelling and Optimization of Progressive Lenses
Gloria Casanellas Penalver, Jordi Castro

Presbyopia is the gradual inability of the eyes to focus on near objects. It appears around forties and requires lenses in order to see correctly in near vision. Progressive lenses correct presbyopia and have a complex design: have an upper region for far vision, the corridor for middle vision and the low region for near vision, with an increase of power. In geometrical terms, the optical power is the difference between the principal curvatures of the surface lens multiplied by a constant, and the power is the mean of the principal curvatures multiplied by the same constant. When changing vertically the power, unwanted lateral astigmatism appears due to Minkwitz theorem. Optimization techniques are used to design these lenses in order to get the lowest astigmatism located as far as possible from the corridor of the lens.

The formulation of the problem in Cartesian coordinates is a non-linear and non-convex problem. In this presentation we will show the Cartesian coordinates model in order to design progressive lenses, as well as the new spherical parameterization. Some numerical results comparing cartesian coordinates and spherical ones will be shown. Finally, a comparative between different solvers will be presented.

2 - Optimal Design and Operation of District Heating Networks
Jessen Page

District heating networks can provide a climate-friendly solution for the provision of heat for space heating and domestic hot water in urban environments. For this centralised solution to be more energetically (and exegetically) efficient than standard decentralised solutions it needs to be designed as part of a heat cascade making optimal use of the heat source and to be operated in such a way as to minimise heat losses and pumping requirements along the network. We present two case studies each investigating one of these two statements. In the first we produce a cost-exergy analysis of the exploitation of vapour generated by a waste incineration plant. This plant is destined to cover the base load of a future high temperature district heating network (the remaining load being met by gas boilers). The scenarios studied include various sizes and operation strategies of a steam turbine as well as various supply temperatures for the district heating network. The optimisation methodology relies on the "pinch analysis". In the second use case we apply model predictive control (MPC) for operating the district heating network of a skiing resort. Most of the connected buildings have a stochastic occupant presence and therefore stochastic heating and domestic hot water demand load. This combined to the stochastic nature of weather conditions (mainly solar radiation) lead to believe that MPC can prove to be a more energy efficient approach than current practice.

3 - On Relations of Classical Problem Formulations in Compliance Minimization and Maximization of Discrete/Discretized Mechanical Structures
Wolfgang Achtziger

We study classical problem formulations minimizing or maximizing compliance of discrete or discretized mechanical structures. Besides displacements we consider non-negative linearly bounded variables controlling the stiffness of each particular structural element. In two different mathematical models, these variables enter the element stiffness matrix linearly or inverse-linearly, respectively. The considered problem formulations play central roles in the field of optimal topology design and in calculations of best/worst case damage distribution of mechanical structures. All considered problem formulations can be equivalently reformulated through potential energy. By this, each problem can be analyzed with respect to its hidden material behaviour at optimal control variables. It turns out that the problems based on the linear and on the inverse-linear model, respectively, are closely related through a convexification concept in terms of element-wise strain energy. Analogous relations hold if complementary energy is considered in the case of truss structures. These relations are not too well known, but some of them can be found in the literature, and some of them are unknown. We present here a unified systematic overview on all problem formulations. Moreover, we present some mathematical relations of the element-wise energy functions linking different problem formulations with each other on an element level.

■ MC-16

Monday, 12:30-14:00 - Building CW, 1st floor, Room 128

Robust Combinatorial Optimization III

Stream: Discrete Optimization under Uncertainty
Chair: *Fabio D Andreagiovanni*

1 - Robustifying Combined Heat-and-Power Operation using Affine Decision Rules
Nils Spiekermann, Stefano Coniglio, Arie Koster, Alexander Hein, Olaf Syben, Leonardo Taccari

Considering the change in the energy supply systems in Europe, the potential of running small sized and variable energy generators attracts a great amount of interest, especially for private investors. In this talk we will consider combined heat and power (CHP) production units with a fixed heat to power ratio, coupled to a heat storage. On the power side we assume market participation, where power can be bought as well as sold day-ahead, and our power balance can be momentarily restored at a cost according to the deviation. Since, under these assumptions only heat uncertainties can result in physical infeasibilities, while other uncertainties solely affect the costs, we will focus on an uncertain heat demand. To compensate for the heat uncertainty, we rely on a limited heat storage which suffers exponential losses over time. The aim is to find a robust production plan, consisting of the energy production as well as the day ahead market activities, which is feasible for all realizations inside an uncertainty set build around a given heat forecast, using historical data. Here, the problem is formulated as a two stage mixed integer linear program (MILP) for both the discrete and gamma-robust uncertainty sets. A comparison between a static solution approach and one based on affine rules is drawn considering realized robustness as well as computational time.

2 - Multiband Robust Optimization for Optimal Energy Offering under Price Uncertainty

Fabio D Andreagiovanni, Giovanni Felici, Fabrizio Lacalandra

We consider the problem of a price-taker generating company that wants to select energy offering strategies for its generation units, to maximize the profit while considering the uncertainty of market price. First, we review central references about the use of Robust Optimization (RO) for price-uncertain energy offering, pointing out how they can expose to the risk of suboptimal and even infeasible offering. We then propose a new RO method for energy offering that overcomes all the limits of other RO methods. We show the effectiveness of the new method on realistic instances provided by our industrial partners, getting very high increases in profit. Our method is based on Multiband Robustness (MR; Büsing, D'Andreagiovanni, 2012), an RO model that refines the classical RO model by Bertsimas and Sim, while maintaining its computational tractability and accessibility. MR is essentially based on the use of histogram-like uncertainty sets, which result particularly suitable to represent empirical distributions commonly available in uncertain real-world optimization problems.

Essential References:

- C. Büsing, F. D'Andreagiovanni: "New Results about Multiband Uncertainty in Robust Optimization". Experimental Algorithms, Springer LNCS, doi: 10.1007/978-3-642-30850-5_7. - F. D'Andreagiovanni, G. Felici, F. Lacalandra: "Revisiting the use of Robust Optimization for optimal energy offering under price uncertainty". Submitted, http://arxiv.org/abs/1601.01728.

3 - Distributionally Robust Approaches to the Minimum Weighted Tree Reconstruction Problem

Cristina Requejo, Olga Oliveira, Michael Poss

We address the Minimum Weighted Tree Reconstruction (MWTR) problem with uncertainties. Distributionally robust approaches to the problem will be discussed in this work when the cost coefficients are subject to uncertainty. The MWTR problem consists of constructing a tree connecting a set of terminal nodes and of associating weights to the edges such that the weight of the path between each pair of terminals is greater than or equal to a given distance between these terminals and the total weight of the tree is minimized. This problem has applications in several areas, namely, the modeling of traffic networks and the analysis of internet infrastructures. The underlying tree topology in not known and the terminals distance is known with uncertainties. We discuss and propose a robust tree reconstruction to the problem. A computational experimentation is reported to show the relevance of the presented approaches.

■ MC-17

Monday, 12:30-14:00 - Building CW, ground floor, Room 0210

Traffic Analysis and Operation

Stream: Transportation

Chair: *Riccardo Rossi*

Chair: *Tom Maertens*

1 - Uniform Traffic Coordination in Arteries

Mariusz Kaczmarek

The presentation is devoted the newer approach to optimal traffic coordination in arteries. Until now the problem had been solved by two main groups of methods: maximal bandwidth coordination or minimal delay coordination. The first ones are based on very simple traffic models which fits to low traffic conditions. The second ones assumed by additive delay functions which are valid only in heavy traffic conditions. Nevertheless the traffic coordination problems are mixed continuous-discrete ones with many local optimal solutions. Our approach is general and usable in any traffic conditions up to saturation based on a group model of traffic flow without specific assumptions. The group model is applied in two versions: a crisp one for fixed time traffic coordination programs optimization, and a fuzzy one for adaptive traffic control in flexible coordination in the framework of windows system. In the methodological part of the presentation, general relationships are derived between new defined coordination parameters, the reserve time in cycle and lack of synchronization which better characterized the problem than the old ones (offsets and splits). The reverse of cycle time is also optimized. In the applied part of the presentation, the methodology is carefully evaluated by a simulation study on traffic models of an artery in West Poznań. The elastic coordination effectiveness is researches in comparison to optimized by TRANSYT method both on TRANSYT and VISSIM models.

2 - Optimization of traffic counting point for the estimation of traffic demand using the flow capturing model

Yoichi Shimakawa, Hiroyuki Goto

There have been several studies for the estimation of trip distributions in the area using observed link-flow. The accuracy of the estimation much depends upon the location and the number of the traffic counting in the network. This study develops and applies mathematical models that locate traffic counting point to observe the maximum volume of vehicle flow. In this paper, two models are proposed, which enable us to extract the effective links for the estimation of trip distributions. One of them is the optimization model to maximize a standard traffic flow and the other is total traveler kilometer. They are optimization problems that maximize the total captured flow and total traveler kilometer by locating points on the link. Inputs to the model include a digital road network with a legal speed, traffic capacity per a day; the assumed origin-destination flow volumes between each origin and destination zone; and the number of the points to build. Geographic Information Systems and mathematical programing are integrated in a spatial decision support system that researcher can use to develop data, enter assumptions and parameters, evaluate tradeoff and analyze sensibility for the parameters, and map results. In numerical simulation, several routes between the origin and destination are assumed. There models applied to the trunk road network of metropolitan city in Asia.

■ MC-18

Monday, 12:30-14:00 - Building CW, ground floor, Room 023

Inventory Management 2

Stream: Production and Operations Management

Chair: *Leonardo Epstein*

1 - Optimal Times and Sizes of Purchases of Items for Rental Operations

Leonardo Epstein, Eduardo González-Császár

Inventory models for rental items are useful to plan operations or services as diverse as rental of tools, access to telephone lines, or access to repair stations. The talk describes models for the special situation where the service provider owns items that he rents-out to customers, but when his inventory is insufficient to meet the demand, the provider can rent additional items from a third party. The process of arrivals of requests for items as well as the time-intervals the items remain rented, are stochastic. The planning of a rental operation project may consider time-lagged purchases of items. This talk uses inventory models with uncertain demand and availability of items from a third party, to determine both the optimal times of future purchases and the corresponding number of items that the manager should purchase at each occasion to add to his inventory.

2 - An inventory model for perishable items having constant demand with time dependent holding cost
Sarbjit Singh

This paper presents an inventory model for perishable items with constant demand, whose holding cost increases with time, the items considered in the model are deteriorating items with a constant rate of deterioration θ. In the majority of the earlier models the holding cost has been considered to be constant which is not true in most of the cases as the insurance cost and record keeping costs or even cost of keeping the items in the cold storage increases with time. In this paper, the time-dependent linear holding cost has been considered, the holding for the items increases with time. The approximate optimal solution has been obtained. Numerical examples are also given to illustrate the model obtained.

3 - The impact of the class division on the average order-picking times
Grzegorz Tarczynski

One of the methods for shortening the average order-picking time is the proper storage location assignment of fast moving items. In practice the items are usually divided into three classes based on the Pareto rule: the A-class consists of 20% of the fastest moving items, the B-class includes 30% of items with ordinary rotation ratio, while the C-class covers 50% of the least frequently ordered items. The author studies the impact of other divisions on the order-picking times. The research shows that the division 20-30-50 is the most stable, but for the specified warehouse parameters and the size of pick lists it is very often not optimal. The research covered the one-block rectangular warehouses. The different storage location assignment policies and three routing methods: return, s-shape and midpoint were considered. For these routing heuristics and unrestricted storage location assignment the equations for the average order picking time were derived. The values obtained by means of equations were verified using Warehouse Real-Time Simulator.

■ MC-19

Monday, 12:30-14:00 - Building CW, ground floor, Room 021

Lot Sizing, Lot Scheduling and Related Problems 3

Stream: Lot Sizing, Lot Scheduling and Production Planning
Chair: *Christian Almeder*

1 - A lot-sizing problem in a flow-shop system with various energy sources
Masmoudi Oussama, Alice Yalaoui, Yassine Ouazene, Farouk Yalaoui, Hicham Chehade

Sustainability in manufacturing is an important requirement due to several reasons such as environmental concerns. The first energy consumer and greenhouse gas emitter in the world is the industrial sector. On average, the generation of 1 KWh of electricity causes 0.71 kg of greenhouse emission. In order to minimize the impact of the traditional electricity generator (like nuclear sources) on the environment, it is recommended to resort to the clean energy forms as solar and wind ones. In this paper, we present an energy based lot-sizing problem in a flow-shop system. The introduction of different energy sources, essentially renewable ones, is considered. The production system is composed of N reliable machines separated by N buffers. Each region has its genetic energetic code composed of different parameters. They are determined from historical statistics. As an example, for a given region, the different periods (low, high, and medium) of the possible renewable sources of energy are identified. In what concerns the solar energy, each period is characterized by a maximum energy capacity and a percentage of solar energy collection. The same principle is available for the other forms of the selected renewable energies. The objective of the proposed model is to find an optimal production plan that minimizes production costs composed of setup and holding on one hand and different sources of energy integrating renewable ones on the other hand.

2 - Analysis of machine flexibility in lot sizing problems
Diego Fiorotto, Raf Jans, Silvio de Araujo

In the literature on supply chain flexibility, it has been shown that adding flexibility to the production process in the form of flexible machines can reduce the overall costs and improve service levels. The principle of chaining indicates that a small amount of flexibility, configured in a smart way, can provide a substantial part of the total value that can be obtained by complete flexibility. In this paper, we analyse the value of machine flexibility in the context of a deterministic lot sizing problem with parallel machines. If there is no machine flexibility (i.e., each machine can only produce one type of product), and the total demand cannot be satisfied on time, the result will be costly backorders, overtime, or outsourcing. Adding flexibility (i.e., some machines can produce several types of products instead of just one) in such a case can decrease the total cost of backlog, overtime and outsourcing. However, in practice it can be very costly to install machines that have complete exibility. Therefore, it might be interesting to only implement a limited amount of exibility such that each machine can produce only certain types of items. We study the value of machine flexibility in lot sizing models, analyse several machine flexibility configurations and determine what the best flexibility configuration would be for a given budget in order to balance the benefits and cost of machine flexibility.

3 - An integrated Mixed-Integer Linear Programming approach to dynamic safety stock planning in the General Lot-sizing and Scheduling Problem
Stefan Minner, Steffen Klosterhalfen, Dariush Tavaghof-Gigloo

We present a mixed integer linear programming approach to integrate dynamic safety stock planning into the standard general lot-sizing and scheduling problem model formulation with continuous and non-equidistant micro-periods and capacity constraints. Demand is non-stationary with a known probability distribution. We consider a periodic review system under a base stock policy with different service measures. We introduce a new model formulation to determine the cumulative mean demand and the cumulative variance of demand on the micro periods over the planning horizon in a simultaneous way as the lot-sizing and scheduling are done. Furthermore, we introduce piece-wise linearization approaches for the nonlinear safety stock functions. Finally, we conduct an extensive numerical study to illustrate the effectiveness of our modelling approach and report the results of a case study.

4 - Designing new decision rules for the capacitated lot sizing problem using Genetic Programming
Fanny Hein, Christian Almeder, Gonçalo Figueira, Bernardo Almada-Lobo

The Capacitated Lot Sizing Problem (CLSP) is a standard optimization problem and one of the most critical in production planning. Since the CLSP is NP-hard, solution methods for large instances are mostly heuristic. Simple period-by-period approaches as proposed by Dixon and Silver (1981) and Maes and Van Wassenhove (1986) are widely-used in research and in practice due to the extremely low computational effort and their suitability for rolling planning horizons. These algorithms consist of three main steps: (i) ranking the products according to a priority index; (ii) deciding if a current production lot is extended or a new lot has to be set up; (iii) a feasibility routine ensuring that stocking up takes place if capacity limitations require it. The aim of this work is to apply genetic programming (GP) to automatically generate new decision rules for those heuristic algorithms for the CLSP. The GP-approach allows us to consider various problem-specific characteristics (such as cost ratios, capacity utilization, cumulative remaining demand or demand variability) leading to more complex rules that adapt to the problem environment. Computational experiments show that we are able to obtain better solutions when using a GP-based priority rule for sorting the products (i) and for the decision on lot extension (ii) compared to Dixon-Silver. Developing adaptive heuristics for the CLSP with uncertain demand is an interesting direction for future work.

■ MC-20

Monday, 12:30-14:00 - Building CW, ground floor, Room 022

Location in transportation systems

Stream: Location
Chair: *Vladimir Marianov*

1 - Optimal location of charging infrastructure for electric and gas fuelled vehicles
Cristina Corchero, Oriol Serch, Sara Gonzalez-Villafranca

Promotion and installation of new charging infrastructure is essential to raise awareness among the population to accelerate the inevitable transition from conventional to alternative fueled vehicles. Our contribution consists of an optimization model to allocate a new charging stations network for different vehicles technologies considering both alternative fueled vehicle users and infrastructure planners interests. Since different objectives can be considered, multiple solutions are provided depending on the priority the decider wants to give to every objective. Two different cases of study will be presented: in the first one, which deals with infrastructure for electric vehicles, the model aims at finding the optimal location for a new fast charge infrastructure network with the objectives of maximizing the captured road network flow minimizing the driven distance for the users to reach a point where to charge their vehicles. The second case study considers gas fueled vehicles. The aim here is to maximize the captured road network flow, as well, but minimizing installation and maintenance costs. In the latter case, candidate locations where to install charging infrastructure take different costs of installation depending on its geographical location and characteristics. A case study for the region of Catalonia is performed and results are obtained.

2 - Multi-period location of flow intercepting portable facilities of an ITS
Antonio Sforza, Claudio Sterle, Annunziata Esposito Amideo

Intelligent transportation systems are of great importance in urban traffic management. In this context variable message signs (VMS) play a major role in providing drivers with useful information and instructions during their trips. Fixed VMS are huge gantries installed on network links. They require a considerable economic investment and may not be in keeping with city's image. They are generally placed along highways or at the entrance to urban areas. By contrast, portable VMS, are relatively small and designed to be moved from one location to another. This makes them environmental-friendly, easy to handle and vey flexible. Hence they can be located and re-located on a highway or on the main roads of an urban area. In this work we consider the problem of finding the optimal location of a set of portable VMS on an urban network where the flow pattern changes at each period of a time horizon. We propose two original solving approaches based on flow intercepting facility location ILP models, in order both to maximize the flow intercepted by a pre-fixed number of portable facilities (or to minimize the number of facilities required to intercept a pre-fixed amount of flow), and to minimize the relocation cost associated with their repositioning over the entire time horizon. The paper presents an application of the proposed approaches to real-like test networks and discusses the results obtained providing some indications on their practical applications.

3 - The maxisum and maximin-maxisum HAZMAT routing problems
Vladimir Marianov, Andrés Bronfman, Germán Paredes-Belmar, Armin Lüer-Villagra

We design routes for transportation of hazardous materials (HAZMAT) in urban areas, with multiple origin-destination pairs. First, we introduce the maxisum HAZMAT routing problem, which maximizes the sum of the population-weighted distances from vulnerable centers to their closest point on the routes. Secondly, the maximin-maxisum HAZMAT routing problem trades-off maxisum versus the population-weighted distance from the route to its closest center. We propose efficient IP formulations for both NP-Hard problems, as well as a polynomial heuristic that reaches gaps below 0.54% in a few seconds on the real case in the city of Santiago, Chile.

4 - PPP motorway ventures - An optimization model to locate interchanges with social welfare and private profit objectives
Hugo Repolho, Antonio Antunes, Richard Church

This paper proposes two optimization models for locating motorway interchanges when dealing with public-private partnerships. The models innovate by considering simultaneously the conflicting goals of the two main parties involved, government and concessionaires, in their pursuit to maximize social welfare benefits and profits, respectively. The models maximize social welfare benefits (using a consumers' surplus measure) such that a given level of profits is ensured, being one deterministic and the other stochastic. The application of the models to a real case study, involving the A25 motorway in Portugal, show that they can help determine win-win solutions for both government and concessionaires, that is, solutions with high levels of profits and social welfare benefits.

■ MC-21

Monday, 12:30-14:00 - Building CW, ground floor, Room 025

Train shunting and service planning

Stream: Public Transportation
Chair: *Bob Huisman*

1 - A Constraint Programming approach to the rail fleet maintenance problem.
Diarmuid Grimes, Barry Osullivan

The scheduling domain has proven particularly successful for Constraint Programming (CP) due to the combination of dedicated inference methods / search strategies, while still allowing sufficient flexibility and expressivity. In this work we propose a CP approach for the rail fleet maintenance problem (RFMP), which involves optimally scheduling a set of preventive (periodic) and corrective maintenance exams in a maintenance depot over a fixed horizon. The schedule is subject to constraints on depot resources and staff, and fleet availability requirements.

We show how CP can be used to obtain the necessary flexibility to handle many variants of the RFMP. For example single/multiple fleets of train operating companies; shift-dependent staff, with overtime and dual staff options; irregular events requiring alteration to the demand profile, staff availability, etc. for a fixed duration during the scheduling horizon.

The RFMP is further complicated by the significant uncertainty inherent in the problem inputs, due to variance in the duration/requirements of maintenance exams. A number of methods are implemented for handling this. In particular, on the proactive side resource/demand buffers can be included in the schedule; while on the reactive side an adaptive search strategy is used to maintain schedule stability when re-solving.

We discuss both the benefits of CP for this problem, but also the challenges the RFMP poses for traditional CP scheduling techniques.

2 - Robust Maintenance Location Routing for Train Units
Denise Tönissen, Joachim Arts, Max Shen

The robust maintenance location routing problem for Train Units is an NP-hard problem, where we locate maintenance facilities, while also taking the maintenance routing into account. Facility location is a long term strategic decision, but the optimal facility locations depend on line planning and rolling stock schedules. Since these change on a regular basis, our objective is to minimize the costs under the worst conceivable line plan and rolling stock schedule. Therefore, we provide a robust optimization formulation and find solutions via Lagrangian relaxation. We show that the relaxed problem can be interpreted as a maintenance routing problem that is similar to the minimum cost flow problem. We exploit this and provide an algorithm that runs in polynomial time for the relaxed problem. Based on this we provide an algorithm to solve the original problem and perform numerical tests.

3 - Integrated Rolling Stock Planning for Suburban Passenger Train Services
Per Thorlacius

A central issue for passenger railway operators is providing sufficient number of seats while minimising operating costs. This process must be conducted taking a large number of practical, railway oriented requirements into account. Because of this complexity, a stepwise solution was previously used, the result being the loss of optimality. The talk will present new heuristic and matheuristic based integrated rolling stock planning models in which the many requirements are handled all at the same time. Real-world results from DSB S-tog, the suburban railway operator of the City of Copenhagen are presented.

4 - A Divide and Conquer Approach to Interactively Solve High-Dimensional Problems
Daan van den Heuvel, Bob Huisman, Cees Witteveen

Sometimes a complex combinatorial problem has easily identifiable subproblems for which methods are available. Often, strong interactions between these subproblems prevent us to use these methods in a straightforward way. In railway industry, finding a schedule for train service and shunting tasks is an example of such a problem with clearly identifiable, interacting subproblems: Trains with given length have to be parked on a track (BinPacking), a route to that track has to exist (Motion Planning), leaving trains need to be composed of multiple train units of arrived trains (SetCover) and service tasks have to be performed to trains (RCPSP). In practice, we often see that humans tend to split such a problem and solve it sequentially, e.g. they first solve the parking problem and then the routing problem. Often, solving such problems in a sequence enforces complex feedback loops.

We present a method to divide such problems into conflict spaces, such that we can solve them interactively. We first create an initial assignment of variables, this may contain conflicts: trains stored on track t exceed its length. We select a non-empty conflict space that must suggest a set of solutions (small variable changes). A solution may cause or solve conflicts within other conflict spaces. The other conflict spaces vote for the solution with the most positive effect on the global schedule. Small variable changes are done until either no conflicts exist or no more changes can be done.

■ MC-22

Monday, 12:30-14:00 - Building CW, ground floor, Room 027

Multiobjective Vehicle Routing Problems

Stream: Combinatorial Optimization

Chair: *Herminia I. Calvete*
Chair: *Ibrahim H. Osman*

1 - Bi-objective Periodic Vehicle Routing Problem with Service Choice
Alfredo G. Hernandez-Diaz, Julian Molina, Ana Dolores López Sánchez

The Periodic Vehicle Routing Problem (PVRP), first proposed by Beltrami and Bodin in 1974, is a generalization of the classic vehicle routing problem (VRP) in which vehicle routes are constructed for a t-day period. Each day within the period, a fleet of capacitated vehicles performs routes that begin and end at a single depot. Customers are visited a preset number of times over the period, with a schedule that is chosen from a menu of schedule options. Each schedule option represents a set of days on which a node is visited. The objective of the PVRP is to find a set of tours for each vehicle over the period that minimizes total travel cost while satisfying required constraints. Later, Francis and Smilowitz proposed in 2006 a variation of the PVRP, called PVRP with Service Choice (PVRP-SC), in which each customer can be visited more times than the minimum number of required visits. Thus, visit frequencies are also considered as variables and must be determined during the search process.

In this talk we propose a bi-objective version of the above single-objective PVRP-SC: minimizing the total travel cost and maximizing the visit frequency. The first objective is interesting for the company' owner while the second one can be viewed as a measure of the level of customer satisfaction. This new bi-objective version fits many real problems such that the waste collection problem, distribution of products to stores (as grocery), etc.

2 - A biobjective school bus routing problem
Herminia I. Calvete, Carmen Galé, Jose A. Iranzo, Paolo Toth

The school bus routing problem addressed in this work focuses on simultaneously considering the problem of selecting the bus stops amongst a set of potential stops, assigning the students to the selected stops and designing the bus routes. It is assumed that there is a single school and the routes are served by identical buses. The objectives to be minimized are the total distance travelled by all vehicles and the total distance walked by students. An evolutionary algorithm is developed to approximate the set of nondominated solutions or Pareto front. Chromosomes provide the selected bus stops. From them, the algorithm combines standard characteristics of evolutionary algorithms with the use of a heuristic to construct feasible solutions to the problem. Moreover, a local search procedure is embedded to improve feasible solutions. A computational experiment is carried out to show the performance of the algorithm.

3 - A hybridisation of adaptive VNS and large neighbourhood search: Application to the vehicle routing problems
Said Salhi, Jeeu Fong Sze, Niaz Wassan

In this study, an adaptive variable neighbourhood search (AVNS) heuristic that incorporates large neighbourhood search (LNS) as a diversification strategy is proposed to solve the vehicle routing problem and its variants. The initial solution is first generated using a series of constructive heuristics followed by a two-stage AVNS. The first stage is the learning phase using the best improvement VNS, whereas the second is a multi-level VNS with a guided local search. In addition, a diversification procedure, which is based on large neighbourhood search (LNS) is incorporated in the AVNS. To increase the efficiency of the overall algorithm, a special data structure together with neighbourhood reductions are proposed and embedded into the search. The hybridisation of VNS with memory and LNS is then used to construct this adaptive metaheuristic which produces very promising results when tested on the data sets from the literature.

■ MC-23

Monday, 12:30-14:00 - Building CW, ground floor, Room 028

Selected Topics

Stream: Graphs and Networks
Chair: *Stephan Westphal*

1 - Multistage Scheduling with Selfish Machines
Michael Hopf, Clemens Thielen

We study a flow show scheduling problem with selfish machines. In this setting, each job consists of several tasks that have to be completed in different stages and the social objective is to maximize the total profit of the accepted jobs. The set of tasks of a job contains one task for each stage and each stage has a dedicated machine corresponding to it that can only process tasks of this stage.

Each machine is a selfish player in a non-cooperative game that tries to maximize her own profit by selecting an appropriate subset of the tasks corresponding to her stage. However, the profit a player obtains from scheduling a task depends on the subset of the other players that also schedule tasks corresponding to the same job. For example, this can be used to model coordination processes between several independent companies in a supply chain.

We show bounds on the price of anarchy and the price of stability for different functions describing the profit a player obtains from scheduling a task subject to the other players' behavior.

2 - A Generalized Fractional Packing Framework and its Application to Network Flow Problems
Michael Holzhauser, Sven Krumke

We present a generalization of the fractional packing framework introduced by Garg and Koenemann (2007) that incorporates Megiddo's (1979) parametric search technique: Given a polyhedral cone that is finitely generated by a (possibly exponential-size) set of non-negative vectors and given an oracle that returns a vector in this set with minimum cost with respect to a given cost vector, we obtain a fully polynomial-time approximation scheme for the problem of minimizing a linear cost function over the cone subject to a set of packing constraints. Among others, this general framework yields several applications for budget-constrained versions of well-known flow problems such as the minimum cost flow problem, minimum cost generalized flow problem, and the minimum cost flow problem in processing networks. For all of these problems, we are able to derive strongly polynomial-time combinatorial FPTASs using this generalized fractional packing framework.

3 - Approximation Algorithms for TSP with Pickup and Delivery
Stephan Westphal, Marco Bender, Joachim Schmidt

In the classical traveling salesman problem (TSP), one is given a set of cities and distances between every pair of cities. The task is to determine a tour (that visits every city exactly once and returns to the origin) such that the total distance is minimized. We consider a generalization of TSP, which can be motivated by a vehicle that is responsible for the transportation of a homogeneous good (e.g., waste) between the two different kinds of cities: Some of the cities (sources) have a surplus of this good that needs to be picked up there and delivered to some of the other cities (sinks). The task is again to determine a shortest tour, with the additional constraint that all units of the good have to be picked up from the sources and delivered to the sinks. Every sink can only store a certain amount of units, and there is also an upper bound on the maximum number of units that can be transported by the vehicle at every point in time. In this talk, we present polynomial-time approximation algorithms for different versions of this problem, and a column-generation framework for solving large instances.

4 - The art of BBQ and applications to online colouring
Marc Demange, Martin Olsen

We consider different online colouring problems in overlap graphs (also called circle graphs) - defined by a set of intervals - that are motivated by some one-dimensional stacking logistics problems or track assignment problems in train shunting operations. To this end we consider two strategies for partitioning the set of intervals. The first strategy revisits a well-know approach consisting in partitioning the intervals with respect to their length so that the lengths of intervals in each part differ at most by a constant factor. We then solve independently each sub-instance. The second strategy partitions the intervals into so-called BBQ arrangements. In terms of graphs it corresponds to partitioning the overlap graph into permutation graphs and allows to transform any online algorithm for permutation graphs into an online algorithm for overlap graphs. We analyse the competitivity behaviour of these strategies, seen as reductions between two online problems. For the usual colouring problem, if intervals are revealed in non-decreasing order of their left endpoint, both strategies give optimal online colouring algorithms. The second strategy remains valid for different kinds of colouring problems and leads, for instance, to an online algorithm for bounded online colouring in overlap graphs.

■ MC-24

Monday, 12:30-14:00 - Building BM, 1st floor, Room 119

Defence and Security 3

Stream: Defence and Security
Chair: *Ana Isabel Barros*

1 - Route Propagation Under Forecast Risk for Maritime Security Applications
Francois-Alex Bourque

The need for planning vessel routes based on spatially- and time-varying information exists in different contexts. For example, a merchant vessel on route to a port may want to avoid areas with inclement weather conditions such as high sea states, while a warship may want to patrol areas known for illicit activities such as smuggling or piracy. At first, these problems seem only loosely related. One common thread, however, is the presence of risk, which may vary in space and in time. This contribution proposes a simple approach to propagating vessel route under forecastable risk. Namely, it advocates building a weighted directed graph of the possible routes over the planning horizon, where each vertex is a waypoint and each arc represents a route segment weighted by the corresponding risk value. Through this lens, propagating vessel routes conditioned upon risk corresponds to a minimum-cost flow problem, where the risk encountered by a vessel is either maximized or minimized depending on the objective (e.g., deterring illicit activities). The approach is illustrated in the context of counter-piracy operations off the Horn of Africa where warships aim to deter and interdict pirates. Such a scenario is germane to current operations conducted under the aegis of the NATO's Operation Ocean Shield. Piracy being the risk factor in this case, a risk forecast is generated based on the observation that prior attacks occur preferably under favourable environmental conditions.

2 - Stackelberg games: A comparison of MIP formulations and a border patrol application
Carlos Casorrán-Amilburu, Bernard Fortz, Martine Labbé, Fernando Ordonez, Victor Bucarey, Hugo Navarrete, Karla Rosas

Stackelberg Games confront contenders with opposed objectives, each wanting to optimize their rewards. Decision-making parties involve a party with the capacity of committing to a given action or strategy, referred to as the leader, and a party responding to the leader's action, called the follower. The objective of the game is for the leader to commit to a reward-maximizing strategy anticipating that the follower will best respond. Finding the optimal mixed strategy of the leader in a Stackelberg Game is NP-hard when the leader faces one out of several followers and polynomial when there exists a single follower. Additionally, games in which the strategies of the leader consist in covering a subset of at most K targets and the strategies of the followers consist in attacking some target are called Stackelberg security games and involve an exponential number of pure strategies for the leader. A Stackelberg game can be modeled as a bilevel bilinear optimization problem which can be reformulated as a single level MILNP. We present different reformulations of this MINLP and compare their LP relaxations from both theoretical and computational points of view. We will conclude with some snippets from a border control application we are developing for Carabineros de Chile. The goal is to provide Carabineros with a monthly patrol schedule along the northern border of that country exploiting our expertise on Stackelberg games such that available resources are optimally deployed.

3 - A Model for Joint Patrolling in Stackelberg Security Games

Victor Bucarey, Fernando Ordonez, Carlos Casorrán-Amilburu

Stackelberg Security Games (SSGs) are a class of games where one defender (leader) wants to protect certain areas or targets committing to a mixed strategy, and then one (or many) attacker (follower) observes this strategy over time and chooses where to attack. In this work we focus on a SSG defined on a graph generated by adjacent clusters of targets (called areas). Due to limited resources and different capabilities the patrolling strategy requires that areas must be paired and a joint patrol is deployed to protect a target within one of these areas. A defender strategy thus consists in a selection of a matching of size m between the areas and a set of targets within these areas where a resource must be deployed. This creates a game with a defender strategy space which is exponential in the number of possible targets. The attacker strategies are the set of possible locations to attack. We propose a new formulation where the decision variables are coverage frequencies on the edges of this graph and coverage frequencies on the location set dramatically reducing the size of the defender strategy space, which allows the solution of this problem for real instances. To build implementable strategies from this solution we propose and compare two sampling methods.

4 - Learning from the Past: Analysing History to Support UK Defence Policy

Rachael Walker, Tom Clarke

For over 30 years the UK Ministry of Defence (MOD), supported by its Defence Science and Technology Laboratory (Dstl) and predecessor organisations, has used systematic analysis of military operations, and developments in academic understanding of conflict to provide vital historical context for contemporary MOD policy decisions. This historical analysis (HA) approach evolved out of a need to capture and quantify some of the intangible factors of conventional warfare - such as the effects of shock and surprise on unit combat capability - but has over time developed into a more widely applicable tool for providing reality checks to the UK Defence policy, planning and operational support communities. HA has a reputation for robust analysis, providing a credible and independent aid to decision-making at all levels within MOD. This paper will outline how the discipline has changed to meet the needs of the current and future defence environments; HA now incorporates a spectrum of techniques from in-depth single case studies, through to large-N statistical analysis. The paper will include examples of the sort of empirical research questions asked by MOD in recent years, at the policy, doctrinal and operational level, to which HA has contributed. This will demonstrate the direct impact that the discipline has had on UK Defence policy and planning, and will continue to have in the challenging times ahead.

■ MC-25

Monday, 12:30-14:00 - Building BM, ground floor, Room 19

Uncertainty, forecasting and policy

Stream: Behavioural Operational Research
Chair: *Devon Barrow*

1 - Improving Construction of Conditional Probability Tables for Ranked Nodes in Bayesian Networks

Pekka Laitila, Kai Virtanen

Bayesian networks (BNs) and their decision theoretical extension, influence diagrams (IDs), are used in many areas to represent uncertain knowledge and to support decision making under uncertainty. In both BNs and IDs, the probabilistic relationships between the nodes are usually encoded in conditional probability tables (CPTs). In the absence of data, CPTs have to be constructed based on expert elicitation involving subjective assessments of a domain expert. The main difficulty here is that assessing all the required probabilities coherently and without biases can be an insuperable problem for the expert due to cognitive strain or scarcity of time. To alleviate this problem, various parametric methods have been developed. Our work elaborates the ranked nodes method (RNM) that is used for constructing CPTs for BNs consisting of a class of nodes called ranked nodes. Such nodes typically represent continuous quantities that lack well-established interval scales and are hence expressed by ordinal scales. In addition, RNM is also commonly applied to nodes that are expressed by interval scales. However, the use of RNM in this way may be ineffective due to challenges which are not addressed in the existing literature but are brought up by us. To overcome the challenges, we introduce a novel approach that facilitates the use of RNM. It provides guidelines for the discretization of the interval scales into ordinal ones and for the elicitation of required parameters from the expert.

2 - Consumer behaviour and residential demand side flexibility - a calibration approach for electricity load profile modelling

Valentin Bertsch, Valeria Di Cosmo, Wolf Fichtner, Marian Hayn

Energy systems based on renewable energy sources require increasing demand side flexibility. While various studies focus on tariffs with variable energy prices to leverage residential demand side flexibility, we incorporate tariffs with a variable capacity price component allowing for the consideration of individual consumer needs. To compare the different tariffs' impact on demand side flexibility, we develop a bottom-up model combining simulation and optimisation approaches. The model output comprises residential load profiles for different tariffs. To account for the consumers' behaviour the model is calibrated on data and observations from a large-scale field trial in which the participants were confronted with variable hourly energy prices on the basis of 3 price steps (very low, moderate, high). These prices were announced on a day-ahead basis. The majority of households reacted on the price signals through manual load shifting. Our calibration approach is based on the definition of probabilities for every combination of season, day of the week and time of the day (which were identified as relevant influencing factors in the trial) ranging from 0 (no manual load shifting) to 1 (full manual load shifting). We show that the calibration approach leads to very good results. While tariffs with variable energy prices induce larger flexibility, the impact of tariffs with variable capacity prices is more predictable and reliable from a supplier's perspective.

3 - Investigating cognitive strategies used in time series decomposition via a think-aloud protocol analysis: Implications for time series forecasting

Devon Barrow, Nikolaos Kourentzes

Time series forecasting is used by many businesses to generate key inputs in the decision making process. As a first step in this forecasting process, decomposition of time series data is used for extracting underlying patterns, gaining an understanding of the time series problem, and to select an appropriate forecasting method. Fundamental to individuals learning how to forecast and which forecast models to apply is therefore an understanding of time series decomposition. However little is currently known about how individuals learn such key forecasting tasks, the cognitive strategies adopted, and the impact on forecasting performance. As a first step, this study applies the think-aloud protocol method for collecting rich verbal data about how 3rd Year Undergraduate and Masters level students on a business forecasting module learn and perform classical time series decomposition. Using a combination of text mining and protocol analysis we identify the types of information required by individuals during the task of time series decomposition, and the how this information is used to solve the decomposition problem including the cognitive strategies used. We go one step further to consider the implications for how individuals learn to forecast, and for the systems designed to support and improve forecasting performance.

4 - Experiments on Commitment and Priming in Supply Chain Decisions
Murat Kaya, Ummuhan Akbay

We conduct decision experiments to study the effects of commitment and priming in a manufacturer-retailer supply chain. In each period, the manufacturer offers a wholesale price contract, and the retailer, who faces the newsvendor problem, reacts by choosing her order quantity to satisfy random demand. The retailer has the chance to reject the contract leading to zero profits for both firms. The firms are represented by human subjects who interact repeatedly throughout the experiment, capturing a long-run relationship. Our first study focuses on the power of commitment to a decision (wholesale price decision and quantity decision) for five periods. We find the committing firm to obtain strategic advantage over the other and to increase her profit share.

Our second study explores what happens if the two firms interact under an exogenously-given "fair" contract (that leads to equal profit shares for the firms) in the first five periods. We conjectured the relatively fair profit shares during these initial periods to act as an anchor that will affect the subjects' subsequent decisions. Contrary to our expectations, the priming effect on the retailers turned out to be weak, while the manufactures acted more aggressively and captured an even higher share of total profits. To shed light on the findings of both studies, we present regression models that explain the retailer's contract rejection, underorder and overorder tendencies.

■ MC-26

Monday, 12:30-14:00 - Building BM, 1st floor, Room 109D

Dynamical Models in Sustainable Development 3

Stream: Dynamical Models in Sustainable Development
Chair: *Andreas Welling*

1 - A system dynamics model to assess the impact of stakeholder pressures and dynamic capabilities on sustainable supply chain management performance
Tobias Rebs, Daniel Thiel, Marcus Brandenburg, Stefan Seuring

Dynamic capabilities are crucial for companies to attain competitive advantage in dynamic business environments. Supply chains (SCs) represent such dynamic environments where multiple SC members and stakeholders are managed by applying distinct practices. The consideration of environmental and social criteria for the management of SCs, i.e., sustainable supply chain management (SSCM), is one source of competitive advantage. The conceptual linkage between dynamic capabilities and sustainable SC practices has been outlined and assessed in the context of the food industry. Related studies define SSCM practices derived from dynamic capabilities and point to SC partner and stakeholder management as pervasive conceptual elements. This paper proposes a system dynamics model to examine the impact of stakeholder pressures on sustainable SC performance. The proposed system dynamics model avails of two models that investigate the complex interplay between SSCM practices and sustainable SC performance and the impact of delayed stakeholder pressures. The combination and extension of the two models allows insight into the development of SSCM practices in face of time delays between stakeholder pressures and their impact on SSCM performance. Feedback loops that stabilize SSCM performance are identified. This approach develops further the work presented at the EURO Conference in Glasgow. As next steps, the model can be tested empirically and compared to different industry contexts.

2 - Trade liberalization and the environment: does "green equilibrium" exist?
Kim Hang Pham Do

The environment and trade debate continues despite vast research. One of main issues in the debate over trade, pollution and the environment is how best to capture the interactions of environment and trade measurement for sustainable development. Studies have so far revealed some linkages between trade and environment through conventional trade theory and economic growth. Existing studies have shown that the structure of environmental regulations should be modified to reflect the existence of trade liberalization and the achievement of UN's sustainable development goals. Therefore, further research on the interaction between trade theory and environmental regulation is needed. This paper studies the potential relationship between environmental quality and trade liberalization. It is assumed that trading countries behave as oligopolists but their costs depend on the level of the global environment. The environmental quality then can be modelled in such a way as: (i) a given stock which is damaged by a flow of pollution and (ii) a renewable resource which is used. Based on the economic growth and oligopoly theory, the paper shows that when all exogenous variables can be controlled for, there exists a relationship between the free trade and the environmental quality (a so-called "green equilibrium") and discusses the existence of no-extinct and multi-equilibrium.

3 - A System Dynamics Model for a Reverse Supply Chain with Competitive Collection
Tiru Arthanari, Liu Yang

The majority of used mobile phones in China were mostly handled by informal sectors through non-environmentally-friendly methods due to the lack of well-established waste electric and electronic equipments (WEEE) regulations. Since the potential demand for secondary mobile phones is substantial in China, formal collectors take the advantage of online platforms to compete with informal sectors to collect used mobile phones through acquisition and recycling strategies. We develop a framework for the reverse supply chain of the mobile phone industry in China considering the competitive collection between online-based formal collectors and peddlers. We adopt a system dynamics (SD) modeling approach. With the purpose of analyzing the behavior of the system, we build a simulation model based on a case study. Another objective is to analyze the effects of the trade-in program and the government subsidy on the system behavior, so that we analyze the system in different scenarios by involving these two policies. Through the scenario analysis, we reach a conclusion that the trade-in program and the government subsidy designed by us have different effects on the system behavior when collectors compete by taking different acquisition and recycling strategies. The former has a significantly positive impact on the economic performance of the formal recycling industry, while the latter has a critical influence on alleviating the problem of uncontrollable disposal.

4 - How to determine the optimal amount and reduction of governmental support
Andreas Welling

Many sustainable investments like investments in the production of renewable electricity would not pay off in absence of governmental support. By the means of technological progress, however, the necessary investment costs decrease and thus the profitability increases. This allows for a decrease of governmental support over time. Consequently, for policy makers it is an important task to determine the optimal combination of the original amount of governmental support and its speed of reduction. We determine this optimal combination given the multi-criteria objective function of the government and taking into account the reaction functions of the different potential investors. The results are illustrated by the example of the German support system for photovoltaic.

■ MC-27

Monday, 12:30-14:00 - Building BM, ground floor, Room 20

Dynamical Systems and Mathematical Modelling in OR

Stream: Dynamical Systems and Mathematical Modelling in OR
Chair: *Gerhard-Wilhelm Weber*
Chair: *Olabode Adewoye*
Chair: *Andreas Novak*

1 - On Generalization of Tanh Method and Its Application to Non-linear Partial Differential Equations
Ali Hamidoglu

The tanh method is used to compute travelling waves solutions of one-dimensional non-linear wave and evolution equations. The technique is based on seeking travelling wave solutions in the form of a finite series in tanh. However, tanh method is not always efficient method to solve some types of one dimensional non-linear partial differential equations in more general sense. In this paper, we construct new general model which is the general form of tanh transformation and see that our design is effective and more general than tanh method in the sense of getting the exact solutions of non-linear partial differential equations; one of which is Fitzhugh-Nagumo equation which arises in population genetics and models the transmission of nerve impulses, and some other crucial non-linear partial differential equations applied in different fields of science.

2 - Decision Making in an Infinite Horizon for Large-Scale System
Olabode Adewoye

Solving optimality problem in an infinite horizon Markov decision process, we have linear programming, policy iteration and successive approximation. Dynamism, complexity and uncertainty have posed greater challenges to man's understanding and control of his physical environment. The Markov models of systems have been used to formulate, analyze complex systems. The object of the work is to present the Markov decision model and semi- Markov decision model, its solutions to challenging areas of human development. Comparison between policy iteration, linear programming and successive approximation were made. The policy iteration method is preferred. The work established that Markov models can be use in any problem areas provided there are states, transition probability, reward structures, and optimization problem.

3 - Solution of an order batching problem by a new mathematical programming approach in pharmaceutical warehouse
Furkan Yener, Harun Yazgan

A warehouse management system is one of the most important activities for many companies. Therefore, it plays an important role in a supply chain management. Order batching problem is one of substantial problems of the warehouse management system. It deals with gathering orders according certain criteria. The objective is to achieve high-volume order processing operations by consolidating small orders into batches. This paper deals with reducing picking time and improving picking route with solution of the order bathing problem. A new mathematical model is developed based on a data mining of the order batching with the maximizing relations of orders in batches for picker-to-parts systems. An order-clustering model based on a 0-1 linear programming is formulated to maximize the associations between orders within each batch. The proposed approach is tested by a simulation in a pharmaceutical warehouse. The results indicate that the proposed approach reduces the time for warehouse operations.

4 - Optimal Intelligence in an Asymmetric Lanchester Model
Andreas Novak

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

■ MC-30

Monday, 12:30-14:00 - Building BM, 1st floor, Room 110

System Dynamics Business Modelling. Workshop for Managers, Consultants and Students 1

Stream: System Dynamics Modeling and Simulation
Chair: *Kim Warren*

1 - System Dynamics Business Modelling. Workshop for Managers, Consultants and Students 1
Kim Warren

System dynamics offers powerful tools for understanding how businesses work and perform over time. This workshop focuses on the practices of system dynamics business modeling, providing a methodology that can be applied to companies and public organizations of any kind. In this hands-on workshop, participants experience the essential principles of system-dynamics-based modeling, and are enabled to apply them, through work on a real business case. They can work on the case individually or in small groups using their own laptops. The participants will go away with the working models of that real case and plenty of other free models and methods.

■ MC-31

Monday, 12:30-14:00 - Building BM, 1st floor, Room 111

Sport Scheduling and Strategy

Stream: OR in Sports
Chair: *Mario Guajardo*

1 - Search Space Connectivity in Sport Scheduling Problems
Sebastián Urrutia, Tiago Januario, Dominique de Werra

The canonical method (also known as the circle method) is widely used to build single round robin schedules for sports competitions. It is also commonly used as initial solutions generator for local search improvement procedures applied to combinatorial optimization problems in the research field. The neighborhood structures used in these algorithms may not connect all of the search space of problems dealing with single round robing tournaments. This fact implies that local search algorithms using those neighborhood structures may not be able to reach most of the feasible schedules.

It is known that the most commonly used neighborhood structures in the sport scheduling literature are in fact disconnected when working with single round robin schedules. In particular, certain properties of the canonical method may entrap local search procedures in tiny portions of the search space containing only schedules that are isomorphic to the one initially produced. In this work, we study the connectivity of the most used neighborhood structures in local search heuristics for single round robin scheduling and characterize the conditions in which this entrapment occurs.

2 - First Computational Experiments with a Salesman Formulation of a Sport League Scheduling Problem
Jörn Schönberger

Competition programs of sport leagues are typically conducted in the round robin mode. Here, each pair of two league members meets once (or several times) in order to determine a ranking. The task of scheduling a sport league comprises the determination of a time (slot) for each meeting of a pair of league members. Integer linear program formulations are the standard way to represent sport league scheduling problems formally. In this contribution, we propose a multiple salesman formulation of a sport league problem. Compared to other program formulations it comes along with different index sets and a varied number of decision variables to take care of. We report first computational experiments in which the proposed formulation is evaluated.

3 - On Symmetry, Breaks Within Double Rounds and the South American World Cup Qualifiers to Russia 2018
Mario Guajardo, Guillermo Durán, Denis Saure

In July 2015, Ronaldo and Forlán drew balls from two pots to define the schedule of the South American World Cup Qualifiers to the 2018 football World Cup Russia. One pot contained the names of the ten national teams that participate in this qualification tournament. The other pot contained ten numbers referring to the position that each team would take in a predefined schedule template. We generated this schedule template by using integer programming. We included criteria such as symmetry and breaks within double rounds. This talk reports on several symmetric formats we considered as alternative to meet these criteria. We also compare our finally adopted solution against a previous schedule that was used in the four previous World Cup qualifiers.

4 - Serving Strategy in Tennis
Yigal Gerchak, Marc Kilgour

A crucial feature of a tennis server's advantage is the opportunity to serve again after one fault. Common practice is to hit a powerful first serve, followed, if necessary, by a weaker second serve that has a lower probability of faulting even if it is easier to return. Recently, some commentators have argued that the second serve should be as difficult to return as the first. This advice contradicts Gale's Theorem, which we reformulate and provide a new (analytic) proof. Then we extend it with a model of a rally that follows a successful return of serve. The general conclusion is that the current practice is in fact optimal.

■ MC-33

Monday, 12:30-14:00 - Building BM, 1st floor, Room 113

Emerging Applications of Data Mining and Computational Statistics 3

Stream: Computational Statistics
Chair: *Pakize Taylan*
Chair: *Gerhard-Wilhelm Weber*
Chair: *Panos Pardalos*

1 - Biomedical Informatics and Network Approaches in Neuroscience Research
Panos Pardalos

Biomedical Informatics is the interdisciplinary science of acquiring, structuring, analyzing and providing access to biomedical data, information and knowledge. Some of the basic tools of Biomedical Informatics include optimization, control, network modeling, data mining, and knowledge discovery techniques.

Many large (and massive) data-sets in neuroscience can be represented as a network. In these networks, certain attributes are associated with vertices and edges. The analysis of these networks often provides useful information about the internal structure of the datasets they represent. We are going to discuss our work on several networks for the epileptic brain, the Parkinson brain and general research on brain dynamics.

2 - A Goal Programming Based Movie Recommendation in Linked Open Data Cloud
Emrah İnan, Cemalettin Ozturk, Fatih Tekbacak

A Recommender system suggests relevant items to users by acquiring user preferences and exploiting them to build a type of user model. The main purpose of such a system is to match the most suitable item for this user model. And hence, finding similar items for user preferences is the most crucial point of any recommender system. General purpose knowledge bases such as DBpedia, Linkedmdb facilitate relevant recommender systems to find similar items within the interconnected cloud. However, the state-of-art recommender systems could not meet the wide coverage requirements and suffer from handling the data sparsity problem. For this reason, we develop a recommendation system gathers data from DBpedia and Linkedmdb knowledge bases and compute similarity scores between movie pairs including their features (cast, genre) with goal programming. Our web-based system combines the content-based and collaborative filtering approaches. The similarity calculation of the contents is supplemented by a goal programming model in the content-based approach. Pearson correlation is selected as a collaborative filtering algorithm and predicts movies to satisfy user tastes considering the content-based similarity scores. Mean Absolute and Square Error and Movielens dataset are used for experimental setup. Our system outperforms the rest of the studies in the literature and when content information is inserted to the calculation of item similarities, it increases the overall system performance.

3 - Load Forecasting Using Multivariate Adaptive Regression Splines for Turkish Electricity System
Gamze Nalçacı, Ayse Özmen, Gerhard-Wilhelm Weber, Omer Melih Gul

In recent years, load forecasting has become one of the major research areas in electrical engineering, and most traditional (univariate and causal) forecasting models and artificial intelligence techniques (e.g., artificial neural networks) have been tried out in this research area. With these techniques, a great number of papers have reported successful experiments and practical tests with them. Nevertheless, the architectures of these methods seemed to be too large for the data samples they intended to model, i.e., there seemed to be too many parameters to be estimated from comparatively too few data points. These solutions apparently over fitted their data and one should, in principle, expect them to yield poor out of sample forecasts. Our aim is to propose a simpler solution for the load forecasting problem in which the forecasting is performed with respect to wind, humidity, temperature, and load data taken from TEIAS (Turkish Electricity Transmission Company). Therefore, we propose a Multivariate Adaptive Regression Splines (MARS) model which has not proposed for the annual load forecasting problem before in Turkish Electricity System. MARS is simpler as compared to other models like random forest or neural networks. Experimental results show that MARS outperforms artificial neural network in terms of prediction error and prediction accuracy.

4 - The Case For Inliers
Jeffry Savitz

The Central Limit Theorem is at the foundation of inferential statistical analysis. Advanced over almost three hundred years ago, it dictates the margins of error associated with estimates of many population parameters from random samples. This paper is about Inliers, subsamples of a random sample that are more reliable than the random sample itself and their use in making equally reliable and accurate estimates of population parameters with far fewer data points than required by a random sample. Empirically it was found that over 60% of a random sample consists of Inliers. Their variance is 2/3 that of a random sample. Hence, only 2/3 as many of them would be needed to replace a random sample and at 2/3 the cost. Moreover, using a nationally representative random sample of 700+ people, they estimated population parameters, the average rating of each of 25 different popular brands, within an average absolute deviation of only 2.3% of the average ratings from the random sample, with almost no bias within 25 key demographic and 16 psychographic segments. Thus, Inliers can be used to make equally accurate and reliable estimates of population parameters for most any subpopulation. Based on statistics provided by the Council of American Survey Research Organizations on the annual cost of sample acquisition in survey research, it is estimated that the use of Inliers in place of random samples could save the research industry more than $300M dollars annually in the U.S. alone.

■ MC-34

Monday, 12:30-14:00 - Building BM, 1st floor, Room 116

Scheduling

Stream: Supply Chain Scheduling and Logistics
Chair: *Malgorzata Sterna*

1 - Approximation Solution in Malleable Tasks Scheduling Problem

Maciej Machowiak

Problem of scheduling Malleable Tasks (MT) with arbitrary processing speed functions has been considered. Malleable means that a task performance depends on the number of processors allocated to it and this relation is described by processing speed function. Additionally, allocation of processors may change during the task execution. Motivation for MT model comes from large scale parallel computation in the multiprocessors systems. In our case arbitrary numbers of tasks and identical parallel processors have been considered as well as arbitrary strictly increasing processing speed function the same for each task. Certain amount of work is associated to each task. In a final schedule there is a finite number of time intervals where the same number of processors is assigned to the same task for all tasks in the same interval. A schedule can be completely characterized by the number of these time intervals and the number of processors assigned to each task in each interval. The problem is to find a schedule with the minimum makespan. To solve this discrete problem we start from a solution of continuous problem in which the numbers of assigned processors could not be integer. First we approximate processing speed function to convex and concave one, next we have two makespan values which are lower and upper bounds of optimal solution for our discrete problem. Finally we use approximation algorithm to find feasible processors allocations.

2 - Scheduling Semiresumable Tasks on a Single Machine with Multiple Non-availability Intervals

Jakub Olszak, Jakub Pietruczuk, Piotr Formanowicz

Scheduling problems with limited availability of machines attracted many researchers in recent years. In such problems three main types of tasks are considered, i.e., resumable, non-resumable and semiresumable ones. In the resumable case processing of a task can be interrupted by a non-availability interval and continued after the end of this interval without any additional cost. In the non-resumable case a task started but not finished before a non-availability interval must be repeated when the machine becomes available again. When tasks are semiresumable they can be preempted by a non-availability period and continued after it but some additional cost of its processing must be taken into account. There are considered two types of semiresumable tasks. In the case of the first of them a machine needs to process an extra work proportional to the part of a task finished before the non-availability interval. In the second case an additional setup time is required to resume a processing of a task. In our work we describe and motivate some new types of semiresumable tasks and consider single machine problems with an arbitrary number of non-availability intervals, where the makespan and the total completion time are the optimality criteria. Since the problems we consider are NP-hard in the strong sense, we provide heuristics whose efficiency is evaluated in extensive computational experiments.

3 - Extended Signatures and their Applications to Time-Dependent Scheduling

Stanislaw Gawiejnowicz, Wieslaw Kurc

We consider a single machine scheduling problem with linearly deteriorating jobs and the total completion time criterion. Applying a matrix form of the problem, we show how it can be solved by using so-called signatures that are functions of job deterioration rates. We introduce new types of such signatures and show their influence on the quality of schedules constructed by two greedy algorithms. Finally, we present relations between the greedy algorithms and fully polynomial-time approximation schemata for the studied problem.

4 - Online and Offline Late Work Scheduling on Parallel Machines

Kateryna Czerniachowska, Jacek Blazewicz, Xin Chen, Xin Han, Malgorzata Sterna

We investigated the scheduling problems on parallel identical machines with a common due date and the total late work criterion. In the offline mode all jobs are known in advance, while in the online mode jobs appear in the system one by one. We proved the binary NP-hardness of the offline problem and proposed the pseudopolynomial time dynamic programming algorithm. Then, we gave the online algorithm, proving its competitive ratio representing the upper bound of the distance between the optimal offline solution and any online solution. The theoretical results are illustrated with results of computational experiments performed for exponential exact offline methods, including dynamic programming, and for heuristic list algorithms working in offline and online modes.

■ MC-35

Monday, 12:30-14:00 - Building BM, ground floor, Room 17

Towards Understanding RNA

Stream: Computational Biology, Bioinformatics and Medicine
Chair: *Marta Szachniuk*
Chair: *Tomasz Żok*

1 - Analysis of RNA Interference Mechanisms after Ionizing Radiation. Experiment and Model

Marzena Dolbniak, Roman Jaksik, Joanna Rzeszowska-Wolny, Krzysztof Fujarewicz

Understanding mechanisms of gene regulation after radiation is still challenging. In this work we focus on process of RNA interference, more precisely, interactions between RNA-induced silencing complexes (RISCs), which include miRNA, and messenger RNAs (mRNAs). Under normal conditions such a mechanism leads to negative regulation of translation or degradation of mRNA. It may be modified by reactive oxygen species (ROS), which are known to oxidize nucleotides after radiation and change their recognition of complementary partners. We have constructed a linear regression model, which predicts changes of mRNA levels in cells exposed to ionizing radiation (fold change). Our analyses are based on data sets for mRNA and miRNA levels in Me45 cell line, measured with Affymetrix (Human Genome U133A) and Agilent microarrays. Our results show significant positive correlation between the predicted and real fold changes of mRNA levels (RHO>0.54). To assess the reproducibility of our results we used Monte Carlo cross validation method (repeated 10000 times). We analyzed the properties of mRNAs and miRNAs fitting and not fitting to the model. Results suggest that some classes of genes may be regulated at the levels of transcripts and may be more sensitive to the effects of ROS than others. Acknowledgements: The authors were supported by the National Science Center (Poland) grant nr DEC-2012/05/B/ST6/03472 (KF), SUT grant BKM-514/RAu1/2015 (MD, RJ)

2 - Tabu Search Algorithm for RNA Partial Degradation Problem (RNA PDP)
Agnieszka Rybarczyk, Alain Hertz, Marta Kasprzak, Jacek Blazewicz

In the last few years there has been observed a great interest in the RNA research due to the discovery of the role that RNA molecules play in the biological systems. They do not only serve as a template in protein synthesis or as adaptors in translation process but also influence and are involved in the regulation of gene expression. It was demonstrated that most of them are produced from the larger molecules due to enzyme processing or spontaneous degradation. In this work, we would like to present our recent results concerning the RNA degradation process. In our studies we used artificial RNA molecules designed according to the rules of degradation developed by Kierzek and co-workers. On the basis of the results of their degradation we have proposed the formulation of the RNA Partial Degradation Problem (RNA PDP) and we have shown that the problem is strongly NP-complete. We would like to propose a new efficient heuristic algorithm based on tabu search approach that allows to reconstruct the cleavage sites of the given RNA molecule.

3 - Computational Riboswitch Detection Using Inverse RNA Folding
Danny Barash

The inverse RNA folding problem for designing sequences that fold into a given RNA secondary structure was introduced in the early 1990's in Vienna. Using a coarse-grain tree graph representation of the RNA secondary structure, we extended the inverse RNA folding problem to include constraints such as thermodynamic stability and mutational robustness, developing a program called RNAexinv. In the next step, we formulated a fragment-based design approach of RNA sequences that can be useful to practitioners in a variety of biological applications. In this shape-based design approach, specific RNA structural motifs with known biological functions are strictly enforced while others can possess more flexibility in their structure in favor of preserving physical attributes and additional constraints. Our program is called RNAfbinv. Detection of riboswitches in genomic sequences using structure based methods, including the incorporation of RNAfbinv, will also be discussed.

4 - Modelling and Simulations - an Application to the RNA World Hypothesis
Natalia Szóstak, Jaroslaw Synak, Szymon Wasik, Jacek Blazewicz

Some of the most compelling questions of the humankind are these concerning the life beginnings. Many chemical and biological experiments focused on explaining a biogenesis have been performed up to date. However, even though they gave us some answers and clues, it seems that the complexity of life makes it very tough to wet lab experimental analysis. Strikingly, mathematics and computing science proved to be very useful for an analysis of many complex biological phenomena. Computational techniques of modelling and simulations of primordial systems are one of the components which gave birth to the broad field called artificial chemistry. AC offers a very wide range of algorithms to model biochemical reactions and evolutionary processes. Here we present modelling and simulation techniques with the application to the RNA World hypothesis, being the most popular and well substantiated theory which tries to explain origins of life on Earth. Moreover, we present a new approach based on the cellular automata and multi agent systems that treats RNA chains as regular chemical molecules. RNAs diffuse, react with other RNAs, replicate and are the subject of mutations. Some variants of the model built on this assumption have been implemented. Based on these models we have performed simulations which allow us to verify the model and infer biologically significant conclusions regarding evolutionary dynamics of putative pre-living systems.

■ MC-36

Monday, 12:30-14:00 - Building BM, ground floor, Room 18

Scheduling in Healthcare 2

Stream: Scheduling in Healthcare
Chair: *Sally Brailsford*

1 - A Robust Approach for a Surgical Case Assignment Problem
Inês Marques, Maria Eugénia Captivo

Uncertainty concerning the duration of a surgery is one major problem for the operating room planning and scheduling. Overestimating surgery durations may lead to underutilization of the surgical suite while an underestimation of the surgery durations increase the risk of cancellation of surgeries and incurs in extra work for the staff of the surgical suite. Underutilization of the surgical suite should be avoided since it represents a great inefficiency of a very expensive service and it contributes to increase the problem of large waiting lists in the health care sector. In the literature, the surgeries duration is often treated as a deterministic parameter, which can be disruptive to the surgical schedule obtained by a mathematical model or a heuristic approach. In this work a robust optimization model is used to handle the uncertainty in the duration of the surgeries, in order to keep the surgical schedules feasible regarding the operating room capacity constraints and also the surgeons' operating time limit. We consider a surgical case assignment problem based on real world data and experiences from a Portuguese hospital. The proposed robust approach allows the surgical suite planner (decision maker) to fix an upper bound on the probability for a surgical schedule to violate the uncertain constraints. Results of computational experiences using data from the hospital will be presented and discussed.

2 - Simulation of Operating Theatre Processes
Esra Agca Aktunc

Health care systems seek solutions to reduce costs of the operating theatre more than ever due to the increasing demand for surgical services of the aging population while trying to improve patient satisfaction. In this study, a discrete-event simulation model that integrates the preoperative processes, including the preparation of the operating room and the patient, with the perioperative process of the surgical act is developed. The stochastic demand and operation times for different surgery types are considered along with emergency surgeries in addition to elective surgeries. The utilization levels of operating theatre resources such as surgeons, nurses, anesthetists, and operating rooms, as well as other performance measures such as average patient waiting times by surgery type will be investigated based on real data. Examples of how this simulation model can be used at the strategic, tactical, and operational levels will be discussed.

3 - Designing the Blood Supply Chain: A Location-allocation Model with Collection and Production Considerations
Andres Felipe Osorio, Sally Brailsford, Honora Smith

Different topologies of the blood supply chain can be found around the world. The design of the network might depend on factors such as geography, policies, costs, and service levels; however, developed countries have aimed to centralise facilities such as production centres. This centralisation has occurred together with the creation of distribution centres, to maintain the service level, as well as meeting distance and time constraints. A large body of literature exists concerning location-allocation problems in general; however, only few publications deal with the blood supply chain. Furthermore, most of the location-allocation models in the blood supply chain have not considered important aspects, such as collection and production alternatives and multiple products that might have an impact on the optimal design of the network. To support decisions such as location, allocation, capacity definition and collection and production strategy, a mixed-integer linear programming is proposed. This model includes multiple constraints such as capacity, demand fulfilment and distance covering. The model seeks to optimize total cost of designing the complete blood supply chain. The proposed methodology is evaluated using actual information from Colombia.

■ MC-39

Monday, 12:30-14:00 - Building WE, 1st floor, Room 107

Networks and Contagions

Stream: Financial and Commodities Modeling
Chair: *Giulia Rotundo*

1 - Networks of assets and options reliability
Roy Cerqueti, Fabio Spizzichino

This talk deals with the development of a barrier basket options model in the language of reliability theory. Specifically, an option is presented as a coherent system with components given by the assets of the basket. The basket is viewed as a network whose nodes are the assets, and the conceptualization of the weights of the arcs is assumed to be driven by the definition of the payoff of the option at the expiration date. An exploration of the reliability function of the option is carried out, to gain insights on its risk profile. Furthermore, a comparison between reliability functions is provided, to highlight the relationship between the risk profile of the option and the interconnections among the assets in the basket.

2 - Contagion in the world's stock exchanges seen as a network of coupled oscillators
Giulia Rotundo

We study how the phenomenon of contagion can take place in the network of the world's stock exchanges due to the behavioral trait "blindeness to small changes". On large scale individual, the delay in the collective response may significantly change the dynamics of the overall system. We explicitely insert a term describing the behavioral phenomenon in a system of equations that describe the build and release of stress across the worldwide stock markets. In the mathematical formulation of the model, each stock exchange acts as an integrate-and-fire oscillator. Calibration on market data validate the model. One advantage of the integrate-and-fire dynamics is that it enables for a direct identification of cause and effect of price movements, without the need for statistical tests such as for example Granger causality tests often used in the identification of causes of contagion. Our methodology can thereby identify the most relevant nodes with respect to onset of contagion in the network of stock exchanges, as well as identify potential periods of high vulnerability of the network. The model is characterized by a separation of time scales created by a slow build up of stresses, for example due to (say monthly/yearly) macroeconomic factors, and then a fast (say hourly/daily) release of stresses through "price-quakes" of price movements across the worlds network of stock exchanges.

3 - Polynomial algorithms for partitioning trees with uniform criteria
Andrea Scozzari, Isabella Lari, Justo Puerto, Federica Ricca

In this paper we provide polynomial time algorithms for the problem of finding uniform centered partitions of a tree, that is, partitions that are as balanced as possible with respect to the cost or the weight of the components. Graph partitioning problems based on this type of optimization criteria belong to the class of uniform partition (or equipartition) problems. Different objective functions can be used to represent the above goal of uniformity, such as the minimization of the maximum cost of a component (min-max uniform problem), or the maximization of the minimum cost (max-min uniform problem), or the minimization of the difference between the maximum and the minimum cost of a component (most uniform problem). In a previous paper we already studied the problem of finding uniform centered partitions of a graph, giving several NP-Completeness results. In particular, we proved that all the above problems are NP-complete even on planar bipartite graphs with vertex degree at most 3 and two centers, and this motivates our interest for studying them now on trees.

■ MC-40

Monday, 12:30-14:00 - Building WE, 1st floor, Room 108

Financial Optimization and Portfolio Management

Stream: Financial Engineering and Optimization
Chair: *Jianjun Gao*

1 - Optimal Solutions of A Behavioral Portfolio Choice Optimization Problem
Youcheng Lou, Duan Li, Shouyang Wang

This paper considers a behavioral portfolio choice optimization problem. It is well-known that it is extremely difficult to give the exact optimal solution for the general power utility due to the nonconvexity and noncavity of the CPT value function under consideration. In this paper, we first show that the optimal solution is a linear function of the relative wealth, and then investigate two special cases in which the market conditions to determine whether to long or short the risky asset are specified.

2 - Portfolio Optimization with Nonparametric Value-at-Risk: A BCD Method
Shushang Zhu

We investigate in this work a portfolio optimization methodology using nonparametric Value-at-Risk (VaR). In particular, we adopt kernel VaR and quadratic VaR as risk measures. As the resulting models are nonconvex and nonsmooth optimization problems, albeit with some special structures, we propose some specially devised block coordinate descent (BCD) methods for finding approximate or local optimal solutions. Computational results show that the BCD methods are efficient for finding local solutions with good quality and they compare favorably with the branch-and-bound based global optimal solution procedures. From the simulation test and empirical analysis which we carry out, we are able to conclude that the mean-VaR models using kernel VaR and quadratic VaR are more robust compared to those using historical VaR or parametric VaR under the normal distribution assumption, especially when the information of the return distribution is limited. (This is a joint work with Xueting Cui, Xiaoling Sun and Duan Li.)

3 - Portfolio optimization with non-recursive reference point updating
Moris Strub, Duan Li

According to cumulative prospect theory, decision makers evaluate prospects in comparison to a reference point instead of with regards to resulting absolute terminal wealth levels. In a dynamic portfolio optimization setting it is thus crucial how investors form and update their reference points, as this directly influences optimal strategies. The empirical findings by Baucells et al. (2011) suggest that reference levels are updated in a non-recursive manner. Motivated by those results, we propose a dynamic portfolio choice model with non-recursive reference point updating. We determine the optimal investment strategy and compare the resulting trading behavior to those implied by other behavioral portfolio choice models in the existing literature.

4 - Dynamic Mean-exceeding probability portfolio selection Problem
Ke Zhou, Duan Li

We solve the mean-exceeding probability portfolio selection problem formu lation completely by using Lagrangian method and Chebyshev's inequality. To derive the mean-exceeding probability effcient frontier, We prove the existence and uniqueness of the corresponding Lagrangian problems. In addition, we show the one to one corresponding relationship between the mean-VaR problem and mean-exceeding probability problem. Furthermore, we consider an inverse problem for the mean-exceeding probability portfolio selection formulation: Given a realizable mean-exceeding probability pair, find the minimum initial investment level which can achieve this given pair.

■ MC-41

Monday, 12:30-14:00 - Building WE, 2nd floor, Room 209

Systemic Risk and Risk Measures

Stream: Financial Mathematics and OR
Chair: *Cagin Ararat*

1 - Modeling and Measuring Systemic Risk
Stefan Weber

Systemic risk is defined as the risk that a financial system is susceptible to failures initiated by the characteristics of the system itself. If strong links between financial institutions are present, a shock to only a small number of entities might propagate through the system and trigger substantial financial losses. The talk presents a comprehensive model of a financial system that integrates local and global interaction of market participants through nominal liabilities, bankruptcy costs, fire sales, and cross-holdings. For the integrated financial market we prove the existence of a price-payment equilibrium and design an algorithm for the computation of the greatest and the least equilibrium. Systemic risk measures and the number of defaults corresponding to the greatest price-payment equilibrium are analyzed in several comparative case studies. These illustrate the individual and joint impact of the underlying factors.

2 - Systemic risk measures from a duality point of view
Cagin Ararat, Birgit Rudloff

Measurement and allocation of the overall risk of an interconnected financial system has been of increasing interest after the recent financial crisis. In this talk, we focus on a recent set-valued approach where systemic risk is measured as a set of capital allocation vectors for which the resulting impact of the financial system to the economy is considered acceptable. We present a dual representation theorem for systemic risk measures and provide economic interpretations of the dual variables. As a corollary, we show that a systemic risk measure can be seen as a multivariate shortfall risk measure under model uncertainty. The special cases we consider include the classical Eisenberg-Noe network model, a flow network model, and a financial system with exponential aggregation mechanism. In particular, while the definition of the systemic risk measure in the Eisenberg-Noe model requires the solutions of certain fixed point problems, the dual representation is free of these fixed points.

■ MC-42

Monday, 12:30-14:00 - Building WE, 1st floor, Room 120

Models of Power and Influence in Game Theory

Stream: Game Theory, Solutions and Structures
Chair: *Jacek Mercik*

1 - Alternative Forms of the Shapley-Shubik Index
Sascha Kurz

In 1996 Felsenthal and Machover considered the following model: An assembly consisting of n voters exercises roll-call. All possible orders in which the voters may be called are assumed to be equiprobable. The votes of each voter are independent with expectation p for an individual vote "yea". For a given decision rule v the pivotal voter in a roll-call is the one whose vote finally decides the aggregated outcome. It turned out that the probability to be pivotal is equivalent to the Shapley-Shubik index. Here we give an easy combinatorial proof of this coincidence and further weaken the assumptions of the underlying model.

2 - Decomposition, Value, and Power
André Casajus, Frank Huettner

We suggest a foundation of the Shapley value via the decomposition of solutions for cooperative games with transferable utility. A decomposer of a solution is another solution that splits the former into a direct part and an indirect part. While the direct part (the decomposer) measures a player's contribution in a game as such, the indirect part indicates how she affects the other players' direct contributions by leaving the game. The Shapley value turns out to be unique decomposable decomposer of the naïve solution, which assigns to any player the difference between the worth of the grand coalition and its worth after this player left the game. Moreover, we apply the decomposition of solutions to the measurement of power in voting games and obtain two new power indices with appealing properties.

3 - The Distribution of Power in the Lebanese Parliament Revisited
Frank Steffen, Mostapha Diss, Abdallah Zouache

Many political analysts consider the Lebanese Republic to be one of the most democratic nations in the Arab world. One main peculiarity of Lebanese Republic is the confessional nature of its political system which is prescribed by its constitution. This adds to the system of democratic elections a guarantee for a pre-defied representation of Muslims and Christians and its various sectarian groups in parliament. In this sense, the composition of the Lebanese Parliament is based on the allocation of a specific number of seats to each of the two major religious groups and its sectarian groups. The allocation of seats to the two religious and its sectarian groups and the total size of the parliament have been, and still are, subject of intensive discussions by Lebanese political parties and political scientists. Recently, applying the theory of voting power Diss and Zouache (2015) have studied the pure distributional power in the parliament. They compared the current parliamentary structure with a proposal for its amendment. Making use of the Banzhaf and the Shapley-Shubik index their study has revealed some paradoxical effects. In this paper, we re-examine their results applying the Banzhaf measure and extend the investigation by including the previous constitution into our analysis. Even under our approach which does not normalize the total amount of power in the parliament to one we are able to demonstrate that the paradoxical results remain to exist.

4 - Johnston Index of Implicit Power as a Measure of Reciprocal Ownership
Jacek Mercik

The multitude of existing forms of business organization and the possibilities of relationships and interactions between them call for the need to recognize individual components of these forms as elements influencing the group decision-making process. Among many possible ways to assess this impact are so-called power indexes, including the implicit index which may serve as a measurement of power in reciprocal ownership structures. Research on the power of different shareholders, in particular on the importance of stakeholder groups for determining the voting power, was initiated by Berle and Means (1932). Shapley and Shubik (1954), introduced the concept of simple game. Gambarelli and Owen (1994) proposed a method of assessing the power of individual shareholders in instances of more complex relationships between different companies being owned by these individual shareholders. Leech (1997, 2002) analysed the relationship between voting power and voting bodies. Leech inclined to the use of power indexes of individual shareholders in a company in direct analysis. Cubbin and Leech (1999) proposed a measure of the voting power of the largest shareholding block. The implicit power index proposed takes into account not only the power of individual shareholding, but also the impact the companies themselves have on implicit relationships. Assuming that decisions in companies are taken by simple majority, we will assess the power of individual entities constituting the companies.

■ MC-43

Monday, 12:30-14:00 - Building WE, ground floor, Room 18

Stochastic Models in Renewable Energy and Related Subjects

Stream: Stochastic Models in Renewably Generated Electricity
Chair: *Endre Bjorndal*

1 - Stochastic LCOE for intermitting renewable energy generation
Marcella Marra, Carlo Mari, Carlo Lucheroni

Levelized Cost of Electricity (LCOE) analysis is an assessment technique routinely used to value electricity production costs, in order to compare them with expected electricity sales revenues, and check if breakeven can be reached. LCOE analysis is widely used in the case of intermittent renewable sources, even though intermittency originates extra costs which are not included in the standard LCOE definition. We will show how to properly include these extra costs in the LCOE by coupling an intermittent source like wind or solar to a dispatchable technology as a gas thermal plant. Then, we will discuss an extension of LCOE, called Stochastic LCOE, which will allow us to include renewable sources into energy portfolio optimization.

2 - Congestion Management in a Stochastic Dispatch Model for Electricity Markets
Endre Bjorndal, Mette Bjørndal, Kjetil Midthun, Golbon Zakeri

We discuss the design of electricity markets with stochastic dispatch. Our discussion is based on a model framework similar to that in (Pritchard et al. 2010) and (Morales et al. 2014), where an electricity market with two sequential market clearings is used. The stochastic market clearing is compared to the (standard) myopic market model in a small example, where wind power generation is uncertain. We examine how changes in market design influence the efficiency of the stochastic dispatch. In particular, we relax the network flow constraints when clearing the day ahead market. We also relax the balancing constraints when clearing the day ahead market to see if this additional flexibility can be valuable to the system.

3 - Integrating Fourier Analysis and ANN for Medium Term Forecasting of Power Demand
Mert Ketenci, Gulgun Kayakutlu, Irem Duzdar

The complexity of power markets are caused by uncertainties, seasonalities, and price volatilities. High fluctuations triggered in industrial and residential power demand are to be smoothened by improved forecasting methods. Country specific energy policies are influenced by Medium Term energy demand forecasting. To be able to study the future demand of electrical energy properly it must be forecasted with lowest possible error. In this paper, artificial neural network and spectrum analysis have been hybridized as the methods to study the future electrical energy demand. The proposed hybrid model is constructed by using the generally accepted time series data for demand. The case study is performed for Turkey to forecast 1-5 years. The achievement will be beneficial for both the energy industry investors and the market balancing authorities.

■ MC-47

Monday, 12:30-14:00 - Building WE, 1st floor, Room 115

Stochastic Modeling and Simulation in Engineering, Management and Science 2

Stream: Stochastic Modeling and Simulation in Engineering, Management and Science
Chair: *Juergen Branke*

1 - An Advertisement Placement Problem Solved by Optimization-simulation Approach
Mirko Vujosevic, Stefan Marković

The advertisement placement problem deals with number of advertisements to be placed in different newspapers. Their positions and sizes in every newspaper should be determined in order to reach the needed views and scores both in total population, and within the target groups. The objective is to achieve all these with the minimum advertisement cost. Daily, weekly and monthly newspapers, their total views, as well as rating for each newspaper for the targeted group are considered. The optimization problem is stated as a mixed integer linear stochastic programming model because the relevant data in constraint set are stochastic. An optimization-simulation approach is proposed for solving the problem. It consists of two phases: the optimization phase, where a scenario is defined by an deterministic counterpart of the original model and solved to optimality, and a simulation phase where the validity of the obtained optimal solution is checked by Monte Carlo simulation. In that way the decision maker is provided by a set of results of different scenarios and it is up to him to make trade-off analysis between cost and risk that some of the constraints in the scenario will not be satisfied.

2 - Optimal Sampling for Simulated Annealing in the Presence of Noise
Juergen Branke, Robin Ball, Stephan Meisel

We propose a Simulated Annealing (SA) variant for optimization problems in which the solution quality can only be estimated by sampling from a random distribution, and the aim is to find the solution with the best expected value. Assuming Gaussian noise with known standard deviation, we derive an optimal fully sequential sampling procedure and decision rule. That is, the procedure starts with a single sample and then continues to draw more until it is able to make a decision. Because our method obeys the detailed balance equation it performs exactly like SA in a deterministic environment (but requiring more samples). An empirical evaluation shows that our approach is indeed more efficient than previously proposed SA variants that claim to obey the detailed balance equation.

3 - On the Efficiency of Total Repair Cost Limit Replacement Policies
Frank Beichelt

In this contribution, functionals of the Brownian motion will be used to model the random cumulative maintenance cost C(t) and the cumulative maintenance cost rate R(t) = C(t)/t caused by the maintenance of a technical system over a given time period [0, t]. The following basic maintenance policies are considered given that a new system starts operating at time t = 0 and replacement times are negligibly small: Policy 1 As soon as C(t) reaches level x, the system is replaced by an equivalent new one. Policy 2 As soon as R(t) reaches level r, the system is replaced by an equivalent new one. In either case, the cost of a replacement is assumed to be a constant c, and the maintenance- replacement process continues to infinity. The efficiencies of these two policies are compared to each other, but also in relation to the economic lifetime policy, i.e., the system is replaced if the expected total maintenance cost rate is minimal. Policies 1 and 2 are generalized by combining them with age-dependent replacement policies, which combine the advantages (and disadvantages) of both purely cost related and age-cost related maintenance policies.

4 - Lateral Chromatic Aberration Correction in Digital Eye Fundu Images
Povilas Treigys, Vytautas Jakstys, V. Marcinkevicius

Chromatic aberration is an unwanted effect of optical system lens refraction that causes the colour waves to focus slightly different. The result of this effect is an image with poor contrast and coloured fringes at edges. Mechanically this effect can be eliminated by adding extra lenses with a negative distance to the focus. According to the Abbe number, lenses can be situated in a manner that red and blue colour focal planes would match each other while wavelength of other colours refraction coincidence as good as possible. This approach eliminates only the axial chromatic aberration problem. When photo camera system is designed without achromatic lenses, it is necessary to apply image processing algorithms for lateral chromatic aberration effect correction. These algorithms tries to scale the fringed colour channels so that all channels spatially overlap each other correctly in the final image. This study deals with images obtained with a portable non-mydriatic eye fundus orbital camera which does not have achromatic lenses. Authors of the study present an investigation of algorithms published in academic literature that corrects the effect of chromatic aberration and provides comparison of those. An important aspect of the investigation is dedicated to accurate camera focal plane centre estimation.

■ MC-48

Monday, 12:30-14:00 - Building WE, 1st floor, Room 116

Long Term Financial Decisions

Stream: Long Term Financial Decisions
Chair: *Heinz Eckart Klingelhöfer*
Chair: *Jean-Luc Prigent*

1 - Optimal investment problems for pairs trading
Zehra Eksi, Suhan Altay

We study certain optimization problems related to the pairs trading, which is an investment strategy that matches a long position in one security with a short position in another one. More precisely, we analyze the optimal portfolio selection problems in a dollar-neutral pairs trading setting by using the stochastic control approach. The relation between pairs, called spread, is generally modeled by a mean-reverting stochastic process. We model the spread dynamics by a Gaussian mean-reverting process, whose drift rate is Markov modulated. First, we assume that the investor can observe the drift of the spread and investigate the corresponding optimization problem in the case of logarithmic and power utility. Second, we repeat the analysis for the setting, in which the drift of the spread process is not observable. This results in an optimization problem under partial information. Using results from filtering theory, we reduce this problem to a problem with full information and obtain the corresponding optimal strategies in the feedback form. In the case of logarithmic utility, it turns out that the certainty equivalent principle holds. At last, we also discuss the same type of utility maximization problems in which the terminal wealth is penalized by the riskiness of the portfolio. This reflects the situation where the risk-aversion of the trader is effectively increased.

2 - On the Stochastic Dominance of Portfolio Insurance Strategies: CPPI with conditional multiples versus OBPI
Jean-Luc Prigent, Hachmi Ben Ameur, Hela Maalej

Portfolio insurance allows the investors to limit downside risk, while benefiting from market rises. It is particularly attractive for investors who do not want to lose part of their initial investment. It corresponds also to the main structured portfolio management and has been recently emphasized by the financial crisis (see, e.g., Prigent, 2007). This paper compares the performance of the two main portfolio insurance strategies, namely the Option-Based Portfolio Insurance (OBPI) of Leland and Rubinstein (1976) and the Constant Proportion Portfolio Insurance (CPPI) with conditional multiples as introduced in Ben Ameur and Prigent (2014). For this purpose, we use the stochastic dominance criterion at several orders. To control the gap risk of such strategies, we introduce both Value-at-Risk (VaR) and Expected Shortfall (ES) risk measures. We illustrate these results for a quite general ARCH type model, including the EGARCH(1,1). We provide explicit sufficient conditions to get stochastic dominance results. When taking account of specific constraints, we use the consistent statistical test proposed by Barret and Donald (2003), similar to the Kolmogrov-Smirnov test but with a complete set of restrictions related to the various forms of stochastic dominance. We find that the CPPI method can perform better than the OBPI according to the stochastic dominance from the third order. Such result has potential important implications for structured portfolio management.

3 - Term structure of defaultable bonds, an approach with Jacobi processes
Suhan Altay

In this study, we propose a novel defaultable term structure model that is capable of capturing negative instantaneous correlation between credit spreads and risk-free rate documented in empirical literature while sustaining the positivity of the default intensity and risk-free rate. Given a multivariate Jacobi (Wright-Fisher) process and a certain functional, we are able to compute the zero-coupon bond prices, both defaultable and default-free, in a relatively tractable way by using the exponential change of measure technique with the help of the "carre du champ" operator as well as by using the transition density function of the process. The resulting formula involves series involving ratios of gamma functions and fast converging exponential decay functions. The main advantage of the proposed reduced form model is that it provides a more flexible correlation structure between state variables governing the (defaultable) term structure within a relatively tractable framework for bond pricing. Moreover, in higher dimensions one does not need to rely on numerical schemes related to the differential equations, which may be difficult to handle (e.g., multi-dimensional Riccati equations in affine and quadratic term structure frameworks), because the transition density function of the state variables are given in a relatively explicit form. (Joint work with Uwe Schmock)

4 - Leaders and followers in mutual funds: a Dynamic Bayesian Approach
Pilar Gargallo, Laura Andreu, Manuel Salvador, José Luis Sarto, José Luis Sarto

In this paper a statistical analysis of the interrelationships between the risk exposures coefficients corresponding to pairs of mutual funds is carried out. To that aim a bivariate state-space framework based on the CAPM model with dynamic beta and alpha of Jensen coefficients is setting out. The methodology is illustrated using a set of Spanish mutual funds where the leader-follower relations are explored using graph theory tools.

■ MC-51

Monday, 12:30-14:00 - Building PA, Room D

Linear Complementarity Problems and Interior-Point Methods

Stream: Mathematical Programming
Chair: *Florian Potra*

1 - Weighted Complementarity Problems and Applications
Florian Potra

The weighted complementarity problem (wCP) is a new paradigm in applied mathematics that provides a unifying framework for analyzing and solving a variety of equilibrium problems in economics, multibody dynamics, atmospheric chemistry and other areas in science and technology. It represents a far reaching generalization of the notion of a complementarity problem (CP). Since many of the very powerful CP solvers developed over the past two decades can be extended to wCP, formulating an equilibrium problem as a wCP opens the possibility of devising highly efficient algorithms for its numerical solution. For example, Fisher's competitive market equilibrium model can be formulated as a wCP, while the Arrow-Debreu competitive market equilibrium problem (due to Nobel prize laureates Kenneth Joseph Arrow and Gerard Debreu) can be formulated as a self-dual wCP.

2 - Iterative Schemes in Interior Point Methods: Sensitivity and Error Control
Lukas Schork, Jacek Gondzio

The linear equation systems usually solved in interior point methods for linear and quadratic programming are known to become increasingly ill conditioned when the iterates approach a solution. When these systems are solved by an iterative scheme, small residuals can heavily affect the step direction and cause the iterates not to converge.

In this talk we analyse the sensitivity of the primal and dual components of the step direction to changes in the right-hand side. An alternative form of the linear system is proposed which prevents growth between the residual and the absolute error in the solution. The new form allows to control the relative error in the approximate solution also for moderately accurate computations. This measure is readily available in practice and can be used as stopping criterion for an iterative solver.

3 - Computing search directions in inteiror point mehods with alternative linear systems
Aurelio Oliveira, Fábio Rodrigues Silva, Marta Velazco

The most expensive step in interior point methods iterations consists on solving linear systems. Most implementations solve either the augmented system or the normal equations system. In this work we present an alternative indefinite linear system, obtained from the augmented system using the splitting preconditioner. Such system has the size of the number of the linear programming variables and could be solved by itself or further reduced to two positive definite linear systems. The first one corresponding to the preconditioned normal equations system while the second one has the size of the difference between the linear programming problem number of columns and constraints. Several approaches are presented to solve such systems and numerical experiments compare their performance with the approach using the preconditioned conjugate gradient method on normal equations using a hybrid preconditioner.

4 - Full- Newton-step Infeasible Interior-Point Method for LCP that Requires Only One Step per Iteration
Goran Lesaja

An improved version of an infeasible full Newton-step interior-point method for linear complementarity problem is considered. In the earlier version, each iteration consisted of one infeasibility step and a few centering steps per iteration while in this version each iteration consists of only one infeasibility step. This improvement has been achieved by a much tighter estimate of the proximity measure after an infeasibility step. However, the best iteration bound known for these types of methods is still achieved.

■ MC-52

Monday, 12:30-14:00 - Building PA, Room C

Methods and Models of Convex Optimization

Stream: Convex, Semi-Infinite and Semidefinite Optimization
Chair: *Petra Weidner*

1 - Portfolio Optimization Models under Various Risk Measures
Carisa Kwok Wai Yu

Risk management plays an important role in portfolio optimization problems. Using an appropriate risk measure is essential. In the literature, various risk measures (such as variance, L-infinity, Value-at-Risk (VaR) and Conditional Value-at-Risk (CVaR)) have been proposed. In this paper, the problems under various measures are formulated as bi-criteria optimization models in which wealth is allocated to various assets by considering the tradeoff of return and risk. In particular, we investigate the portfolio optimization models under three risk measures (including L-infinity, VaR and CVaR risk measures). According to an equivalence relation between a multi-criteria linear program and its weighted sum linear programs, and by a simple transformation, the model under L-infinity risk measure can be solved by considering its weighted sum linear programs. As CVaR risk measure can be formulated as a convex piecewise linear function, the model under CVaR risk measure can be solved by linear simplex algorithm. The model under VaR risk measure can be reformulated by applying the modeling of a mixed 0-1 linear multi-criteria program. Computational experiments are conducted using real stocks from the Hong Kong stock market. We discuss the optimal solution sets of these three bi-criteria portfolio optimization models through empirical results.

The work described in this paper was fully supported by a grant from the Research Grants Council of the HKSAR, China (UGC/FDS14/P03/14).

2 - A New Calculus for Extended Real-Valued Functions
Petra Weidner

Extended real-valued functionals became an essential part in models of optimization, economic theory and finance, since restrictions can be connected with an objective function in an extended real-valued function via an indicator function and since functionals can be extended to extended real-valued functions which are defined on the entire space. Such functionals are, e.g., used as risk measures, in separation theorems in functional analysis and in vector optimization. In the classical approach, extended real-valued functionals have to be handled in different ways for infimum problems and supremum problems. In the presentation, a unified calculus for all types of functions which attain real values and/or involve limits is introduced. It is illustrated that extended real-valued functions have to be handled in another way than real-valued functions. This refers to the calculus, to comparisons and to the definition of properties like, e.g., convexity or linearity. In contrast to the classical theory, the approach presented to extended real-valued functions preserves continuity and semi-continuity when extending a function to the whole space and gives the possibility to study affine functions which are not necessarily finite-valued.

3 - Optimization with flexible objectives and constraints
Van Nam Tran

In non-standard analysis, uncertainties can be modelled through neutrices, i.e., bounded convex subgroups of the real line, a sort of generalized zeros. A sum of a real number and a neutrix is called an external number. It is a set of real numbers relatively close to a given real number, being stable under small perturbations and expressing some flexibilities. The calculus of external numbers may be seen as a model of propagation of errors [1], [2]. A function with values in external numbers is called a flexible function and objectives and constraints in terms of external numbers are also called flexible. In this work we shall present necessary and sufficient conditions for the existence of (nearly) optimal solutions for both linear programming and nonlinear optimization problems with flexible objectives and constraints, and study some of its characteristics.

References: [1] B. Dinis, I.P. van den Berg. Algebraic properties of external numbers, Journal of Logic & Analysis 3:9, 1-30, 2011. [2] J. Justino, I.P. van den Berg, Cramer's rule applied to flexible systems of linear equations, Electronic Journal of Linear Algebra, Volume 24, 126-152, 2012.

■ MC-53

Monday, 12:30-14:00 - Building PA, Room A

OR Promotion among Academia, Businesses, Governments, etc.

Stream: Initiatives for OR Education
Chair: *Liudmyla Pavlenko*

1 - TrainERGY - Training for energy efficiency operations
Antonio Diglio, Giuseppe Bruno, Andrea Genovese, Bartosz Kalinowski, Panayiotis Ketikidis, Lenny Koh, Agata Rudnicka, Adrian Solomon, Grażyna Wieteska

The environmental sustainability agenda is growing in importance in the EU, which has a commitment to reduce Greenhouse Gas Emissions by 80-95% by 2050, with reference to 1990 levels. In such a context, SMEs will be increasingly assessed on their environmental performances, as 23% of CO2 global emissions is attributed to business operations. Due to this external pressure, SMEs should start to take into account the environmental impact of their operations and make informed decisions accordingly. However, they have not appropriate knowledge and skills, due to the lack of curricula, offered by academic institutions (such as universities and centers), focusing on concepts related to this field. In order to address such existing training needs, TrainERGY (Training for Energy Efficient Operations) Project aims at developing an open-innovation and co-creation framework that will enable a proper development of more marked oriented energy efficient operations (EEO) curricula. The project consortium comprises academic institutions, SMEs and industrial association from different sectors and countries. Through co-creation, academic knowledge provided by the higher education institutions can be used to provide solutions for the industry in relation to effective design and implementation of EEO; alternatively, academia can gain useful input from industry to enhance their offered curricula on the basis of the current needs of the industry.

2 - Stability Theory Methods and Scientific Background in Art of Modelling for OR Education
Lyudmila Kuzmina

Main focus of the work is investigation of important problems related to decision-making process for Education System at Higher Schools in whole and to the development of special methodology for Operations Researchers/Nonlinear Analysts (OR/NA). We discuss actual questions connected with the level and quality of fundamental knowledge and with developing mentality in training-teaching of specialists in different areas, the principles of subject teaching, which are leading to the activating and governing methods of learning in Higher Schools. The study contains development of constructive approximate asymptotic methods that are very effective for modelling nonlinear systems of general nature on the basis of A.M. Lyapunov theory and N.G. Chetayev stability postulate, generalizing herewith the concepts of parametric stability and singularity postulate. Here, stability theory methodology, N.G. Chetayev postulate, combined with asymptotic approach, allow to establish the effective method as additional activity tool for OR in problems of modelling complex systems, qualitative analysis, control, synthesis.

3 - An Overview of the stream "Operational Research: Environment and Climate" of the Summer School "Technology for Future"
Liudmyla Pavlenko, Kuhuk Jane, Sandra Yaremchuk

The first edition of the Summer School "Technology for Future" will be held in Kyiv, Ukraine (July 10-18, 2016). The event will bring together some 50 MSc and PhD students both from abroad and Ukraine, with 25 of them participating in the Operational Research: Environment and Climate stream. The program featuring lectures, technical visits to enterprises, team work on case studies, speed networking and final examination aims to ensure the development of OR skills and their further implementation in the field of environment protection. We are seeking to promote OR techniques by organizing a number of OR-related events, including such formats as a summer school, workshop and contests.

4 - Job Performance of DMMMSU-CGS Graduates
Remedios Neroza

Education improves human resources by raising individual productivity, thus promoting economic growth, and in thus lies important role in the process of development. Human beings are both the means and the end of economic development. Given this premise, it could be inferred that economic development is dependent upon the productivity of human resources which also depend on the quality of education. At present, the College of Graduate Studies has a limited data/information with respect to job performance of graduates and students. the goal of the College of Graduate Studies is to prepare globally competitive human resources who are imbued with the ideals, aspirations and traditions of Philippine culture sufficiently equipped with broad range of knowledge, skills and competencies for effective delivery system. The study mad use of descriptive research design. The respondents were the administrators of the alumni of DMMMSU-SLUC College of Graduate Studies a total of 88 respondents. It reflects from the findings that personal appearance ranked first from the indicators of job performance, followed by adherence to policies and third is on administration. This is an indication, that the training's received by the alumni and their attendance in the CGS contributed in his ability to withstand the rigors of administrative responsibilities. Knowledge of work ranked fourth which means that the performance of the alumni along this dimension is consistently superior.

■ MC-54

Monday, 12:30-14:00 - Building PA, Room B

Implicit splitting methods for convex optimization

Stream: Convex Optimization
Chair: *Dirk Lorenz*

1 - Relaxed and inertial preconditioned Douglas-Rachford splitting method
Hongpeng Sun, Kristian Bredies

We study relaxed and inertial strategies for a class of Douglas-Rachford methods aiming at the solution of convex-concave saddle-point problems with preconditioning. The ergodic convergence rate of restricted primal-dual gaps and the weak convergence of the iteration sequences are discussed. All methods allow the inexact solution of the implicit linear step, to maintain the unconditional stable property of the original Douglas-Rachford splitting method, which is different from the forward-backward splitting methods or lots of linearization strategies for Douglas-Rachford method, where certain constraint of the step size appeared. The efficiency of the proposed methods is verified numerically, accelerations are observed compared with the preconditioned Douglas-Rachford splitting method without relaxation or inertia.

2 - Line Search for Averaged Operator Iteration
Pontus Giselsson

Many popular first order algorithms for convex optimization, such as forward backward splitting, Douglas-Rachford splitting, and the alternating direction method of multipliers (ADMM), can be formulated as averaged iteration of a nonexpansive mapping. In this talk we present a line search for averaged iteration that preserves the theoretical convergence guarantee, while often accelerating practical convergence. We discuss several general cases in which the additional computational cost of the line search is modest compared to the savings obtained.

3 - **A Forward-Backward Quasi-Newton algorithm for minimizing the sum of two nonconvex functions**
Panagiotis Patrinos, Andreas Themelis, Lorenzo Stella

In this talk we present a globally and superlinearly convergent splitting algorithm for minimizing the sum of two nonconvex functions, one of which is smooth and the other prox-bounded and possibly nonsmooth. Our approach uses exactly the same oracle information as forward-backward splitting and is based on the Forward-Backward Envelope (FBE), namely a locally Lipschitz continuous function whose global minimizers and stationary points coincide with those of the original problem. The algorithm asymptotically reduces to a quasi-Newton method for finding a zero of the forward-backward fixed point residual (FPR) which, although multivalued for nonconvex problems, under mild prox-regularity assumptions it is single-valued around points of interest. Theoretical results are backed up by promising numerical simulations on large-scale problems, where the proposed algorithm with limited BFGS updates dramatically outperforms, even in the convex case, popular algorithms like ADMM and the fast proximal gradient method.

Monday, 14:30-16:00

■ MD-01

Monday, 14:30-16:00 - Building CW, AULA MAGNA

Keynote Hans Georg Bock

Stream: Plenary, Keynote and Tutorial Sessions
Chair: *Ekaterina Kostina*

1 - **Mixed-Integer Optimal Control - Theory, Numerical Solution and Nonlinear Model Predictive Control**
Hans Geog Bock

The presentation discusses theoretical and numerical aspects of optimal control problems with integer-valued control variables. Despite the practical relevance and ubiquity of integer or logical decision variables such as valves, gears or the start-up of sub-units in chemical plants, optimization methods capable of solving such nonlinear mixed-integer optimal control problems (MIOCP) for large-scale systems and in real-time have only recently come within reach. Nonlinear MIOCP such as the minimum energy operation of subway trains equipped with discrete acceleration modes were solved as early as the late seventies for the city of New York. Indeed one can prove that the Pontryagin Maximum Principle holds which makes an indirect solution approach feasible. Based on the "Competing Hamiltonians Algorithm" (Bock, Longman '81), open loop and feedback solutions for problems with discontinuous dynamics were computed that allowed a tested reduction of 18 per cent in traction energy. However, such "indirect" methods are relatively complex to apply and numerically less suitable for large-scale real-time optimization problems. We present a new "direct" approach based on a functional analytic approach leading to a relaxed problem without integer gap, the so-called "outer convexification" which is then solved by a modification of the direct multiple shooting method as an "all-at-once" approach. Moreover, it can be arbitrarily closely approximated by an integer solution with finitely many switches. The gain in performance is enormous, orders of magnitude of speed-up over a state-of-the-art MINLP approach to the discretized problem, where the NP hardness of the problem is computationally prohibitive. Real-time applications by a "multi-level real-time iteration" NMPC method for on-board energy optimal cruise control of heavy duty trucks and minimum time control of a race car around the Hockenheim race track are presented. (Presentation based on joint work with F. Kehrle, C. Kirches, E. A. Kostina, R. W. Longman, S. Sager and J. P. Schlöder)

■ MD-03

Monday, 14:30-16:00 - Building CW, 1st floor, Room 13

MADM Application 4

Stream: Multiple Criteria Decision Analysis
Chair: *Chun-Hsien Wang*

1 - **Technology Analysis and Management by Mining Patent Documents**
Hei Chia Wang, I-Chia Chiang

Patents are one of forms which people record their intellectual property, and comprise a plurality of research results. By reading patents, one can know some special issue of a new technology domain. In R&D process, collecting patents can accumulated technical knowledge, inspire new creative inspiration, avoid conflict with existing patents, and reduce legal disputes. Patent has its own legal issue. Omitting any important patent will cause decision-makers to make wrong decisions. Therefore, providing users with more comprehensive and more efficient way of acquiring necessary patents has become very important.

In this study, bootstrapping and topic map are used for finding and store key technologies in patents. Bootstrapping is a machine learning technique that use a little seed human assigned, and automatically learn information we need from data. Topic map is a kind of knowledge map that save time when browsing and enhance query quality. In this paper, we use bootstrapping to train patterns and use these patterns to extract technology elements in patents as keywords of topics. The experimental result showed that learning patterns via bootstrapping could help in recognizing technology elements that a patent used. We also show that the constructed topic map helped user to find patent they needed.

2 - A New Fuzzy Quality Control Chart Using Fuzzy Random Variables
Liang-Hsuan Chen, Chia-Jung Chang, Chun-Yu Lin

Quality control of products is very important during production to ensure the pre-determined quality level of products for achieving customer satisfaction. Control charts are a process-monitoring technique to detect the occurrences of assignable causes of variations of product quality. However, for some quality inspection practices in industry, subjective judgements based on the inspectors' experience and knowledge may be required for some particular quality characteristics, in which observations include randomness and fuzziness. To monitor the variability of production processes in terms of randomness and fuzziness, this study developed a new fuzzy control chart using fuzzy random variables to detect such two kinds of variability. Two sets of numerical control limits are developed to separately monitor the two variabilities. Compared with the existing approaches, the proposed approaches remain more fuzzy information and provide more efficient detection processes. Through the exemplified numerical cases, the proposed approaches demonstrate the ability that can effectively check the production process status in terms of randomness and fuzziness.

3 - The research of two-stage perishable supply chain under discontinuous stages
Tai-Yue Wang, Wei-Hsiang Lo

Food supply chain has suffered most from the deterioration of inventory among supply chains. Nowadays, people purchase their foods and produces at supermarkets and these supermarkets usually provide both fresh products and the cooked products for consumers to meet different demands. Providing both of them could raise a difficult issue on inventory control because the retailers have to decide the right quantities at the right time to place their orders. On the contrary, the suppliers have to decide how many fresh products to retailers. In this study, a model of a two-stage perishable supply chain under discontinuous stages is implemented to minimize the total supply chain cost and develop the inventory policies for this supply chain. In this model, one supplier and multiple retailers are included in a supply chain. Both constant deterioration rate and varying deterioration rate following the Weibull distribution are discussed. Finally, a numerical example is provided to verify the appropriateness of this model. And the sensitivity analysis is conducted to explore the influences of different parameters with regard to the total cost and inventory policies. The results show that the model under Weibull deterioration rate is more sensitive on total cost than the one under constant deterioration rate.

4 - Measuring Nonprofit Business Strategy Performance Based on View of Leadership: The Case of National Museums
Yi-Shan Chen, Pei-Hsuan Tsai, Chin-Tsai Lin

The purpose of this study is to find the critical factors that influence national museum business performance based on curators' views and explore the causal relationships among the criteria of each sub-criteria. Since developing a business strategy is a multiple-criteria decision-making (MCDM) problem, this study adopts a causal-effect model of decision making trial and evaluation laboratory (DEMATEL). The DEMATEL technique simplifies and visualizes the interrelationships among decision-making criteria. This study found that four core criteria - benefits, opportunity, costs, and risks - influence national museum business performance. The key criteria of each sub-criteria were also identified, and an influential network relations map was obtained. The results of this study provide national museum curators with an idea-based understanding of how to create business and marketing strategies that enhance exhibition features, experience activities, and facilities to satisfy visitors' needs and encourage return visits.

5 - Unpacking network ties: The moderating effects of technology diversity on technology alliance portfolios
Chun-Hsien Wang, Chie-bein Chen, Chin-Tsai Lin

To understand how firms facing diverse external technological knowledge acquire from alliance portfolios, this study unpack interfirm alliance network into strong ties, weak ties, and dual ties component corresponding to use of diverse and complementary technological knowledge resources. Exploring a firm's interfirm alliance activities, we hypothesized that technology diversity in the interfirm collaboration network is associated with its impact on firm's technological knowledge resources acquisition. Hierarchical negative binomial regression is used to test the hypotheses on a database of 169 biomedical firms. The empirical findings provide strong support for the conjecture that technology diversity has a strong moderating effect between different network ties and technology alliance portfolios. The empirical results indicate that a high level of technology diversity may mitigate the benefits of external technology acquisitions because more diversified technologies weaken interfirm technology alliance network when firms source external technological knowledge.

■ MD-04

Monday, 14:30-16:00 - Building CW, ground floor, Room 6

OR and CO in Web Engineering 2

Stream: Operations Research and Combinatorial Optimization in Web Engineering
Chair: *Jedrzej Musial*

1 - A Conic Optimization Model for Replicated Data Stores in Geo-distributed Cloud Applications
Julio Góez, Juan F. Pérez

We consider a software application provider that serves a set of geographically distributed users by exploiting cloud resources. The application relies heavily on data as it provides its users with a service to access content via a set of channels, a service that must comply with a certain quality of service (QoS). In fact, data replication is implemented to ensure both availability and QoS. The application provider must decide where to locate and how to replicate the data, considering costs, QoS, and traffic patterns. The goal is to find the deployment of minimum cost, subject to quality constraints, defined in terms of the application response times. For this problem we introduce a mixed integer non-linear optimization model and show that it can be reformulated as an equivalent mixed integer second order cone optimization problem. We find that in many of our test instances CPLEX reaches the time limit without determining if the problem has a solution. To circumvent this issue we develop a feasibility test that also allows the derivation of an initial feasible solution for the problem.

2 - Dynamic Composition of Web Service Based on Cloud Computing
Nadia Halfoune, Hassina Nacer

Traditional web service discovery composition technology is hard to get adapted to dynamic, flexible modern business workflow. Due to the advantage of Cloud computing,dynamic, distributed, heterogeneous and autonomous nature to solve this problem provides a new way of thinking. This paper proposes a cloud computing environment that supports dynamic application service composition model, and in order to meet the real dynamic workflow environment, proposed cloud computing Web Service composition and workflow management system.

3 - Empirical examination of load time impact on search engine ranking
Jedrzej Marszalkowski, Jakub Marszałkowski, Maciej Drozdowski

Search engine ranking position is essential for e-business marketing. The factors influencing this position are not well-known and there is a lot of confusion over them. It is supposed that web page performance is one of the factors. We analyze the role of web page load time in the algorithm ranking the search results in Google. We made experiments on 40 phrases and load times, measured for the first 30 results for each phrase (which altogether makes 1200 websites). We studied two types of load time factors: crawl time and page load time, a.k.a. page speed. From the two metrics we studied, Google seemed to use the crawl time, i.e. time spent downloading a page by their robot. To quantitatively confirm the results, simulation of the ranking algorithm was performed. The simulations show that the load time factor plays role in the Google algorithm, although its weight is not very high. We also made a second set of experiments to confirm that load time is not only correlated with the ranking position, but also effectively determines this position.

4 - CSS-Sprite Packing Problem
Maciej Drozdowski, Jakub Marszałkowski, Jan Mizgajski, Dariusz Mokwa

CSS-sprite is a technique of packing many pictures of a web page into one image to reduce network transfer time. Construction of a CSS-sprite involves geometric packing, image compression and communication performance modeling. A problem of constructing CSS-sprites is formulated as transfer time optimization challenge. A method allowing to construct multiple sprites for one website is proposed. In order to test our method on practical data, benchmarking of real user web browsers communication performance covering latency, bandwidth, number of concurrent channels as well as speedup from parallel download has been performed. Our method, called Spritepack, is evaluated and it outperforms the existing solutions.

■ MD-05

Monday, 14:30-16:00 - Building CW, 1st floor, Room 8

Preferences and Problem Formulation in Multicriteria Optimization 2

Stream: Multiobjective Optimization
Chair: *Michael Emmerich*
Chair: *Iryna Yevseyeva*

1 - Portfolio Optimization Problem Formulation for Non-Standard Applications
Iryna Yevseyeva, Michael Emmerich

In this work we discuss portfolio optimization for different problem domains. Some examples follow: (1) selecting a team of experts with various complementary skills that together are best at completing a particular project; or (2) selecting a combination of websites matching best the search keywords in the recommendation systems; or (3) selecting a subset of countermeasures that together serve as the best protection of a system against potential cyber attacks; or (4) selecting a set of geo-exploration sites; or (5) selecting a set of molecules with highest chance for discovering a new drug. Closer analysis of these problems shows that they have some structural features in common: (a) there is a need for selecting not a single solution but a subset of solutions from a larger set, (b) the total quality of the selected subset has to be maximized, and (c) there is a need for preserving diversity of the selected items. Probably most detailed analysis of a similar formulation was taken in economics when solving portfolio selection problem, in which diversified assets have to be selected into a portfolio with potentially maximal return. Taking probability of success and diversity information into account one can search for a subset of items that simultaneously maximize expected gain of the portfolio and minimize risk of failing in finding successful portfolio. Here, models from financial portfolio theory are taken as a basis and extended to other applications.

2 - Solving Framework Based on Decomposition and integration for task planning of Satellite-ground time synchronization in GNSS
Feng Yao, Zhongshan Zhang, Longmei Li, Renjie He, Michael Emmerich

Satellite-ground time synchronization (SGTS) operation is a core operation in global navigation satellite system (GNSS). The task planning of satellite-ground time synchronization (SGCSTP) is to schedule ground stations to establish communication links with visible satellites for executing SGTS tasks. The SGCSTP is a complex multi-objective ground station scheduling problem, in which maximizing the minimal task duration and minimizing the maximal interval of two neighborhood tasks are two conflicting objectives. In this paper, the problem formulation is established and the computational complexity is analyzed by comparing with other ground station scheduling problems and several classical scheduling problems. Taking the difficulty of numerous variables and undeterminable decision variables into account, a solution framework based on decomposition and integration is proposed. This framework divides the plan horizon into many non-interactional plan periods evenly as well as all time windows are also divided into many nuclear tasks that distributed in each period, based on which the task planning problem turns into a nuclear tasks combinatorial optimization problem in each period, that is, a 0-1 programming problem. On the basis of decomposition we plan nuclear tasks in each period until all nuclear tasks are determined and then apply a splicing operation to integrate all nuclear tasks. In more detail, we design the decomposition framework as well as integration strategy.

3 - Industrial Application for Multi-criterial Decision Support
Daniel Ackerschott, Sebastian Engell

The high complexity of integrated processing plants makes it a hard problem for managers and operators to find the best operational strategy. And it becomes even more difficult when they have to deal with more than one criterion for optimality if trade-offs between conflicting goals have to be taken into account. Usually optimisation problems are set-up with a single objective function, where several criteria are compressed into one figure by weighting factors. Thus, the result is a single number without any leeway in decision making. In contrast, multi-criterial optimisation reveals the room for manoeuvre. Since the plant personnel have to balance several requirements in order to run the plant in an "optimal" fashion, we propose to use multi-criterial optimisation to assist them in their daily decisions.

The approach is applied to a real-world problem as a butadiene plant in combination with cooling towers; both models being in operation at the industry. While the butadiene plant consists of distillation columns and consumes a solvent, heating steam and cooling water, the cooling towers need electricity. Thus, the criteria for the optimisation are the minimisation of these utilities. As they are interchangeable to some extent, conflicting goals appear naturally while the multi-criterial optimisation reveals the important interdependencies. Here a variant of the NSGA-II algorithm is used to solve the MINLP.

4 - Maximizing the Total Net Revenue for Selection and Scheduling Problem with Earliness-tardiness Consideration Using Differential Evolutionary Algorithm
Xiaolu Liu, Cheng Chen, Renjie He, Feng Yao, Zhiwei Yang, Thomas Bäck

Our motivation originates from the agile earth observing satellite scheduling. Each target on the earth is described as a job. The satellite can look forwards or look backwards with different pitch angle within the limited time window which decides the earliest start time and the latest end time for observing the target. The best image quality is obtained when the satellite is right above the target with zero pitch angle. If the target is observed earlier or later than this time, relatively larger pitch angle is needed and the deterioration of image quality is incurred. We describe this problem as a selection and scheduling problem with earliness-tardiness consideration on a single machine with an objective of maximizing the total net revenue. Accepted jobs must be processed within their release dates and deadlines. An accepted job is punished on the revenue if it is delivered either before or after its due date. A hybrid differential evolution algorithm is proposed to solve this problem. Under each real-parameter vector, a directed acyclic graph is constructed satisfying the sequence-dependent setup times. The weight of each arc is the penalized revenue of the sink node of the arc. The individual is evaluated by finding a longest path in the graph. Experimental results illustrate that our proposed algorithm outperforms the classical DEs as well as another two variants of DE for solving the studied problem.

■ MD-06

Monday, 14:30-16:00 - Building CW, ground floor, Room 2

Group Decision and Negotiation

Stream: Multiple Criteria Decision Aiding
Chair: *Tomasz Wachowicz*
Chair: *Gregory Kersten*

1 - An Impact of Decision Making Profiles on Usefulness and Efficacy of Selected MCDM Methods in Building Reliable Scoring Systems

Tomasz Wachowicz, Ewa Roszkowska

One of the most important decision support tools in negotiations is the negotiation offers scoring system, which is a formal structure representing the negotiator's preferences in quantitative way - most preferably by means of cardinal ratings. It allows negotiators to evaluate the negotiation offers submitted during the negotiation process, measure the scale of concessions and analyze the negotiation progress. In this paper we analyze the usefulness and efficacy of selected methods MCDA as the potential tools for supporting the decision makers and negotiators in building the negotiation offer scoring systems. The online multiple criteria decision making experiment is described, in which the participants were using SAW, AHP and TOPSIS to analyze a pre-defined multi-criteria decision making problem. The usefulness of a method was measured by means of the decision maker subjective evaluation of the method's ease of use and usability; the efficacy describes the capability of the method to generate the ranking of alternatives that reflects the decision maker's preferences accurately. We analyze the results with respect to the decision making profiles of the experiment participants that were determined by means of the Rational-Experiential Inventory (REI).

2 - Brexit negotiations: applying different multi-criteria decision aiding techniques in the process of evaluating the negotiation template

Dorota Górecka

In a negotiation process, knowing the preferences of the decision-maker and building a negotiation offers scoring system are very difficult tasks. There are many different methods that can be used to develop such a negotiation support tool, including, but not limited to, techniques based on the multiattribute utility theory (MAUT) and the outranking relation, for instance SAW, AHP or PROMETHEE II, but all of them have some advantages and disadvantages. Thus, because of the great diversity of MCDM/A techniques proposed so far within the literature, making a decision on which method to choose is not easy and it requires the systematic analysis of their assumptions and properties. In this presentation the main strengths and weaknesses of particular aiding tools applicable to the problem of evaluating the negotiation template, namely MARS, SIPRES and WINGS, will be shown. Moreover, they will be compared with such approaches as TOPSIS and EXPROM II. As an illustrative example the problem of Brexit negotiations will be elaborated.

3 - Multi-attribute reverse auctions, buyers' transaction monopoly, and economic inefficiency

Gregory Kersten

Decision analysis shows that multi-attribute reverse auction mechanisms can be efficient only in situations that economists consider unrealistic. This means that the winning bids may be efficient solutions that maximize the buyers' surplus but they do not maximize social welfare, i.e., they are economic inefficient. The winning bids' surplus maximization and the social welfare loss are the result of the buyer's "transaction monopoly" rather than the mechanism's qualities. A modification that aims at increasing social welfare is based on the introduction of a post-auction negotiation during which the set of attributes is enlarged. A criticism of this approach is to acknowledge the multi-attribute reverse auctions inherent contradictions. This raises two questions: What mechanisms can replace reverse auctions without increasing frictions while at the same time maintain process efficiency? Should the design of exchange mechanisms be solely focused on the economic aspects of exchanges or include also their social aspects? Following the presentation of the formal underpinnings on which the above claims regarding the mechanism's inefficiencies are based, this talk aims at addressing these two questions.

4 - On the need for alternative approaches to building the negotiation offer scoring systems

Ewa Roszkowska, Tomasz Wachowicz

Simple Additive Weighting (SAW) is the most popular preference analysis method that is used for decision support in multi-issue negotiations. It is applied to structure the negotiation problems and build the negotiation offers scoring systems that represents the negotiator's preferences over the negotiation issues and offers in quantitative way. SAW is considered to be an easy and straightforward approach of low cognitive demand; some recent experimental researches suggest, however, that many negotiators are not able to use it effectively in building accurate and reliable scoring systems that reflect their intrinsic preferences correctly. In this paper we analyze the results of the online negotiation experiment conducted by means of the Inspire negotiation support system, in which the SAW-based preference elicitation method is applied. We study the accuracy of SAW-based scoring systems built individually by the negotiators and verify if they have used an additional preference analysis mechanism based on the conjoint analysis and implemented in Inspire. This mechanism changes the evaluation perspective and offers a holistic way of preference elicitation. We study how many negotiators used such mechanism in their pre-negotiation analysis and what was the effect of using it on scoring system accuracy. Acknowledgments: This research was supported by the grant from Polish National Science Centre (2015/17/B/HS4/00941).

■ MD-07

Monday, 14:30-16:00 - Building CW, 1st floor, Room 123

EURO Excellence in Practice, part II

Stream: EURO Awards and Journals
Chair: *Ton de Kok*

1 - An Integrated Approach to Tactical Transportation Planning

Jannik Matuschke, Tobias Harks, Felix G. König, Alexander Richter, Jens Schulz

Logistics costs constitute a major cost driver in today's economy and efficient planning of transportation processes is an important necessity for companies of all sizes and industries. We introduce a new model for tactical planning of freight transportation, capturing all important aspects of this logistical task: the routes of commodities within the network, the corresponding tariff choices as well as delivery frequencies and inventory levels. These different decisions are integrated into a unified capacitated network design formulation using a cyclic network expansion and a set of graph-based gadgets for realistically modelling the different classes of transportation tariffs occurring in practice. We complement our model by providing various algorithmic methods for solving the resulting optimization problem, most notably a local search procedure based on flow decomposition and an aggregated mixed integer programming formulation. These results are the outcome of a joint research project of TU Berlin and 4flow AG, a leading provider of supply chain consulting, software, and fourth-party logistics services. Throughout development, the model and the algorithms have been constantly evaluated on a broad set of instances obtained from recent and ongoing customer projects of 4flow AG. In a case study, a 14% decrease in logistics cost was achieved compared to previous optimization approaches. Our algorithmic toolkit has now been integrated into the standard software for logistics planning 4flow vista.

2 - Evaluating Gas Network Capacities

Thorsten Koch, Benjamin Hiller, Marc Pfetsch, Lars Schewe

In 2009 Open Grid Europe (OGE, at that time E.ON Gastransport) Germany's largest Transmission System Operator (TSO) initiated the ForNe project (in German "Forschungskooperation Netzwerkoptimierung") due to the new challenging problems resulting from the liberalization of the gas market. Over decades, gas transport had been more or less steady state with long-term delivery contracts and weather forecast predictable demands. Now, demand and supply change on a daily basis and are triggered by market prices, not by security of supply. Nevertheless, a TSO like OGE has to guarantee the latter, having only little influence on the trading process. These facts result in enormously challenging problems simultaneously including uncertainties, dynamical aspects, and feasibility questions. Mathematically, these problems lead to stochastic mixed-integer non-linear nonconvex optimization problems including PDE and ODE constraints. The research part of the project run until 2015 and and it was necessary to bring together expertise in mixed-integer programming, nonlinear programming, mixed-integer non-linear programming, stochastics, simulation, gas physics, network planning, law and regulations. The project involved about 40 people from OGE, five universities, and two research institutes. The whole team developed new mathematical models and methods, provided new theoretical insights into this kind of problems that lead to a completely new methodology for validating booked capacities, a task at the core of OGE's business operations. This cutting edge research was turned into a software system, bringing it directly into the workplace of the company. This software is now maintained and further developed by two university spin-offs working closely together with OGE's IT-department. To the best of our knowledge, the ForNe project was for the first time able to solve real-world mixed-integer non-linear non-convex optimization problems with tens of thousands of binary and continuous variables. This is a breakthrough in computational mixed-integer non-linear programming and will have influence on many other areas where OR and engineering aspects come together. The results of this research project are documented in the book "Evaluating Gas Network Capacities" published in 2015 in the SIAM-MOS Series on Optimization, in nine PhD theses and several publications.

3 - Using Mathematical Optimization for Scheduling Heat Treatment Production

Karin Thörnblad

During my studies for PhD, I developed an iterative scheduling procedure for the scheduling of a real flexible job shop, the so-called multitask cell at GKN Aerospace Engine Systems in Sweden. A time-indexed mathematical optimization formulation of the problem is repeatedly solved with increasing accuracy using smaller and smaller length of the time steps. To my knowledge it was the first time-indexed model formulated for a flexible job shop, and the first mathematical optimization model to include side constraints regarding preventive maintenance, fixture availability, and unmanned night shifts. After my dissertation, I was given the opportunity to further develop the scheduling model in order to adjust it to the planning situation of the heat treatment department at GKN Aerospace Engine Systems. The difficulties that were overcome during implementation and a first analysis of the impact of the first quarter of usage of the scheduling procedure in comparison with the corresponding quarter the previous year are presented. The main result from the analysis is that the utilization rate of the heat treatment department increased significantly between the two evaluated quarters.

■ MD-08

Monday, 14:30-16:00 - Building CW, 1st floor, Room 9

Complex preference learning in MCDA 5

Stream: Multiple Criteria Decision Aiding

Chair: *Chergui Zhor*

1 - Assessment of some MCDA methods: a comparative study

Chergui Zhor, Moncef Abbas

In this paper, we propose a new test to evaluate the multicriteria methods. It can help the decision maker to choose the best solution to his decision problem among several best solutions. This test was also used to compare between some MCDA methods. The test proposed is characterized by a remarkable flexibility in the selection of the best alternative. Indeed, there is no additional parameter involved in the computation (thresholds, reference points ...). Moreover, the ratio established between performances allowing to avoid normalization which can cause a serious stability problem. On the other hand, it makes exploitable the importance of variance between the performances. On different examples, we can show how this aggregation can privilege an equilibrant alternative compared to another having certain evaluations very weak and some qualities elsewhere; it can also weaken the effect of exaggerated compensation in the presence of important conflicts between criteria of two different alternatives. In addition, this formula involves a very small degree of intransitivity which depends, mainly, on the number of methods used. In order to study the percentage of intransitivity in existence of more than two good solutions, a statistical study was established. Using a randomly generated data (decision matrix and weight) we count the number of instances comprising at least one intransitive relation. In this paper, the proposed test is used to compare between some MCDA methods.

2 - The evaluation model of service development strategies for mobile instant message service based on IOA-NRM approach

Lin Chia Li, Gwo-Hshiung Tzeng

This study attempts to analyze the service functions for application of mobile instant message services and determine the service innovation driving forces of mobile instant message services based on users' needs. Additionally, this study explores users' needs for mobile instant message services and integrates the users' preferences of service innovation and service needs for the apps of mobile instant message services. This study proposes the IOA-NRM model (Innovation-Opportunity Analysis - Network Relation Map model), integrating the IOA technique and NRM technique. This study uses two analytic axles, i.e., service innovation axle (SII) and market opportunity axle (MOI), to build the IOA model. The IOA model can help decision makers determine the state of critical factors (aspects/criteria) and improve the innovation opportunity gap of critical factors. Besides, this study also uses the NRM (Network Relation Map) technique to understand the structure of the relationship between critical factors (aspects/criteria) and determine the critical driving factor in the network relation map. The IOA-NRM model can help decision makers determine the service innovation strategies and increase the service competitiveness and service loyalty for the Apps of mobile instant message services.

3 - Selection of Buses for a Travel Company with fuzzy TOPSIS Method

Funda Samanlioglu, Berfu Tayse, Merve Ceren Demircan, Gorkem Peker

Selection of the appropriate bus types for travel companies is a complex problem that requires an extensive evaluation process. In this research, as alternative bus types of a travel company in Turkey, Mercedes Travego, Neoplan Cityliner, Neoplan Efficientline, Temsa Safir, Temsa Safir-VIP, and Setra Double Deck are taken into consideration.

These decision alternatives are evaluated with respect to several benefit criteria such as fuel efficiency, cost efficiency, bus endurance, seat capacity, comfort and brand value. As the multiple attributes decision-making method; fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method is implemented in order to evaluate and rank these bus alternatives. In this method, linguistic preferences, specifically the weights of criteria and ratings of alternatives are converted to triangular fuzzy numbers and then used in the fuzzy TOPSIS calculations.

4 - A multi criteria model to evaluate research project proposals for public supports
Betül Cansu Özçakmak, Metin Dagdeviren

There are several public institutions providing support for R&D projects to the researchers. TÜBİTAK-ARDEB is a public institutions providing this kind of supports in Turkey. ARDEB provides non-repayable support to all researchers for R&D projects, especially to academics. ARDEB accepts project applications from all scientific fields with 8 different support programs and evaluates these applications using a specific evaluation system. Support decision is a complex decision problem.When the project proposals are evaluated, factors such as the R&D content, the original value, innovative aspect, the method should be taken into simultaneously. Determining the priority values of these factors is an important decision problem.The priority values of factors must be different in this problem discussed in the study. R&D content of the project proposal is more important than other factor in the evaluation process.In some cases, R&D projects which are lack of R&D content, are excluded from evaluation in terms of other factors. Decision makers generally decide subjectively in the process. So a multi-criteria model that will provide a more objective evaluation, was implemented. First project evaluation factors used in the evaluation process were prioritized and a practice was made for evaluation of 4 candidate projects using priorities. In practice, a sensitivity analysis based on the weight of R&D content factor was made. Effect of the weight change on project priority have been shown.

■ MD-09

Monday, 14:30-16:00 - Building CW, 1st floor, Room 12

MIP Software

Stream: Mathematical Programming Software
Chair: *Zsolt Csizmadia*

1 - Conflict Analysis in the Gurobi MIP Solver
Tobias Achterberg

Conflict analysis was invented in the SAT community by Marques-Silva and Sakallah (1999) and is now one of the key ingredients of modern SAT solvers. Ten years ago, conflict analysis was generalized to MIP solvers by augmenting the backwards propagation from SAT with an initial conflict extraction from an infeasible LP relaxation.

In this talk we take another look at conflict analysis and explain an alternative approach that is used inside the Gurobi optimizer. We discuss additional extensions that will be part of the next major release and investigate their computational impact.

2 - Reoptimization in Mixed-Integer Programming
Jakob Witzig

In many optimization algorithms several quite similar mixed-integer programs (MIPs) are solved as subproblems subsequently, e.g., solving the pricing problem in column generation. In this talk we present reoptimization techniques to benefit from information obtained by solving previous problems instead of solving each problem from scratch. We focus on the case that subsequent MIPs differ only in the objective function or that the feasible region is reduced. We propose an extension of the branch-and-bound algorithm based on the idea of "warm-starting" at the final search frontier of the previous solve.

3 - Parallelization of the FICO Xpress Optimizer
Timo Berthold, Stefan Heinz, Michael Perregaard

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

■ MD-10

Monday, 14:30-16:00 - Building CW, ground floor, Room 1

Complex Societal Processes, OR and Ethics

Stream: OR and Ethics
Chair: *Cathal Brugha*
Chair: *Dorien DeTombe*
Chair: *Gerhard-Wilhelm Weber*

1 - Behavioral analysis of social actors in municipal sanitation problematic
Juliana de Souza Hyczy Hamberland, Mischel Carmen N. Belderrain

Sanitation services have been a priority for public management because of the growing concern regarding environmental and public health issues. Sanitation covers four major infrastructure services: waste management, water treatment, sewage treatment and urban drainage. These four subsystems have a common, relevant social actor: the local population. Although not having the ability to make decisions for solving problems related to the subject, the population influences the decision-making actions as well as the consequences of those actions since population behavior may signify the success or the failure of a decision. Regarding the current scenario of the Brazilian municipality of Tibagi, Parana, Brazil, this paper presents the sanitation problem structuring considering the behavioral actions of the population in order to understand how population behavior impacts the four subsystems as well as the whole municipal sanitation system. A cause and effect analysis of the relevant variables that affect the sanitation services was performed. Also, an idealized design was conceived for further study applying System Dynamics modelling.

2 - Qualitative Analysis of Social Synchrony
Shantanu Biswas, Nirmal Kumar Sivaraman, Sakthi Balan Muthiah, Pushkal Agarwal

In this paper we intend to study the qualitative aspect of the synchrony of action in online social media. We collect the text content from the online social media over a time period. This time period is divided into smaller time slices of equal duration. Then we analyze the content qualitatively in two ways: (1) we look at each time slice and collect the contents posted in that time slice, and (2) we collect all the content with respect to each user over the entire time period. The qualitative analysis is the analysis of the content with respect to abstraction and expression. Abstraction refers to objective assertions about the topic or issue in question, while expression refers to communication of user's subjective feeling or emotion in that situation. Our main objective of looking this in two ways is to see if there are any pattern that we can find between the individual behavior and the group behavior in a social phenomena. The qualitative study of social synchrony is useful in many areas, for example, in identifying the suitable time slices and the suitable contents for viral marketing and identifying unethical behaviour in online MOOCs. We have done experiments on large data sets crawled from the popular social media site Twitter. Our experiments indicate that our model can identify the patterns in user actions during periods with and without synchrony.

3 - Combining Equity and Utilitarianism - Comparison of Two Approaches in Diet Modelling Context
J.c. Gerdessen, Argyris Kanellopoulos, G.D.H. (Frits) Claassen

Diet modelling is a useful approach for addressing complex issues regarding global food, nutrition and health challenges. Many diet models use some form of goal programming. Extended Goal Programming (EGP) is a widely used approach in multi-criteria decision making. It balances between equity and utilitarianism by optimizing a convex combination of a Rawlsian criterion and a utilitarian criterion. It is difficult to determine the precise value of the associated parameter. Recently, a novel approach for Combining Equity and Utilitarianism (CEU) was introduced. Its parameter has an intuitive meaning. We compare EGP and CEU in the context of a diet modelling problem. We contribute to the insight in CEU and in the added value of applying CEU in general and in diet modelling context.

4 - A New Analytics Model for Rethinking Ethics and Community
Cathal Brugha

We use nomology to rethink ethics, which comes from 'ethos' and relates to 'morals' and 'custom' in the community. Nomology balances the subjective 'logical' as in psychology with the objective 'nomical' as in economics; and 'self' with 'others' perspectives. Ethics is about excelling in four processes. Being 'subjectively' ethical 'oneself' is about 'committing' to developing the community through needs to preferences to providing value, having values. Corporate greed and political extremism are unethical. 'Subjectively' relating ethically to 'others' is about the duty to 'convince': firstly virtuous oneself, next deontologically in relation to others, and then about the consequences of one's impact on the world of practice. Corporate codes of conduct exist, but are not evidence of ethics. 'Objectively' in relation to 'others' there should be a balance between: capacity, capability, community, and contribution; responsibility, transparency, authority, and accountability; financiers, bureaucrats, citizens, and owners; banking, government, households, and corporate. An ethical deficit is about failure to protect the community; their authority over decisions; rights of citizens; impacts on households. In relation to 'self' one should 'objectively' balance addressing: fears, anxieties, guilt, and resentment; by faith, hope, righteousness, and love. A weak 'moral compass' ignores guilt, and righteousness.

■ MD-11

Monday, 14:30-16:00 - Building CW, 1st floor, Room 127

Discrete and Global Optimization 2

Stream: Discrete and Global Optimization
Chair: *Gerhard-Wilhelm Weber*
Chair: *Szymon Wasik*

1 - Finding Link Patterns in Networks
Stefan Wiesberg, Gerhard Reinelt

In network analysis, an established way to understand the structure of a network is to partition its vertices into regular equivalence classes. In the case of trading networks, for example, the relations between these classes reveal the type of the trading market: Some markets resemble production chains, where goods are iteratively sold from one group of companies to the next one (hierarchical market structure), others have a group of companies in the center of the market, which sell their goods to several peripheral company groups (center-peripheral market structure). To classify a given market in this manner is hence interesting from both a scientific and a strategic viewpoint. This classification problem can be modelled as a graph coloring problem, which we show to be NP-hard. We express the problem as a nonlinear integer program with polynomial constraints. We show that the problem is a generalization of well-known problems such as the Quadratic Assignment, Linear Ordering, and the Traveling Salesman Problem. An exact solver is presented which uses new linearization techniques for polynomial constraints and exploits the relations to the problem's well-known special cases. It is able to classify networks up to 50,000 times faster than comparable approaches from the literature. As this enables us to exactly evaluate networks with more than 100 vertices, we analyze the world trading network provided by the United Nations and present new structural results.

2 - Modification of the Assignment Problem for Counterfactual Impact Evaluation Purposes
Michal Švarc

Counterfactual evaluation is one of several possible approaches how to determine effects of projects or other activities like social politics interventions or impacts of new drugs. The first part of this paper focus only on propensity score matching as a technic how to determine average treatment effects. Next part of this article proposes an alternative method for matching which is using basic principles of assignment problem and provides an extension of this mathematical model for matching.

3 - Optil.io: a Platform for Organizing Challenges to Solve Optimization Problems
Szymon Wasik, Maciej Antczak, Jan Badura, Artur Laskowski, Tomasz Sternal

The objective of the talk is to present the OPTIL.io platform which was designed to make it possible to organize programming challenges based on the optimization problems. The platform runs in a cloud using the platform as a service model and allows researchers from all over the world to solve computational problems using a form of programming competition. Each of them can submit a solution using the on-line judge system that receives the source code of algorithmic solutions, compiles them, executes in a homogeneous run-time environment and objectively evaluates using the predefined set of test cases. The evaluation result is presented in the on-line, live ranking of all solutions to make it possible to follow how the solution compares to algorithms of other participants. The cloud environment provides the homogenous run-time environment that allows defining time and memory limits for evaluated solutions and supports almost any programming language. It includes among others C++, Java, C#, Python, as well as Linux binary files and CMake packages. Moreover, new compilers can be added quickly on request. It is also possible to integrate the environment with external libraries and software, such as linear programming solvers. We verified it during internal experiments at the Poznan University of Technology by judging over 1000 solutions in several programming languages.

4 - Methodology for Evaluation of Optimization Algorithms Executing on GPU
Jan Badura, Artur Laskowski, Maciej Antczak, Szymon Wasik

A significant problem that is often overlooked during the evaluation of optimization algorithms is the ability to optimize processing through the use of additional hardware accelerators such as graphic cards (so called General-Purpose Computing on Graphics Processing Unit, GPGPU). Efficient use of this hardware architecture may in some cases radically shorten the processing time. We would like to present a methodology and the platform that we designed to make it possible to compare optimization algorithms utilizing GPGPU in a homogenous environment. The platform called Optil.io is designed to allow users to utilize GPU in their algorithms. It also allows organizing programming competitions. During such contests, the usage of GPU is efficiently measured and can be compared among all participants. This approach was verified during internal experiments at the Poznan University of Technology and is ready to expand.

■ MD-12

Monday, 14:30-16:00 - Building CW, ground floor, Room 029

VeRoLog: Vehicle Routing Problems with Compartments and Other Variants

Stream: Vehicle Routing and Logistics Optimization
Chair: *Paolo Gianessi*

1 - Grocery Distribution with Multi-Compartment Vehicles
Manuel Ostermeier, Sara Martins, Alexander Hübner, Pedro Amorim

In this presentation, a capacitated vehicle routing problem (VRP) is discussed that occurs in the context of grocery distribution. Different temperature-specific product segments (e.g., frozen, ambient) are transported from a retail warehouse to outlets. The different product segments can either be transported separately on different trucks or together when multi-compartment vehicles are used. These trucks are technically able to have different temperature zones on the same truck by separating the capacity of a vehicle flexibly into a limited number of compartments. Hence, it has to be decided, which product segments and consequently which orders should be combined on each truck and which customers should be supplied with a direct-shipment. The number of compartments and joint delivery of product segments impact logistics costs in several ways. Therefore, a more specific distinction for the chosen way of delivery and the setting of each vehicle has to be made. For this problem, a model formulation that integrates these different cost aspects together with additional requirements into a VRP is introduced. In line with the new model, the development of a new solution approach is presented. It is tested using a case study with a retailer, benchmark data and simulated data. Contemplating the performed analyses, it is shown that the differentiation between divergent cost factors and the introduction of multi-compartment vehicles yield a significant savings potential for retailers.

2 - A hybrid metaheuristic applied to the refrigerated- and general-type vehicles routing problem for the delivery of perishable products
Jesus David Galarcio Noguera, Jorge Mario López Pereira, Helman Enrique Hernandez Riaño

The vehicle route planning, the selection of the vehicle type to transport products among other logistics decisions are being oriented toward the customer satisfaction, whose perception on the received product will directly affect the company. This study addresses this type of routing problem for refrigerated and general-type vehicles which deliver a perishable product knowing the demand, customer location, vehicle capacity and maximum number of vehicles of both types available. A nonlinear mathematical model for this problem is proposed, the objective is to maximize customer satisfaction considering the freshness and door openings of vehicles on the route, to solve this problem a hybrid algorithm that combines two metaheuristics is implemented, genetic algorithm (GA) and chromatic algorithm (CA), obtaining competitive solutions over other algorithms reported in the literature.

3 - A Branch-and-Cut-Algorithm for the Multi-Compartment Vehicle Routing Problem
Tino Henke, M. Grazia Speranza, Gerhard Wäscher

In this presentation, a variant of the multi-compartment vehicle routing problem (MCVRP) is considered. The MCVRP arises in a variety of problem settings where several product types need to be kept separated from each other while being transported. We investigate a variant of this problem which occurs in the context of glass recycling. In this problem, a set of locations exists, each of which offers a number of containers for the collection of different types of glass waste (e.g., colorless, green, brown glass). In order to pick up the contents from the containers, a fleet of homogeneous disposal vehicles is available. Individually for each disposal vehicle, the capacity can be discretely separated into a limited number of compartments to which different glass waste types are assigned. The objective of the problem is to minimize the total distance to be traveled by the disposal vehicles. For solving this problem to optimality, a branch-and-cut algorithm has been developed and implemented. Extensive numerical experiments have been conducted in order to evaluate the algorithm and to gain insights into the problem structure. The corresponding results will be presented.

4 - Linear-time Split algorithm and applications
Thibaut Vidal

The Split algorithm is a key ingredient of route-first cluster-second heuristics and modern genetic algorithms for several variants of vehicle routing problems. The classic algorithm is assimilated to the search for a shortest path in an acyclic directed graph, and performed in O(n'), where n is the number of delivery points. This complexity becomes O(Bn) when the number of customers per route is bounded by a constant B. In this presentation, we introduce a very simple and efficient labeling algorithm in O(n). We extend the method to deal with a limited fleet and soft capacity constraints, and exploit this enhanced efficiency to deal with side attributes, such as intermediate facilities or recharging stations for electric vehicles.

■ MD-13

Monday, 14:30-16:00 - Building CW, ground floor, Room 3

VeRoLog: Integrated Logistics Problems

Stream: Vehicle Routing and Logistics Optimization
Chair: *Demetrio Laganà*
Chair: *Luca Bertazzi*
Chair: *Christos Orlis*

1 - A Computation-Implementation Parallelization Approach for Computation-Time Limited Vehicle Routing Problem with Soft Time Windows
Bahar Cavdar, Joel Sokol

Increasing competition in supply chains forces companies into making better but computationally more demanding decisions. Therefore, solving integrated problems rather than focusing on one at a time has gained more importance. In addition to that, with the growing size of the problem instances, finding solutions to integrated routing problems in reasonable times can be difficult even for heuristic methods. This becomes a bigger challenge especially in real-time large-scale parcel delivery, where there is very little time between finalizing the problem instance and the time solution needs to be executed. In this study, we focus on a real-time Vehicle Routing Problem (VRP) with soft time windows and an additional constraint on the total time spent during the computation and loading. In the traditional compute-first implement-later approach, the convention is to use faster solution methods sacrificing the solution quality. As an alternative, we propose a computation-implementation parallelization approach. Our study is in two phases. In the first phase, we develop an effective heuristic for the VRP with soft time windows. Our tabu search algorithm employs a preprocessing step to speed up the computation. In the second phase, we propose new methods to embed the computation time into the loading. By this means, we can reduce the computation-only time and use it to improve the customer service level.

2 - An Exact algorithm for the Vehicle Routing Problem with Private Fleet and Common Carrier
Said Dabia, David Lai, Daniele Vigo

In this talk, I will present an exact approach based on a branch-and-cut-and-price algorithm for the Vehicle Routing Problem with Private Fleet and Common Carrier (VRPPC). The VRPPC is a generalization of the classical Vehicle Routing Problem where the owner of a private fleet can either visit a customer with one of his vehicles or assign the customer to a common carrier. The latter case occurs if the demand exceeds the total capacity of the private fleet or if it is more economical to do so. The owner's objective is to minimize the variable and fixed costs for operating his fleet plus the total costs charged by the common carrier. I will present the more general and practical case where the cost charged by the external common carrier is based on cost structures inspired from practice.

3 - A Branch-and-Cut algorithm for a Periodic Inventory Routing Problem

Demetrio Laganà, Domenico Ventura, Luca Bertazzi, Jeffrey Ohlmann

In an effort to remain competitive, companies are concerned with managing the transportation costs and inventory costs related to the operation of their supply chains. Popularized by the success of the Toyota Production System, many companies have incorporated the principles of lean manufacturing into the management of their supply chains. We present a mathematical model to determine a periodic routing plan that supports the lean principles of level production planning and standardized work.We consider a production system consisting of a single manufacturing plant and a set of geographically-dispersed suppliers. While supporting lean manufacturing principles, we seek to determine an inbound routing plan that collects component inventory from suppliers and delivers it to the plant at the minimum transportation and inventory holding cost.

4 - The Undirected Capacitated Routing Problem with Profits and Service Level Requirements

Christos Orlis, Demetrio Laganà, Wout Dullaert, Daniele Vigo

We consider the problem of collecting profits from servicing customers subject to a service level requirement. If this requirement is not met, a penalty is applied. The objective consists of finding vehicle routes maximizing the difference between the collected profit and the costs incurred by the total transportation costs and the (possible) penalty in such a way that the demand collected by each vehicle does not exceed the capacity and the total duration of each route is not greater than a given time limit. A fleet of homogeneous vehicles is given to serve the customers and outsourced vehicles are available if profitable. Computational experiments inspired by real-life data illustrate the impact of different penalty rules.

■ MD-14

Monday, 14:30-16:00 - Building CW, 1st floor, Room 125

MILP Applications 1

Stream: Mixed-Integer Linear and Nonlinear Programming

Chair: *Pablo Benalcazar*

1 - A Mixed Integer Linear Programming Model for Capacity Allocation and Shift Scheduling in a Multi-Product, Multi-Resource Environment for Multiple Periods

Ensar Kelez, Gorkem Yilmaz

One of the problems with productivity in manufacturing could generally be addressed to weakness in scheduling, by determining which tasks to be performed on which items with how much resources and when. In capacity planning for labor-intensive facilities with parallel assembly lines, capacity allocation is one of the most important topics and production capacity is directly related to the working hours and the size of workforce, therefore, shift scheduling provides flexibility in capacity planning. For each period, the number of workers to be hired or fired, crew assignment, shift scheduling including non-working days and shift length for every line and crew and the capacity allocation decisions are crucial in such facilities, and sub optimal decisions on these issues end up with extra cost. In this study we work on the problem of capacity allocation and shift scheduling in multi-product, multi-resource environment for multiple periods. A mixed-integer linear programming model is proposed to minimize the total cost of production which mostly depends on labor cost. The robustness of the model is tested by using past demand data in Vestel Electronics Inc. The results show that the model is strong enough to simulate the real life and a remarkable amount of reduction in total cost is expected.

2 - Matematical Programming Based Solution Approaches for Classification Problems in Data Mining

Müge Acar, Refail Kasimbeyli

Data mining is an important area for researchers because of developing technology. Classification is a significant technique of data mining. There are different mathematical programming approaches of classification in recent years. A technique uses mathematical model based polyhedral conic functions as an optimization tool. We present modified mathematical models used in that technique based on PCF functions. There are some comparisons on how mathematical models work on that technique. It is applied to real-world data sets.

3 - Restructuring Warehouse Locations: An Optimization Model

Pablo Benalcazar, Jacek Kamiński

Facility location plays a critical role on the economics of logistics and the energy consumption of road freight transport. The rising concern over the increasing fuel costs has motivated companies and supply chains to re-engineer and restructure their distribution networks. Around the world, various mathematical optimization techniques have been used to address the issue of cost efficient freight transportation. The primary goal of this paper is to develop a mixed-integer linear programming model (MILP) that can be applied as a decision-support tool for cost optimization and the strategic restructuring of a distribution network.

■ MD-15

Monday, 14:30-16:00 - Building CW, 1st floor, Room 126

Engineering Optimization 2

Stream: Engineering Optimization

Chair: *Wolfgang Achtziger*

Chair: *Ben Lev*

1 - A New Mathematical Model for Assembly Line Balancing with Station Paralleling

Hakan Altunay, H. Cenk Özmutlu, Seda Ozmutlu

An assembly line is a manufacturing process which consists of a set of workstations connected together by transport mechanisms such as conveyor systems. The problem of assigning tasks to workstations so that the total time required at each workstation is approximately the same by considering some constraints about cycle time or precedence relationships is known as the assembly line balancing problem. In this study, single model assembly line balancing problem with station paralleling is considered. Firstly, a new binary integer programming model is presented to solve the problem. The objective function of the model is minimizing the cycle time for a given number of workstation. However, any level of station paralleling is allowed in the model. Then, the proposed model is tested with a case study and some computational analysis are conducted to assess the performance of the mathematical model.

2 - Telecommunication Network Capacity Planning with Consideration of User Mobility Patterns
Argon Chen

With the booming use of smart phones and wearables, the mobile service industry is also in a thriving development pace. It also causes mobile users' increasing network demand. The uncertainty of wireless network demand is not only from the spatial and temporal variations, but also affected by user mobility behavior. The problem is how to manage and plan the network capacity to satisfy the highly volatile demand. Recent research has shown that the user mobility can be predicted to a certain degree of accuracy. For this reason, we propose to build a model of user transition pattern to describe the user spatial and temporal mobility behavior. With the model built, the network capacity planning is optimized accordingly. This research uses statistical data mining techniques to construct the transition matrix to describe the users' aggregated mobility behavior. We then develop heuristic aggregation strategies based on clustering algorithm and optimization techniques, such as hierarchical clustering, k-means, greedy and genetic algorithms according to performance surrogates and objective functions. These strategies are then used to improve the efficiency of wireless network resource planning.

3 - Solving the Airline Pilot Manpower Planning Problem using Matheuristics
Björn Thalén, Per Sjögren

The pilot manpower planning problem consists of the long term planning of recruitment and promotion to meet the forecasted crew need. The major complication of this problem is that many airlines have a strict seniority model for promotions of pilots, i.e., a pilot who has worked longer at the company should always be promoted first, if the pilot prefers the position. Additionally, resources used for training are both limited and very expensive.

Training a crew member to a new position may take up to six months, implying that training too many could be just as expensive as training too few due to loss of productivity during training. For each given time period; simulators, instructors and other training resources need constraints to avoid overuse. Distribution of vacation, recurrent training units, part-time, temporary moves and leave is also part of the manpower planning problem, and has been incorporated into the model. The model has been formulated into a mixed integer program. Naturally the problem is too large to solve directly, even as an LP relaxation. The solution approach focuses on LP-based construction heuristics, time sweep methods, and other very large-scale neighborhood search methods.

Substantial savings has been seen by airlines using Jeppesen products. In the talk we will give a more detailed description of the problem as well as present a high-level description of the mixed integer model, the heuristic solution process and successful applications.

■ MD-16

Monday, 14:30-16:00 - Building CW, 1st floor, Room 128

Dial-a-Ride Problems

Stream: Healthcare Logistics
Chair: *Marco Oberscheider*

1 - Multiple Passenger Dynamic Ride Sharing Transportation Models: An Analysis of Dispatching Policies
Lídia Montero, M' Paz Linares, Jaume Barceló, Carlos Carmona

Urban areas are complex systems that must address from a holistic perspective the challenges of sustainability. Mobility is a main component whose strong interactions with others has to be taken into account, namely in what concerns the transformational shift represented by the growing trend of "Ride Sharing" models enabled by the pervasive penetration of Information and Communication Technologies (ICT). This paper analyzes Multiple Passenger Dynamic Ride Sharing as a user-oriented public transport, characterized by flexible routing and scheduling of small/medium vehicles operating in shared-ride mode between pick-up and drop-off locations according to passenger needs; assuming that customers book the trip electronically, providing pickup and drop off locations and the desired pickup up and drop off time windows. Furthermore, the system is also aware of the current and short term forecasted traffic conditions to timely determine the optimal routes satisfying customers' time constraints. Our work deals with supporting the decision making process of assigning a vehicle to optimally provide the requested service for a customer, taking into account the new service requirements, the confirmed rights of the customers already being provided the service, and the current and estimated travel times in the urban network. The Decision Support System develops an ad hoc pickup and delivery real-time services with time windows (PDPTW) considering time-dependent shortest paths.

2 - Demand-Responsive Transit Systems: Optimization and network design strategies for large complex networks
Claudia Bongiovanni, Nikolas Geroliminis

In this paper, we present new strategies for the design and management of Demand Responsive Transit Systems (DRTS) for autonomous vehicles. The design of autonomous vehicles to be integrated with DRTS is currently under ongoing work for various Swiss cities. In OR literature, a class of models have been developed to deal with such systems, all of which are generalizations of the well-known Traveling Salesman Problem. In the dynamic Dial-A-Ride Problem with Time Windows (DARPTW), the goal is to optimize the dynamic routing and scheduling of a fleet of capacitated vehicles in an urban network in which demand changes over time and space with no a priori knowledge. The DARPTW has also been extensively investigated for the static case, in which demand is completely known in advance. In both cases, the optimization can be performed considering operational and quality costs, finding the trade-off between the agency's and the user's interests. Since the DARPTW is NP-hard, several strategies have been proposed in order to deal with large instances, including the cluster-first-route-second strategy. In this paper, real data are employed in order to investigate a mixed-static-and-dynamic case, in which part of demand is known in advance but new online requests are also allowed. We then seek to find ways to deal with the large-scale mixed-static-and dynamic DARPTW for autonomous vehicles in large complex networks by system design, dynamic clustering and learning strategies.

3 - Horizontal Cooperation in Dial-a-Ride Services
Yves Molenbruch, Kris Braekers, An Caris

A dial-a-ride system is an application of demand-dependent, collective people transportation. Users request a trip between an origin and a destination of choice, to which service level requirements are linked. The service provider attempts to develop efficient vehicle routes and time schedules, respecting these requirements and the technical constraints of a pickup and delivery problem. Given the ageing population, dial-a-ride systems gain importance to complement regular transportation modes. The current practice consists in that users choose a provider to submit their request. Multiple providers operating in the same area solve separate routing problems based on the requests they received. However, research in freight transportation suggests that joint route planning, i.e., a sharing of requests and vehicle capacity among providers, may cause joint operational benefits. The present research determines whether these benefits also apply to people transportation, characterized by tighter quality requirements. A new large neighborhood search algorithm is designed to solve the joint route planning problem, taking an integrated decision on (1) the assignment of requests to service providers and (2) the allocation of vehicles among the depots involved. A real-life case study confirms that such horizontal cooperation reduces joint distance traveled and required fleet size, without compromising the service level. A pattern is observed in which requests are exchanged among providers.

4 - Implementation of an Adaptive Large Neighborhood Search based Decision Support System for a Real-World Dynamic Dial-a-Ride Problem
Marco Oberscheider, Patrick Hirsch
The presentation deals with a real-world application of a dynamic dial-a-ride problem to optimize non-emergency ambulance services of the Red Cross in Lower Austria. The objective of the implemented adaptive large neighborhood search is to minimize the operation time of the dispatched vehicles while observing various types of constraints. The problem is specified by multiple depots with a varying number of heterogeneous vehicles. Vehicles start at depots on their first requested service and have to return after a specified shift length. Moreover, mandatory breaks have to be taken. With vehicles of type A up to three ambulant patients can be served, while vehicles of type B are able to transport a maximum of two patients with different types of mobility (ambulant, recumbent, wheelchair). Time windows are given at pickup locations and/or delivery locations and the extension of the ride time of one patient, due to the service of additional patients, is constrained. The duration for servicing patients at pickup or delivery nodes depends on the type of mobility, the vehicle type, the combination of patients and the pickup or delivery locations. Weekly problem instances with up to 11,438 requests are tested on real-life data. The solutions reveal the potential of the implemented decision support system.

■ MD-18
Monday, 14:30-16:00 - Building CW, ground floor, Room 023

Sustainability 1

Stream: Production and Operations Management
Chair: *Emanuel Melachrinoudis*

1 - A Green Approach to Reduce In-flight Food Waste under Uncertainty: a Preliminary Study
Lay Eng Teoh, Hooi Ling Khoo
Globally, climate change issue is getting critical nowadays and hence more attention from the operators of the air transport system is certainly required. In order to fulfill the social responsibility in preserving the environment, airlines should concern this issue not only in their planning but also operations. Besides, airlines' profit margin should be taken into consideration in fulfilling their social responsibility. As such, this paper develops an in-flight food weight control model with the aim to minimize the food waste of the in-flight catering services. The reduction of food waste would also contribute to the cost savings of the airline. The proposed study commences by resizing the in-flight meals, i.e., by offering a smaller portion of meal (which is termed as a light meal) to the passengers in addition to the existing in-flight meals with a standard portion. The results of illustrative example show that the food waste of the airline could be reduced to a greater extent. Besides, the airline would have a greater flexibility to meet the needs of the passengers under uncertainty. It is anticipated that the proposed green approach in this study may reveal some useful insights to the airlines in providing in-flight catering services environmentally and profitably.

2 - Optimizing the Collection Period of Products Returns under Uncertainty
Nizar Zaarour, Emanuel Melachrinoudis
We consider the problem of the collection of returned products from consumers and their shipping to manufacturers through initial collection points under freight quantity discounts. We develop a mathematical model that determines the optimal collection period at an initial collection point, while taking into account the uncertain rate of returns for these products. The optimal collection period is sought in order to minimize the total expected inventory carrying costs and shipping costs. To reflect the complexity of the product return process, we formulate a general model for a single product following both discrete and continuous probability distribution, and analyze the case for Poisson and Normal distributions.

3 - Time Series Price Dynamics of New and Remanufactured Products
Gu Pang, Supanan Phantratanamongkol, Luc Muyldermans

Extending the life-cycle of products has received increasing attention in the recent literature of closed-loop supply chains and reverse logistics. In this study, our aim is to empirically investigate price dynamics in terms of speed and timing of price erosion during a product life-cycle, and volatility and seasonality of time series. We collect prices for new and remanufactured smartphones and tables sold on eBay over a period of six months. We carry out the analysis by using SARIMA, ARIMA-GARCH, vector error correction models. Our results provide both original equipment manufacturers (OEMs) and remanufactures a better understanding of attaining time series economic value from co-existed new and remanufactured products.

4 - An empirical analysis of the relationship between product life cycle and return rate in IT industry
Hsiu-Chen Yang

Reducing product return rate is a critical task to manufacturers for warranty evaluation under severely market competition. Conventional business is to sell product under warranty base where additional revenue expected with low return rate. Very limited study investigating product life cycle as well as channel type may be the effective approach to diminish product return rate enabling manufacturers taking proper action timely. This study attempts to exam whether the product life cycle is related to the return rate. By collecting empirical data, the relationship for two channel types - B2B and B2C are analyzed.

■ MD-19
Monday, 14:30-16:00 - Building CW, ground floor, Room 021

Flows and routing problems

Stream: Telecommunications and Network Optimization
Chair: *Bernard Fortz*

1 - On the Convex Piecewise Linear Unsplittable Multicommodity Flow Problem
Martim Joyce-Moniz, Bernard Fortz, Luís Gouveia

We consider the problem of finding the cheapest routing for a set of commodities over a directed graph, such that: i) each commodity flows through a single path, ii) the routing cost of each arc is given by a convex piecewise linear function of the load, i.e., the total flow) traversing it. We propose a new mixed-integer programming formulation for this problem. This formulation gives a complete description of the associated polyhedron for the single commodity case, and produces very tight linear programming bounds for the multi-commodity case.

2 - New Lagrangian Relaxation Approach for the Discrete Cost Multicommodity Network Design Problem
Nesrine Bakkar Ennaifer, Safa Bhar Layeb, Farah Zeghal Mansour

The Network Design Problems (NDP) represent an important class of combinatorial optimization problems. We investigate a variant of the NDP called the Discrete Cost Multicommodity Network Design Problem (DCMNDP) which is defined by a connected undirected graph with a set of facilities that can be installed on each edge and a set of commodity demand flows. Each facility is characterized by a fixed installation cost and a capacity on the bidirectional flow that may traverse it. Each commodity requires the routing of a flow value from a specified source node to a specified sink node. So, the DCMNDP requires designing a minimum-cost network by installing at most one facility on each edge such that the installed capacities permit the prescribed commodity demand flows to be routed simultaneously across the network.

First, we derive quick lower bounds for this NP-hard problem by applying the Lagrangian relaxation technique on an arc-based formulation for the DCMNDP. To solve the obtained Lagrangian dual problem, we explore several variants of the deflected subgradient algorithm as well as a recent variant of the volume algorithm, using various direction-search and step-length strategies. Second, we derive feasible solutions by tailoring a new Lagrangian-based heuristic. We report the results of our extensive computational experiments on randomly generated and real-world instances, among them a set of benchmarks for the special case considering a single-facility and per unit costs.

3 - Modeling the Steering of International Roaming Traffic
Maria da Conceicao Fonseca, Carlos Lúcio Martins, Margarida Vaz Pato

Telecommunications operators that offer international roaming services need to decide to which foreign networks they should steer their customers in order to benefit from the most advantageous wholesale commercial conditions. This operational managerial decision, to be taken after the commercial conditions are set, translates to a traffic routing problem that is hereby conceived as an optimization problem. For this novel business application five mixed integer linear programming models corresponding to the most common commercial agreements in force in the industry are introduced under a year-planning managerial approach with multi-period decision dependency and uncertainty. The models are based on a minimum cost flow problem over a layered network. A computational experience was carried out using a comprehensive framework designed to generate structured semi-random instances that simulate diverse real-like market and business scenarios. Results for this experience are discussed according to business sustainability performance metrics and confirm the soundness of the models developed. Computational effort required in the experience was reduced.

■ MD-20

Monday, 14:30-16:00 - Building CW, ground floor, Room 022

Location in supply chains

Stream: Location
Chair: *Begun Efeoglu*

1 - Analyzing the Impact of Capacity Volatility on the Design of a Supply Chain Network
Diego Ruiz-Hernandez, Mozart Menezes, Kai Luo, Oihab Allal-Cherif

We attempt to shed light on the effect of demand stochasticity on the location and capacity decisions for new production facilities. We consider the case of a firm that aims at entering a new market, or introducing a new product in a known market. We allow the firm to rely on outsourcing when the built capacity is not enough to cover an unexpectedly high demand. This is particularly important when the market is being tested in order to get knowledge about the potential demand. The framework is that of a traditional Newsvendor problem where decisions will generate expected under- and over-capacity costs, which are function of both capacity investment and transportation cost (which in turn depends on the facilities location). What distinguishes this work from other inventory-location problems is that, in our case, the "critical fractile" is not uniform across facilities. Instead, we focus on the situation where the decision maker may intend to provide a higher service level to a group of demand points and a lower one to others. The objective of the decision maker is to maximise revenue profit net of transportation, capacity and outsourcing costs. This paper fits the stream of research aimed at jointly considering facility location and inventory management. From the location point of view, it is an extension of the Capacitated Facility Location Problem; however, we focus on the problem's structural properties and the insights they can bring for real-life applications.

2 - Impact of Demand Stochasticity on Facility Layouts
Begun Efeoglu, Melih Çelik, Haldun Sural

This study investigates the effect of demand uncertainty and the relayout cost on the choice of layout type in stochastic facility layout problems. To evaluate layout flexibility, alternative performance measures other than total material handling cost are defined. Using a two-stage scenario-based stochastic integer programming, we simulate its results in order to measure operational performance of the system in a dynamic environment. We then use dynamic programming model to explore the effect of the relayout cost on multi-period problems.

3 - The Risk-Aware Multi-Period Capacitated Plant Location Problem (CPLP-Risk)
Iris Heckmann, Stefan Nickel, Francisco Saldanha-da-Gama

Unexpected deviations and disruptions - subsumed under the notion of supply chain risk - increasingly aggravate the planning and optimization of supply chains. Over the last decade there has been a growing interest in including risk aspects for supply chain optimization models. This development has led to the adoption of risk concepts, terminologies and methods defined and applied in a broad variety of related research fields and methodologies. In Heckmann et al. 2015 the core characteristics of supply chain risk have been identified. Based on contemporary research gaps identified in Heckmann et al. 2015 for optimization approaches we introduce a mixed-integer two-stage stochastic programming model that extends the capacitated plant location problem and additionally offers the possibility to formalize and operationalize supply chain risk. The evaluation of the developed optimization model discloses its usefulness in terms of providing risk-aware solutions and of approaching risk by stochastic programming.

■ MD-21

Monday, 14:30-16:00 - Building CW, ground floor, Room 025

Crew planning

Stream: Public Transportation
Chair: *Dennis Huisman*

1 - Integrated Duty Assignment and Crew Rostering at Netherlands Railways
Thomas Breugem

This paper deals with the rostering of personnel at Netherlands Railways (NS), the main railway operator in the Netherlands. A main part of the overall planning process at NS is the Crew Planning process, i.e., assigning the set of tasks to the employees. A task is the smallest piece of work, e.g., most tasks consist of driving a train from one station to another.

Crew Planning at NS is solved in three phases: Crew Scheduling, Duty Assignment and Crew Rostering. The Duty Assignment problem consists of finding a 'fair' allocation (according to some measure) of the duties among the roster groups. The Crew Rostering problem is well known in literature, and consists of finding good rosters given a set of duties.

In the current approaches each of these problems is solved individually, although some interaction is present (e.g., adding constraints to assure a high chance of feasibility in next phases). Our main contribution is to integrate the Duty Assignment and Crew Rostering problem, thereby setting a new step into the direction of a fully integrated approach. We also demonstrate the benefit of using our integrated approach on practical instances from NS.

2 - Integrating Timetabling and Crew Scheduling at a Freight Railway Operator
Twan Dollevoet, Lukas Bach, Dennis Huisman

The planning process at a freight railway operator is commonly decomposed into three phases. First, a timetable is constructed for the trains; then, engines are assigned to all trains in the timetable and finally, duties are generated for the crew members. This paper focuses on the crew scheduling phase. Usually, a fixed timetable and engine schedule are used as input for the crew scheduling problem. We observed a low utilization in the engine schedules. As a consequence, many different optimal, and near-optimal, solutions exist for the first planning phases. We exploit these alternative solutions, by leaving some of the timetable decisions open for adjustment when scheduling the crew. When doing so, we make sure that the engine schedules remain feasible. In particular, we fix the order of tasks in each individual engine schedule, but allow to adjust the exact timing of these tasks when scheduling the crew. We have implemented a heuristic branch-and-price algorithm to solve this model. In the master problem, the timetable is determined and a suitable set of duties is selected. In the pricing problem, new crew duties are generated. The pricing problem is modeled as a set of resource-constrained shortest-path problems, which can be solved in parallel. We have performed an empirical study on cases from a European freight operator and show that costs can be significantly reduced in comparison to a purely sequential approach.

3 - Crew Rescheduling for the winter timetable of Netherlands Railways
Dennis Huisman

In this talk, we will consider the railway crew rescheduling problem, in case of a modified (winter) timetable. This winter timetable is operated when heavy winter weather is predicted. In a period of about 12 hours, the timetable, rolling stock and crew schedule are modified. A computation time of a few hours is possible for rescheduling the crew. In this talk, we present a new model and algorithm which has been developed to solve this particular problem. The algorithm uses column generation techniques combined with Lagrangian relaxation. Moreover, we discuss the challenges and outcomes of the tests that were performed such that the new algorithm and the new process could be used in the Winter 2015/16.

■ MD-22

Monday, 14:30-16:00 - Building CW, ground floor, Room 027

Applications in Combinatorial Optimization 1

Stream: Combinatorial Optimization
Chair: *Valentina Cacchiani*

1 - Heuristic and exact separation of robust cut-set inequalities
Daniel Schmidt, Chrysanthos E. Gounaris

We address the exact solution of a Robust Network Design problem with a single commodity. In this problem, the flow demands are uncertain and are realized from an uncertainty polytope. We consider the standard Hose uncertainty polytope and a hierarchical variant. Under these polytopes, we show how to separate robust cut-set inequalities for an integer linear programing formulation and propose both a tabu search separation heuristic and an exact separation algorithm that uses a mixed integer linear program.

2 - Solving Minimum-Cost Shared Arborescence Problems
Eduardo Álvarez-Miranda, Ivana Ljubic, Martin Luipersbeck, Markus Sinnl

In this work the minimum-cost shared network problem (MCSN) is introduced, where the objective is to find a minimum-cost subgraph, which is shared among multiple entities such that each entity is able to fulfil its own set of topological constraints. The topological constraints may induce structures like Steiner trees, minimum spanning trees, shortest paths, etc. The cost function to be minimized is a combination of the costs for the shared network and the costs incurred by each entity.

The minimum cost shared Steiner arborescence problem (SAS) is a special case of the MCSN, in which the underlying structures take the form of Steiner trees. The SAS has been used in the literature to establish shared functional modules in protein interaction networks. A cut formulation for the SAS and Benders decomposition thereof are proposed in this article and computationally evaluated and compared with a previously proposed flow-based formulation. The effectiveness of the algorithms is illustrated on two types of instances derived from protein-interaction networks (available from the previous literature) and from telecommunication access networks.

3 - Rolling stock optimization for the Danish railway system
Federico Farina, Roberto Roberti, Stefan Ropke, Evelien van der Hurk

In this talk, we present our work on rolling stock planning optimization. This work extends and analyzes the model and methods described in "A rolling stock circulation model for combining and splitting of passenger trains" (2006) by Fioole, Kroon, Maroti and Schrijver, which given departure and arrival times as well as expected number of passengers, assigns the rolling stock to the timetabled services. As proposed in this paper we also consider multiple objectives, the minimization of the total number of carriage kilometers, the total number of seat shortage and the shunting movements. We test variations of the original and present valid inequalities for the problem. We show the result of the different models applied to real life instances from the Danish national railway system for regional, intercity trains provided by the main train operator.

4 - Flight Retiming in an Integrated Airline Scheduling Problem
Valentina Cacchiani, Juan José Salazar González

We integrate three stages of the airline scheduling problem, namely fleet assignment, aircraft routing, and crew pairing, and combine the integrated problem with flight retiming (i.e., we allow a given discrete set of alternative departure times for each flight). Our goal is to determine solutions that are robust against delays, but also efficient in terms of cost minimization. To achieve this goal we adapt a solution approach proposed in (Cacchiani and Salazar-Gonzalez,2015), so as to improve the robustness and efficiency of the derived solutions. We formulate the problem as an Integer Linear Programming (ILP) model, with path variables that define the crew pairing and arc-flow variables that represent the aircraft routing. Column generation of the path variables is applied to solve its Linear Programming relaxation. A heuristic solution for the problem is computed by solving a restricted ILP model that contains all the arc-flow variables and only the path variables generated during the column generation process. Preliminary computational experiments on a set of real-world instances, provided by a regional airline company flying in Canary Islands, show that flight retiming is very effective in reducing the short and the long connections, thus leading to a more robust and efficient schedule.

■ MD-23

Monday, 14:30-16:00 - Building CW, ground floor, Room 028

Social Networks

Stream: Graphs and Networks
Chair: *Natalia Meshcheryakova*

1 - On the similarity of central nodes in complex and sparse networks
Sergey Shvydun

The detection of central nodes in complex networks is one of most challenging tasks in network theory. Many centrality measures that allow to rank nodes of the network based on their topological importance were designed. Unfortunately, most of them cannot be applied to complex networks due to their high computational complexity. This leads to the fact that simpler measures in terms of their complexity should be used or some other techniques should be designed. We propose another approach on how to detect central elements in complex networks. Instead of calculating centrality measures with a high computational complexity on complex networks, we can apply them on its smaller analogues. If the sets of central nodes in small and complex networks are similar, some centrality measures with a high computational complexity can applied to complex networks. Thus, we consider different existing centrality measures as well as some rules from social choice theory based on majority relation (uncovered sets, untrapped sets, etc.) and different network elimination techniques. Our main focus is on the study of the similarity of sets of key nodes in complex networks and its subnetworks. The results show how the initial network should be narrowed in order to maintain a set of key nodes of the complex network and which centrality measures can be applied to complex networks. The experiments were performed on random networks with exponential degree distribution as well as on some real networks.

2 - Algebraic operators for the improvement of centrality indices

Valter Senna, Hernane Pereira, Andre Chastinet

This paper focuses on centrality indices for social and complex networks. Specifically, in the social network literature, there are several indices that attempt to capture the importance or pre-eminence of actors in a network: degree centrality, eigenvector centrality, closeness centrality, betweenness centrality, etc. We believe that to study diffusion on networks, most available indices do not perform well as they do not account for the relative importance of actors due to the importance of their neighbours and of the neighbours of their neighbours at different linking paths. We therefore introduce some algebraic operators that act upon those indices to transform them, in order to take into consideration the importance of the other actors in the network at different distances. From simulations so far, we show that an information or disease originating from actors with a high value on these transformed indices spreads faster than those that originate on actors with high values on the same untransformed index, as traditionally used in the Social Network literature.

3 - Influence estimation in networks by long-range interactions

Natalia Meshcheryakova

We propose new methods for influence estimation of nodes in a network. Our methodology takes into consideration the intensity of the connections between nodes as well as their individual attributes. We consider different decisive groups of nodes, estimate their influence to each node of the network and then aggregate the results to a single value. A distinct feature of our methods is that they consider both direct and indirect connections between nodes and take into account possible chain reactions in the system. The approach is based on two different ideas: the first one is the analysis of the distance between nodes where we examine the influence through all paths between them; the second one is the analysis of the influence with the help of simulations where we actuate some groups of nodes and then analyze the changes in the system. We impose additional parameters (the maximum path's length, the size of nodes groups, etc.), which can be changed with respect to the problem and used to reduce the computational complexity. Various methods on how to evaluate the power of each path between nodes and aggregate path's influences are proposed. We applied our methodology to real networks and compared results with the existing techniques of influence estimation. The results showed that our approach elucidates hidden participants that are influential in the system.

4 - Overlapping Kernel-Based Community Detection with Node Attributes

Elisabetta Fersini, Enza Messina

Community detection is an important task that allows the discovery of the structure and organization of online social networks. This problem is usually addressed by exploiting some structural properties of the graph underlying the social network, assuming that connections among users can be used to model homophily. However, users can be characterized by several attributes (e.g. user profiles, posts, etc. . .) that can be used to measure user similarity and improve the accuracy of the community discovery. In this work we consider both user/nodes cohesion and similarity in order to identify community structures of auxiliary members aggregated around kernel users (opinion leaders). We first determine an initial hypothesis of kernel users through a greedy approach. Then, we formulate an optimization problem that considers both the graph structure and the node attributes to identify kernel users, and propose a heuristic approach for determining the optimal kernels. Finally auxiliary users are associated to the identified kernels allowing overlapping among communities. We will present a comparative analysis on three benchmark datasets, derived from Wikipedia, Twitter and Facebook respectively, showing that considering node attributes and modelling overlapping communities can strongly improve the accuracy of the detected communities.

■ MD-24

Monday, 14:30-16:00 - Building BM, 1st floor, Room 119

Defence and Security 4

Stream: Defence and Security

Chair: *Ana Isabel Barros*

1 - Terror Queue Staffing and The Detection of Terror Plots

Edward Kaplan

How many good guys are needed to find the bad guys? To answer this question, simple staffing formulas are developed with the objective of preventing a specified fraction of terror attacks (or related objectives). These results depend upon the terror queue model of the detection of terror plots. Terror queue models equate newly hatched terror plots to arriving customers, ongoing terror plots to the queue of customers waiting for service, and undercover agents or informants to service providers. Not all plots are interdicted (receive service); successful terror attacks correspond to customers who abandon the queue! Motivated by a recently published estimate of the probability distribution for the duration of Jihadi plots in the US (time from plot initiation until interdiction or an attempted attack, whichever comes first), the staffing formulas are shown to hold for terror queues with proportional hazards, that is, when the instantaneous probability of detecting a plot is proportional to the instantaneous chance of a terror attack.

2 - Understanding Terrorist Attacks: Evidence Based Estimation of Terrorist Organizations' Search Patterns

Johannes Jaspersen, Gilberto Montibeller

The continuing threat of terrorist attacks poses severe challenges to policy makers in charge of counter-defense strategies and highlights the importance of understanding the patterns of terrorists' actions. In early applications, methods from probabilistic risk analysis have been applied to support decisions about counterterrorism measures. In these models, the behavior of terrorists was assumed as static, similar to modeling a natural catastrophe. Because terrorists are purposeful agents, game theoretic models of terrorist-counterterrorist interactions have been suggested since then. However, the implicit assumptions of common knowledge and rational behavior of terrorists in these models have also been criticized. The consequence of this debate was the emergence of a new generation of models in which terrorists are seen as boundedly rational. Despite this evolution, none of the models are based on empirical evidence about terrorists' behavior and thus may not be descriptively valid.

We attempt to fill this gap in counterterrorism modelling by using a global database on terrorism incidents to understand how terrorist organizations choose their modes of attack. Using well-established models on search patterns from psychology, we provide insights on how behaviorally valid, evidence based models of terrorist behavior might be developed. Such models can be used in the development of counterterrorism strategies for defense measures.

3 - The Impact of Timetabling on the Efficient Evacuation of a Facility in the Event of an Emergency
Hendrik Vermuyten

In many situations, a large number of people gathers in a single location. Examples include people attending a conference or students in large university buildings. In the event of an emergency, such as a fire, the efficient evacuation of the facility is of primary importance. Many optimization models have been developed to find optimal evacuation plans. These models currently only consider evacuation route choice and phased evacuation, where different groups of people start evacuation at different times, as decision variables. However, the timetable of the event impacts the evacuation as well, because the assignment of activities (e.g., sessions or lectures) to timeslots and locations determines the distribution of people over the facility over time. In this research, we investigate how this aspect can be incorporated into the timetabling problem.

4 - Real-Time Police Patrol Guidance
Johanna Leigh

There is currently an emphasis within police forces to base their policing on evidence rather than past procedures or bias opinions. An area where evidence based policing can be applied is patrolling of response officers. There are two main requirements of patrols, firstly they should position officers in a configuration which can cover response demand within target response times and secondly they must target high crime areas, hotspots. Presently there is little in the way of patrol positioning for demand coverage unlike similar emergency services such as ambulances which have extensive research in the area. This is due to the added requirement for police to be visible to the public, as this has the potential to deter crime. This research develops an algorithm which determines best positioning of patrols in real-time. Hotspots are identified by kernel density estimation using historical crime data. These hotspots are then used as regions to direct patrols towards, as a uniformed officer presence in these areas can deter crime. Response demand is also analysed to determine the levels of demand over the region. The positioning problem is then solved in real-time choosing certain hotpots to direct patrols to; based on the number of officers available, officer locations, the history of hotspot visiting and the configuration which provides the best demand coverage. Simulation proves that using predictive policing in this application reduces response times and overall crime levels.

■ MD-25

Monday, 14:30-16:00 - Building BM, ground floor, Room 19

Modelling human behaviour

Stream: Behavioural Operational Research
Chair: *Sean Manzi*

1 - Analyzing supply chain planning behaviors with agent-based modeling and simulation
Can Sun, Thomas Ponsignon, Thomas Rose

Supply chain planning in manufacturing has multiple interfaces with sales, marketing, production and logistics, which are responsible by respective planners collaborating with each other. The quality of supply chain planning is determined by the accuracy and stability of planners' behaviors. This brings challenges to the semiconductor manufacturing characterized by long cycle time, where improper planning behaviors might lead to significant negative impact to the entire supply chain. However, it is difficult to align them since planners have their own cognitive biases and may behave diversely. Risk literacy is considered to be a dominant cognitive factor which could affect human's decision making. Therefore, we hypothesize that human performance is correlated to the individual risk literacy and then validate it using experiments. Our research target is the supply chain planner, a representative agent with two tasks: demand forecasting and inventory planning. A four-stage beer game is conducted in order to gather the empirical data and extract behavior patterns under different risk literacy settings. Using agent-based modeling technique we can program these patterns into a simulation engine and thus analyze various behaviors and performance under different scenarios. Preliminary experimental results show directions to apply the behavior simulation model to the real semiconductor industry. In the next step, other criteria which influence the behaviors will be investigated.

2 - An Agent-Based Model of Teams under External Shocks
Duncan Robertson, Leroy White

In this paper, we review the mechanisms for creating artificial social networks. We use an agent-based model to generate dynamic Preferential Attachment networks, and expose these networks to exogenous shocks. This causes these networks to cleave under their weakest point, using Newman's concept of modularity. We examine the resultant giant component and repeat the process to examine whether exposing a social network to repeated shocks creates more robust or less robust networks. We compare these results with empirical data from a longitudinal network study. We provide findings which may be of use not only to the behavioral operational research community but also to the wider human resources management community.

3 - Soft OR and SNA for Simulating Human Behaviour
Salimeh Pour Mohammad, Angela Espinosa, Richard Vidgen

Although soft OR tools advocate specific solutions for complexity management in organisations, there is little account of research on using soft OR tools to deal with complexity of knowledge sharing projects. In addition, research on simulating social networks through soft OR, being designed specifically for knowledge sharing projects is very scarce. This paper fills these gaps, presenting an experimental action research where the authors facilitate a process of knowledge sharing through goal orientation in a non-hierarchical and collaborative fashion, leading to performance improvement and capability development. We use Viable System Model and domains of viable knowledge for problem structuring to simulate the human behaviour in a social network of knowledge. Embedding distinctive features of VSM, the intervention encourages participants to embark on specific type of variety engineering in social network at different levels. We reflect on the distinctiveness of the methods used and their contributions to research in soft OR and social network simulation in knowledge sharing projects.

4 - The basic components for simulating human behaviour in complex systems and associated research challenges
Sean Manzi

One aspect of behavioural operational research (BOR) is simulating human behaviour in systems. This presentation will discuss the minimal components required to construct a simulation of human behaviour and compare different techniques for creating these components. Two of the most basic facets of human behaviour are our ability to make decisions and learn from our interaction with our environment. This simplification of human behaviour can serve as a basis for simulating it. Psychology and ecology have used linear threshold models (also known as aggregation models) to model decision making. These models have found favour due to their biological similarity to neuronal firing and transmission. Simpler mechanisms are available and will be compared. People make decisions based on previous experience whether consciously or unconsciously. Memory and the integration of information can be represented using different methods such as a linear operator learning rule to the use of genetic algorithms and machine learning. Deterministic and stochastic rule based structures can be used in a simulation of a complex human system to coordinate the decision making and learning of the individual, producing measurable system behaviour. Understanding how best to bring together decision and learning mechanisms, under what circumstances certain techniques will work best and how such these models can be validated are topics that need to be high on the BOR research agenda.

■ MD-26

Monday, 14:30-16:00 - Building BM, 1st floor, Room 109D

Dynamical Models in Sustainable Development 4

Stream: Dynamical Models in Sustainable Development
Chair: *Yao Liang*

1 - Decision-making for energy system planning using TIMES: the uptake of decentralized generation and storage technologies on a community-scale
Mashael Yazdanie, Martin Densing

This study presents a framework to quantitatively evaluate the role of decentralized generation and storage technologies (DGST) in future energy systems planning and policy-making on a community level. Cost optimization energy system models are developed for a rural and urban community in order to analyze long-term capacity planning and dispatch. Energy system models are built using the TIMES framework. TIMES enables the development of bottom-up energy system models using linear programming for cost optimization. The developed models capture the entire energy system and conversion chain, including residential, service and industrial sectors. End-use energy demand includes heat and electricity. Several scenarios are developed to assess the impacts of different technology mixes and carbon mitigation policies. The degree of DGST adoption is case-dependent and influenced by several factors, including the existing energy system, resource availability and technology access. A shift towards decentralized electricity and heating systems is observed in both the rural and urban case study, accompanied by a substantial reduction in national grid imports. Storage technologies, such as building-level heat storage, also enable notable savings, partly due to reduced investments in grid infrastructure. Small hydro, solar and micro-CHP technologies play a key role in the future energy mix of the communities studied. Carbon pricing policies are also found to be effective in reducing emissions.

2 - Methodology for the reduction of Greenhouse Gas Emission in an Ethanol Supply Chain
Bruno Ignácio, Sergio Pereira

The proposed research aims to analyze the application of a methodology that seeks to reduce the emission of greenhouse gases in an ethanol supply chain located in Brazil. In summary, it intends to assist the decision-making process in situations involving the management of greenhouse gases (GHG) emissions. In this sense, this research considers that the supply chain management (SCM) and sustainability studies have become more relevant to organizations during the recent years. However, even with this relevance, the SCM theory must be improved to meet environmental aspects. Initially, the environmental procedures were focused on the internal scope, with time it was developed new environmental techniques that were not restricted to companies' borders, such as reverse logistics, green supply chain management and the administration of GHG emission. This study assumes that the GHG reduction processes should consider all activities that happens in the supply chain. With that it is proposed a methodology to optimize it. To validate it, was simulated an implementation in an ethanol SC, which begins in the state of Mato Grosso do Sul and ends at the port of Santos, where the product is exported to different countries. The results obtained in the simulations show that the implementation of the methodology can optimize greenhouse gases emissions of the ethanol SC analyzed in all simulated scenarios.

3 - The problems of modelling and analysing in complex multi-scale systems dynamics
Lyudmila Kuzmina

The research is aimed at developing approximate methods in nonlinear multi-scale dynamics based on A.M. Lyapunov methodology. The stability theory methods, with asymptotic approach allow to establish the comparison method in reference to fundamental modelling, optimization, control problems in complex systems dynamics, to get the extension of reduction principle for general qualitative analysis, covering critical cases (quasi-Tikhonov's systems). Original model, adequate to real process, as a rule is very complex, multi-disciplinary; and it is leading to nonlinear highly-dimensional, multi-connected problems (for instance,in dynamics of oscillation systems, gyroscopic systems, robotic-technical systems, vibration-protection systems ...). The existence of processes with different characteristic times is generating the additional difficulties in study by numerical methods; it is causing the specific problems of computing process stability (the badly conditioned matrices). This generates the need of system decomposition, of reduction to shortened subsystem, giving qualitatively equivalent shortened model. The fundamental problem is arising: the development of regular algorithm for the building and substantiation of decomposed models acceptability. The constructed approach allows to develop optimal ways of mathematical modelling, to establish the approximate methods in exact analysis for engineering practice with generalizing classical results.

4 - Assessing coordinated development of society, economy and environment based on ecosystem service value: A case study of Beijing City, China
Yao Liang

In the context of China's rapid urbanization, the conflicts among society, economy, and environment in urban area have become increasingly intensive and serious, which greatly threaten regional sustainability. This paper presented a comprehensive assessment of coordinated development level in a society-economy-environment system by integrating ecosystem service value (ESV) into the coordination indicator system. Beijing, the capital and one of the most developed cities in China, was employed as the study case. On the basis of panel data in 2003, 2008 and 2013 for Beijing city, main results can be shown as follows: (1) the total ecosystem service value of Beijing decreased from 34,107.62 million Yuan in 2003 to 29,088.01 million Yuan in 2008, and increased to 32,047.47 million Yuan in 2013. (2) the dynamic of coordinated development level in Beijing presented a U-shape curve. (3) Beijing's coordinated development level evolved from preliminary unbalanced development to barely balanced development during the study period. This study has practical policy implications for government to balance social, economic and environmental development under urbanization and industrialization process.

■ MD-27

Monday, 14:30-16:00 - Building BM, ground floor, Room 20

Dynamic Programming 1

Stream: Dynamic Programming
Chair: *Lidija Zadnik Stirn*

1 - Google's AlphaGo, Monte-Carlo Tree Search, and Dynamic Programming
Michael Fu

In March of 2016 in Seoul, Korea, Google DeepMind's AlphaGo, a computer Go-playing program, defeated the reigning human world champion Go player, 4-1, a feat far more impressive than previous victories by computer programs in chess (Deep Blue) and Jeopardy (Watson). The main engine behind the program combines machine learning approaches with a technique called Monte-Carlo tree search, a term coined by Rémi Coulom in his 2006 paper. Current versions of Monte Carlo tree search used in Go-playing algorithms are based on a version developed for games called UCT (Upper Confidence Bound 1 applied to trees), proposed by Kocsis and Szepesvári (2006), which addresses the well-known exploration-exploitation trade-off that arises in multi-armed bandit problems by using upper confidence bounds (UCBs), a concept introduced to the machine learning community by Auer, Cesa-Bianchi, and Fischer (2002). We review the main ideas behind UCBs and UCT and show how UCT traces its roots back to the adaptive multi-stage sampling dynamic programming (DP) algorithm for estimating the value function in finite-horizon Markov decision processes

(MDPs) introduced by Chang, Fu, Hu, and Marcus (2005). This 2005 paper was published in Operations Research and was the first to use UCBs for Monte-Carlo simulation-based DP solution of MDPs.

2 - A simple model for a timber transportation scheduling problem
Jean-Sébastien Tancrez

Timber transportation is a major activity in the forest industry and leads to challenging operational research problems. In this work, we study a log-truck scheduling problem inspired by a real case from a Belgian forest company. It aims at designing the weekly schedule for the transportation of timber from harvest to demand points. In this problem, drivers start and end their working day at home and have a limited working time per day. The quantity available in harvest points is typically several truckloads and full truckloads are thus supposed. The cost function is proportional to the total number of working days (by all drivers), and time windows at the harvest and demand points are not included. The characteristics of the case allow us to propose an integer optimization model which is easy to implement and solve. In particular, the model does not include the order in which forests are visited by a driver. While the log-truck scheduling problem is often related to pickup and delivery problems in the literature, the order of the nodes in the route do not have to be included in our modeling, as truck flow balancing is sufficient. When applying our approach to the inspiring case, our model shows to be efficient, finding good solutions (optimality gap of few percent) in a reasonable time (few minutes). The results reveal a significant improvement compared to the actual schedule used by the company.

3 - A Model for Scheduling Tanker Shipments
Mico Kurilic

A tanker can carry different products from one of the origin ports to one of the destination ports. For known supply of products and demand due dates, the model determines timing and quantities to be loaded and discharged from tankers so that tank capacities at port terminals are not exceeded. The objective of the mixed integer programming model is to minimize total transportation cost of all tanker shipments. Our heuristics builds the schedule of tankers along planning horizon and adds one shipment at the time by selecting its origin, departure date, tanker size, and quantities of products to be shipped. At any current iteration for every origin-destination pair and for each product separately, a look-forward function computes maximum product quantities that can be shipped on different departure dates without violating storage capacities in terminals. A tanker size and departure date are selected for every origin-destination shipment so that the total quantity of all products that can be shipped on that date is maximized. Only one tanker shipment with maximum potential saving in transportation cost is added to schedule.Inventory data is updated and procedure repeats until the end of planning horizon is reached.

4 - The Attended Home Delivery Management by Approximate Dynamic Programming with Continuous Delivery Distance Approximation
Xinan Yang, Arne Karsten Strauss

Attended home delivery is the most popular delivery strategy that has been considered by e-grocers. To provide such services, the firm sends out delivery vans to visit customer locations within pre-decided time slots to drop orders. This leads to a logistics challenge for the firm to effectively manage the geographical location of customers and their time-window requirements, as delivering an order in one time slot or another normally yields very different costs to the firm. In this study we investigate how to manage the delivery price dynamically to steer customers' choices of time slots to enhance the e-grocer's profit. The opportunity cost of this problem consists of two parts: the potential revenue loss of committing a new order and the additional cost for delivering it. Unlike revenue management in airline, the second part relies on the solution of a full routing problem which is itself NP-hard. To provide an instant online estimation to the additional delivery cost, we propose a geographical decomposition of the service area based on a continuous routing distance approximation strategy, and use ADP with linear regression to calculate the opportunity cost. The resulting model balances out the unfairness for orders arriving at different times over the booking horizon, and effectively increases the average revenue of the accepted orders. Numerical study with a major e-grocer's data justifies the performance of our pricing policy.

■ MD-30

Monday, 14:30-16:00 - Building BM, 1st floor, Room 110

System Dynamics Business Modelling. Workshop for Managers, Consultants and Students 2

Stream: System Dynamics Modeling and Simulation
Chair: *Kim Warren*

1 - System Dynamics Business Modelling. Workshop for Managers, Consultants and Students 2
Kim Warren, Markus Schwaninger

This is the second part the system dynamics business modeling workshop

■ MD-31

Monday, 14:30-16:00 - Building BM, 1st floor, Room 111

Performance Analysis in Sports

Stream: OR in Sports
Chair: *Uday Damodaran*

1 - Spatial Skills of Players of the Beautiful Game
Deepak Dhayanithy

Soccer players are continually trying to not only contest, pass or shoot, but also to cover ground and change their position on the pitch. This spatial maneuvering is in a bid to create the best conditions for the team as a whole to succeed. Whereas player ratings (www.whoscored.com) have begun to acknowledge subtler player skills, such as through balls, runs and decoys, they continue to be goal and event oriented. While soccer fans already observe, for example, how top players are positioned on the flanks to create space for other teammates, the study of astute tactical maneuverings, continues to be absent in research. Player ratings too may not currently reflect the full array of soccer skills. Using player position as the spatial variable inter-relating players, we model season player ratings using a Spatial Autoregressive Disturbance (SARAR) model, and as a function of (a) total minutes played, (b) goals scored, (c) assists, (d) shots on goal, (e) pass percentage, and (f) aerial ball possessions won. The model allows for spatial interactions in the dependent and exogenous variables, and in the disturbances. With the growth of digital frame-by-frame data of flowing games such as soccer (and hockey), spatial regression methodologies can bridge the gap between the complex position and tactical maneuverings of players and their ratings. The effect on modeled player ratings and valuations could be significant.

2 - Suggestive Model for Career Decisions in Football Using Data Mining Techniques
Amit Kumar Gupta, Anay Rennie

Media coverage of one of the most famous games in the family of team sports, football, has provided us with a great pool of information especially about the behaviour, health and career of the football players.

During their lifetime, the football players go through myriad genres of events which have direct and indirect correlation to their performance on the ground and in their respective career-path.

Based on the social, psychological and professional circumstances in the life of numerous football players, our research caters a suggestive model to the present generation of football professionals in order to guide them in taking optimal career decisions.

We perform statistical analysis and develop a regressive model on the mined data. For this purpose we have studied a blend of numerical data, newspaper articles and player interviews from the European Leagues over a period of sixteen years.

3 - Determinants of Non-penalty Goals Scored per Game by Football Teams in Europe's Elite Leagues
Sumit Sarkar, Soumyakanti Chakraborty

We constructed different efficiency measures of performance of football (soccer) teams in Europe's elite leagues. The efficiency measures are passing efficiency, long pass efficiency, shooting efficiency, dribbling efficiency, possession share, corner-kick accuracy and cross accuracy. Using data from the premier division leagues in England, Spain, Germany, France and Italy, for the on-going season, we tested the impact of these efficiency measures on non-penalty goals scored by the teams, per game. The impact of passing efficiency, shooting efficiency and possession are found to be statistically significant overall, and in English Premier League and Spanish La Liga. However, in Bundesliga, Ligue One and Serie A the impact of only shooting efficiency and possession share are statistically significant. We also ran the regression separately on the 42 teams for which the non-penalty goals scored per game is above the average, and on the 56 teams for which it is below the average. For the 42 teams above the average, the impact of passing efficiency, shooting efficiency and possession share, on non-penalty goals scored per game, are statistically significant. But for the 56 teams below the average, only the impact of shooting efficiency is statistically significant.

4 - Analyzing the Effect of Discontinuation of Batting Power Play on Bowlers' Performance
Abhishek Chakraborty

In limited overs format, it was decided by ICC (cricket's governing body) in May 2016 that they wanted to get rid of batting power play so as to allow the bowlers a little more breathing space in a format that has been largely dominated by batsmen. In this paper we want to test the hypothesis that post ruling related to the discontinuation of batting power play, whether it has really helped the bowlers. We have developed statistical models to test the same hypothesis.

■ MD-33

Monday, 14:30-16:00 - Building BM, 1st floor, Room 113

Emerging Applications of Data Mining and Computational Statistics 4

Stream: Computational Statistics
Chair: *Pakize Taylan*
Chair: *Gerhard-Wilhelm Weber*
Chair: *Koen W. De Bock*

1 - Enhancing Rule Ensembles with Smoothing Splines and Constrained Feature Selection: an Application in Bankruptcy Prediction
Koen W. De Bock

In this study, customer scoring is tackled using rule ensembles, a recently proposed ensemble learning technique that reconciles strong accuracy and advanced model comprehensibility. Rule ensembles decompose trees into rules and only retain a compact set of rules derived from these trees through the application of lasso regression. The original features are also added as terms to the lasso regression. This study introduces and exemplifies two improvements to the method: (i) the inclusion of smoothing spline terms for continuous variables to better accommodate individual nonlinear effects, and (ii) the replacement of lasso regression by constrained feature selection to govern term selection and enhance model interpretation.

2 - Automated Blood Vessel Detection and Pathological Changes Identification in Eye Fundus Images
Jolita Bernatavičien, Gintautas Dzemyda, Alvydas Paunksnis, Giedrius Stabingis, Povilas Treigys

Diabetes is one of major medical problems throughout the world. In Europe more than 52.8 million people are diagnosed with diabetes and the number expected to rise to 64 million by 2030. Diabetes causes an array of long-term systemic complications. The most common and potentially most blinding of these complications is diabetic retinopathy. Automated early diagnosis of diabetic retinopathy in these circumstances becomes crucial and most important for timely treatment. One of the most important solution for early diagnosis of diabetic retinopathy is eye fundus image analysis. Early diagnostics depends on large scale screening and monitoring, and this can be done only at primary level facilities. The main goal of the research is to provide the overview of solution of automatic image recognition and measurement for pathological changes identification in eye fundus images. The solution can be especially useful for family doctors to identify the pathological changes in eye fundus images obtained by portable eye fundus cameras. To achieve the goal, authors propose the algorithms for segmentation of retinal vessels, identification abnormal widths in blood vessel, automated identification arteries and veins, calculation the arteriolar-to-venular diameter ratio.

3 - Data Analysis Method for Facility Breakdown Prediction in the Semiconductor Manufacturing Process
Youngji Yoo, Jun-Geol Baek

In the semiconductor manufacturing process, the equipment health diagnosis and prognosis is one of the most important issues in order to avoid sudden breakdowns and maintain good status of the facility. Discontinuities in the production process by the facility breakdowns cause repair cost and production loss. Therefore, it is very important that predict and prevent the unexpected breakdown of the facility. The facility is equipped with a lot of sensors, and a vast amount of monitoring data is collected from sensors during the manufacturing process. When the status of the facility is normal, the regular pattern of cyclic signal from sensors are generated. On the other hand, if the facility is broken, a different pattern to the normal pattern can be collected from the sensor attached to the faulty part. In the paper, we propose the unexpected breakdown prediction method using cyclic signal data collected from the semiconductor manufacturing process. The method detect the sensor that collect the unusual pattern by monitoring the cyclic signal and predict unexpected facility breakdowns. In the paper, we experiment and verify the performance of the algorithm using the data collected in the field. The algorithm will be helpful to reduce costs and production increase by minimizing unexpected breakdowns.

4 - Estimation in Partially Linear Regression Models Based on Regression Spline under Right Censored Data
Ersin Yilmaz, Dursun Aydın

This paper presents the effects of covariates on a right censored response variable with unknown distribution. We used the partially linear models in order to consider cases where the functional form of the effect of one or more covariates is unknown. In this paper, we propose a new estimation approach for these models, in which we use regression splines to approximate the parametric and nonparametric components of the partially linear models.For this purpose, a simulation study has been performed by using a program written in MATLAB. A simulation study has been performed to denote the performance of the suggested estimation method and to examine the effect of the censorship. In this connection, 1000 replications have been performed in simulation for sample sets with different sizes and different censored levels. A real data example is also considered to prove the claim mentioned here. In this way, this study is supported with a simulation and a real data example.

■ MD-34

Monday, 14:30-16:00 - Building BM, 1st floor, Room 116

Scheduling of Personnel and Nonrenewable Resources

Stream: Supply Chain Scheduling and Logistics
Chair: *Erwin Pesch*
Chair: *Alena Otto*

1 - Combined manpower teaming and routing problem
Yulia Anoshkina, Frank Meisel

In the context of workforce routing and scheduling there are many applications in which tasks must be performed in geographically dispersed locations, each of which requires certain qualifications. In many such applications, a group of workers is required for performing a task due to the different qualifications of the workers. Examples are found in maintenance operations, the construction sector, healthcare operations, or consultancies. In this paper, we analyze the combined problem of composing worker groups (teams) and routing these teams, with the goal to minimize the total completion time of a given set of tasks. We develop mathematical optimization models for a sequential solution of the teaming problem and the routing problem as well as a combined model that includes both decisions. The resulting problem shares similarities with the VRP but it also differs in relevant aspects that result from the teaming decisions and the qualification requirements. Computational experiments are conducted for identifying the tradeoff of better solution quality and computational effort that comes along with combining the two problems into a single monolithic optimization model. We also discuss additional settings, where tasks require a cooperation of two or more teams.

2 - A two-phase approach for the multi-department personnel scheduling problem
Sarra Souissi, Guy Desaulniers

Generally, large companies are divided into different departments and their workload peaks do not necessarily occur at the same time in all the departments. To avoid hiring new employees, these companies qualify employees to work in different departments. Each employee has a primary qualification and other qualifications. When an employee works outside the department of his primary qualification, we say that he/she is transferred. Certain rules such as only one transfer per day restrict the employee transfers. The proposed solution approach addresses the problem in two phases. Both phases are based on integer programming which is used to determine the assignment of each employee. The first phase solves independently the problem in each department without considering any transfers. The second phase detects the undercoverings in each department and generate new potential shifts with transfers, before optimizing the whole problem using a limited subset of variables. In the second phase, we allow the revision of the shifts assigned to an employee in his primary department under certain conditions.

3 - Shift schedule re-optimization after a small perturbation during the operations
Rachid Hassani, Issmail Elhallaoui

This talk is about a real-time optimization method to adapt a preset schedule after a small perturbation that can result from delay or absence of employees. The method provides schedule's rectification choices to the decision-maker taking into account the immediate cost (management costs) and a deterministic future cost (impact of changes on future schedules and employees' remuneration). The application of this method on different scenarios randomly generated shows that it gives an optimal solution in 93% of cases.

4 - Approximation schemes for resource scheduling problems on parallel machines
Péter Györgyi, Tamas Kis

We study parallel machine scheduling problems with jobs requiring some non-renewable resources (e.g., raw materials). Each resource has an initial stock, which is replenished in known quantities at given dates. A schedule is feasible if no two jobs overlap in time, and when a job is started enough resources are available to cover its requirements. The jobs consume the required resources. The problem has a great practical interest. We have the following results: 1) If the number of the machines is not a constant then the problem is APX-hard even in case of 2 resources and 2 supply dates. 2) There is a PTAS for the makespan minimization problem if the number of the machines and the number of the resources are both bounded by a constant. This is the first approximation scheme that does not require constant number of the supplies or a strong link between the processing times and the resource requirements. We have the same result if the jobs are dedicated to the machines. We can extend both results by enabling release dates as well. 3) In case of one resource and the resource requirement of each job is equal to its processing time we consider lateness as an objective. Since the optimum lateness may be 0, a standard trick is to increase the lateness of the jobs by a constant. For this objective we have PTAS for constant number of machines. This is first approximation scheme of the topic for the lateness objective. Ack.: This work has been supported by the OTKA grant K112881.

■ MD-35

Monday, 14:30-16:00 - Building BM, ground floor, Room 17

Algorithms for Biomedicine

Stream: Computational Biology, Bioinformatics and Medicine
Chair: *Marek Ostaszewski*

1 - Disturbing Effect of Hyperlipidemia on the Monocyte-Macrophage Axis Modeled and Analyzed Using Time Petri Nets
Katarzyna Rżosińska, Dorota Formanowicz, Piotr Formanowicz

Our understanding of atherosclerosis has progressed remarkably over the past years. The discovery of subsets of inflammatory and resident monocytes, macrophages, natural killer cells, and regulatory T cells opened new perspectives on the role of inflammation and immune responses in atherosclerosis. Assuming that the disease state, like hyperlipidemia is a displacement from homeostasis, inflammation is the tissue response for restoring homeostasis. It should be emphasized that monocyte-macrophage axis is central to atherogenesis process because it regulates cholesterol traffic and inflammation state in the arterial wall. According to various microenvironmental signals, the differentiation from monocytes sub-populations into macrophages occurs in concomitance with the acquisition of a functional phenotype (M1 or M2). M1 and M2 macrophages play opposite roles during inflammation, but both are present in atherosclerotic lesions. These mentioned phenomena are particularly important because they regulate vascular homeostasis, whose disruption appears to be the key issue for sustaining atherogenesis. To better reflect the relations between the mentioned phenomena, we have built their extended model expressed in the language of Petri net theory that takes into account time dependencies. It has enabled more comprehensive understanding of the analyzed process, in comparison to the previously developed qualitative model, and has led to formulation of interesting biological conclusions.

2 - The Influence of Blood Pressure on the Formation and Development of Atherosclerosis Modeled and Analyzed Using Stochastic Petri Nets
Marcin Radom, Dorota Formanowicz, Radosław Urbaniak, Piotr Formanowicz

A lot of clinical and experimental studies strongly indicate that elevated blood pressure is a major contributing factor in coronary heart disease. The detrimental effect of the hypertension on the cardiovascular system appears to be due mainly to the mechanical stress placed on the heart and blood vessels. However, hypertension is not only a well-established cardiovascular risk factor but also increases the risk of atherosclerosis. A synergistic reaction between hypertension and hyperlipidemia, causing and/or enhancing atherosclerosis, may occur because both states are associated with a common causal mechanism: induction of alterations in redox state in vessels. The aforementioned biological phenomena have been modeled using a Stochastic Petri Net (SPN). Such a net is built over a classical Petri net structure, i.e., all the standard analytical approaches like invariants, MCT sets or cluster analysis are still available. However, the SPN provides more possibilities for the analysis of the model than a classical Petri net. In a stochastic net a firing rate for each transition is given, providing a stochastic waiting time before the transition fires. This feature allows, e.g., a more detailed and thorough simulation of the model. From such simulations a more subtle interactions between the model components can be observed, further extending the knowledge about the analyzed biological process.

3 - Forecasting Approach for the Progression of CCHF Infections

Muhammad Irfan Azhar, Metin Turkay

Crimean-Congo haemorrhagic fever (CCHF) is a widely spread viral disease that often results in fatality. The disease is caused by the Nairo virus and Hyalomma Marginatum tick is the most important vector associated with the disease. The life cycle of the Hyalomma Marginatum ticks consists of different stages like eggs, larva, nymph and adults. The development and mortality rates for these stages depend on climate parameters like average monthly values of temperature, vapor pressure deficit, precipitation and minimum and maximum temperatures. The activity rates for questing ticks also depend on temperature. The ticks are most active during the summer season and that is the time when most of the infections occur in humans. In this talk, we investigate the relationship between climate parameters and the rate at which CCHF infections occur for a region where tick population is established. Poisson and Negative Binomial regression models are used to forecast the number of cases as a function of weather data. Most significant climate parameters are identified. The model generates a reasonable forecast for the number of cases occurring during the summer months. An early warning criterion for spring is also discussed, considering the temperature and precipitation trends during the winter.

4 - Multilayer Spatial Evolutionary Games and Cancer Cells Heterogeneity

Andrzej Swierniak

Living cells, similarly like whole living organisms during evolution, communicate with their neighbours, interact with the environment, divide, change their phenotypes and die. Development of specific ways of communication (receptors and signalling molecules) allows some cellular subpopulations to better survive, coordinate physiological status and during embryonal development to create tissues and organs or in some conditions to become tumours . Populations of cells cultured in vitro interact similarly, also compete for space and nutrients and stimulate themselves to better survive or to die. The results of intercellular interactions of different type seem to be good examples of biological evolutionary games, and were subjects of simulations by the methods of evolutionary game theory where individual cells are treated as players. Here we present examples of intercellular contacts in the population of living human melanoma cells cultured in vitro and propose an evolutionary game theory approach to modelling of the development of such populations. We propose a new technique termed mixed spatial evolutionary games (MSEG) which are played on multiple lattices corresponding to the possible cellular phenotypes what gives the possibility of simulating and investigating the effects of heterogeneity at the cellular level in addition to the one resulting from polyphormism of the population.

■ MD-36

Monday, 14:30-16:00 - Building BM, ground floor, Room 18

Scheduling in Healthcare 3

Stream: Scheduling in Healthcare
Chair: *Rosita Guido*

1 - Personnel Rostering with Individual Preferences in Care Facilities

Lena Wolbeck, Natalia Kliewer

A common issue in care facilities is staff scheduling, especially at 24/7 service. The past few years have witnessed a continuous increase in well-performing solution approaches for personnel rostering problems. These methods often focus on solutions based on an economic point of view and slightly incorporate employees' needs. In contrast to these approaches, the main objective that motivates our research is maximizing the employees' satisfaction by considering individual preferences during the planning process. Since working in shifts is known to have a great influence on private life, our solution approach allows employees to take part in duty scheduling resulting in stronger self-determination. A care facility for disabled people serves as example for our study. In addition to common constraints such as legal, policy and tariff regulations, there are many further requirements due to the different needs concerning residents' care. Furthermore, lots of individual arrangements regarding working time plus monthly changes of individual preferences exist. The aim of this study is to develop a method to find a feasible solution to the specified personnel rostering problem. Afterwards, we want to enhance the solution within the meaning of justice using simulated annealing. As a result, a roster is formed which considers preferences equally and assigns unpopular shifts fairly among employees.

2 - Scheduling Home Hospice Care with Logic-Based Benders Decomposition

John Hooker, Aliza R. Heching

We propose an exact optimization method for home hospice care staffing and scheduling, using logic-based Benders decomposition (LBBD). The objective is to match hospice care aides with patients and schedule visits to patient homes, so as to maximize the number of patients serviced by available staff, while meeting patient and staff requirements. We report computational results for problem instances obtained from a major hospice care provider. We find that LBBD is superior to state-of-the-art MIP and solves problems of realistic size, if the aim is to conduct staff planning on a rolling basis while maintaining continuity of the care arrangement for patients currently receiving service.

3 - A Matheuristic Approach for Solving the Offline Bed Assignment Problem

Rosita Guido, Maria Carmela Groccia, Domenico Conforti

The bed assignment problem here addressed consists in assigning elective patients to hospital beds by considering constraints such as bed availability in departments, competing requests for beds, clinical characteristics of patients. The process of matching patients with beds is similar to a dynamic assignment problem because of admissions and discharges of patients in a defined planning horizon. It has been demonstrated that the problem with some particular constraints is NP-hard. The high complexity of the problem and needs of tools to support bed managers in making fast decisions motivate researchers to design suitable approaches. In this study, we formulate three mathematical models to support a hospital manager in the bed assignment decision-making process. We propose a matheuristic solution framework based on solving a sequence of subproblems. The solution approach is tested on benchmark instances and we improve most of the best known bounds.

■ MD-38

Monday, 14:30-16:00 - Building BM, 1st floor, Room 109M

Health Care Operations

Stream: Health Care Management
Chair: *Jens Brunner*

1 - Solution Methods for the Tray Optimization Problem
Theresia van Essen, Twan Dollevoet, Kristiaan Glorie

During surgery, sterile instruments are used which usually are grouped in trays. Such a tray can contain the items needed for a particular surgery, but the content of a tray can also be needed for several types of surgery, or one type of surgery requires trays of different types. After surgery, the instruments have to be sterilized before they can be used again. The composition of the trays strongly influences the required number of trays and instruments as well as the number of required sterilization cycles. Optimizing the composition of the trays can lead to substantial cost savings and to increased availability of instruments. The tray optimization problem (TOP) consists of two main decisions: 1) instruments are assigned to trays, and 2) trays are assigned to surgeries. These assignments have to be made such that for each surgery sufficient instruments are available and such that the total costs are minimized. These total costs can consist of several parts, for example, acquiring costs, depreciation costs, storage costs, sterilization costs and handling costs. To solve TOP, we present an exact solution method and several heuristic solution methods, namely delayed row & column generation, simulated annealing, and genetic algorithms. We compare these solution methods on computation time and solution quality, and in addition, we conduct a simulation study to evaluate the performance of the resulting solutions in the long run.

2 - Operational Bed Allocation in Large Hospital Settings
Alexander Hübner, Manuel Walther

Increasing cost pressure for large maximum care hospitals combined with a decrease in average lengths of stay raises the importance of having an efficient bed occupancy management system in place. On an operational level, the actual bed assignment is typically subject to patient preferences, staff workloads, and medical constraints. Planning and committing to specific bed assignments in advance seems impractical given the uncertainty typically seen in hospitals due to high levels of emergency inpatients, frequent changes in lengths of stay, and no-shows among others. To tackle this planning problem, we propose a new approach which allows hospitals to reassess any given occupancy situation, while incorporating anticipated emergency patient arrivals, currently planned elective patients as well as cross-departmental overflow. Furthermore, our approach is designed to be applied to large hospital settings with pooled ward capacities and gives hospital planners the possibility to quickly assess impact on multiple objectives. The algorithm developed is tested with actual data from a large German maximum care hospital. First comparisons with existing approaches in literature show promising results.

3 - Decision Support for Physician Scheduling at a German Hospital
Jan Schoenfelder, Christian Pfefferlen

The process of manually constructing monthly working schedules for physicians is a very time-consuming and error-prone task in medium-sized and large hospital departments. We develop a mathematical model that formalizes every rule and regulation necessary to generate lawful schedules in an anesthesiology department at a hospital in Berlin, Germany. We embed our detailed and complex mixed-integer programming formulation in an Excel environment to ensure ease of use, maximum flexibility with respect to changing relevant inputs, and visual output representation for practitioners. The automated approach reduces the workload for the scheduler dramatically, and it offers a means to transfer scheduling duties from the current expert to another employee in the future. Our generated schedules significantly reduce the number of violations of regulations and contractual agreements. Moreover, they outperform manually created schedules with respect to assigned overtime, fairness considerations, and the number of granted shift requests.

4 - Physician staffing subject to stochastic demand
Jens Brunner, Andreas Fügener

In hospitals, personnel generates the biggest and most important cost block. So, efficient scheduling of physicians at hospitals is an important topic. Heterogeneous demand and 24/7 service make the problem even more challenging. We introduce stochastic demand for physician staffing using a scenario-based approach. To incorporate this kind of uncertainty in the scheduling process, we extend flexible shift scheduling (i.e., variable shift starting times and shift lengths) by allowing variable shift extensions. If a variable shift extension is scheduled, the physician knows that with a given probability he or she may have to work few periods longer. Thus, we ensure matching supply with demand and at the same time we increase predictability of working hours for the physicians. We propose a mixed-integer linear program to model the strategic problem and then we present a column generation based heuristic to solve our model. We evaluate the model using experimental data from a large German university hospital with approximately 1200 beds. Our computational experiments demonstrate that our approach manages to reduce unplanned overtime by more than 80 per cent with a constant workforce. In cases of similar levels of unplanned overtime, the required workforce level may be decreased by 20 per cent. Our findings help management to design working contracts for physicians in hospitals.

■ MD-39

Monday, 14:30-16:00 - Building WE, 1st floor, Room 107

Markov Decision Processes in Revenue Management

Stream: Advances in Revenue Management
Chair: *Darius Walczak*

1 - When is Bad "Bad Enough”? A Linearization Framework for Analyzing Benefits of Coordination under Externalities
Anna Klis

This paper addresses the problem of determining when coordination is beneficial in complex games. I describe a negative externality game containing a "worsening parameter" and develop a framework linearizing this parameter for tractable examination. As an example, such a worsening parameter could describe the transition process of a Markov problem, such as the probability of transitioning from a good state to a bad one. This worsening parameter can be classified according to "own effect" - changing the marginal utility of a player’s own action, "opponent effect" - altering the marginal externality, or "submodular effect" - strengthening the game’s submodularity. Using this framework, I examine the sufficient conditions for parameter changes to move non-cooperative and cooperative solutions in opposite directions. In a symmetric game, an increase in own effect will increase the distance between utility and action level of the non-cooperative and cooperative solutions. In a non-symmetric game, there are sufficient conditions on the second derivatives which give this pattern as well. I argue that situations behaving in this manner and with a higher parameter value have more benefit to coordination through the increased range in actions.

2 - Revenue Management under Reviews and Online Ratings
Dirk Sierag, Diederik Roijers

This talk proposes a revenue management model that integrates reviews and rating. A Markov-decision process is formulated with a feedback mechanism of reviews: on one side the content of a review depends on the product the customer purchases, and on the other side reviews impact the demand. By sacrificing revenue now in order to get better reviews, long-term revenue can be increased substantially. A novel solution methodology is proposed to solve a problem of such complexity, using a multi-objective setting of revenue and rating.

Stochastic mixture policies are considered that keep the rating constant while optimising revenue. The constant rating that gives maximal revenue is then selected. Numerical studies show that taking ratings into account can lead to an increase in revenue of up to 11% compared to the case where the sole objective is revenue.

3 - Constrained Markov Decision Processes in Revenue Management
Darius Walczak

Constrained Markov Decision Processes ('MDP') have so far received little attention in revenue management ('RM') or pricing optimization despite offering a way to model optimization problems where one metric is maximized subject to a constraint on another, with revenue maximization and load factor being the prime example. Such problems are important in applications but are presently mainly addressed via heuristics. We review results available in the literature on constrained MDPs and assess their suitability for implementable RM systems via theoretical considerations as well as numerical examples.

■ MD-40

Monday, 14:30-16:00 - Building WE, 1st floor, Room 108

Portfolio Optimization and Risk Management

Stream: Financial Engineering and Optimization
Chair: *Shushang Zhu*

1 - Integration of dynamic mean-risk and expected utility maximization frameworks
Duan Li

The current practice of portfolio selection has been guided by two schools of governing doctrines, a framework of expected utility maximization and a mean-risk framework. While the utility maximization framework enjoys a scientific rigor in forming a portfolio decision, it lacks appreciation from investors due to the abstract nature of global utility functions. On the other hand, while various risk measures seem intuitive to investors and are thus popular in real investment practice, some of the dynamic mean-risk frameworks display certain undesirable properties, for example, violation of the coherence, and almost all of them suffer from time inconsistency, thus resulting in computational intractability. In this research, we devote efforts to integrate the two. Under a realistic premise that investors only thoroughly understand their investment goals in terms of the mean and risk measures, we assume that investors prescribe their investment targets by setting certain attainable levels for the mean and risk measures. We then translate such mean-risk investment targets into a corresponding expected utility maximization problem which possesses favorable properties and is computationally tractable. We demonstrate certain advantages of adopting such a risk measure derived expected utility maximization framework in dynamic portfolio selection.

2 - Asset allocation under loss aversion and minimum performance constraint in a DC pension plan with inflation risk
Zhongfei Li

We consider an optimal investment problem of a defined-contribution pension plan when a loss-averse member faces inflation and longevity risks and requires a minimum performance at retirement. The loss-aversion is characterized by an S-shaped utility. We provide a fully analytical characterization of the optimal investment strategy in an indexed bond, a stock and a risk-free asset using the martingale approach. Our theoretical and numerical results show that the percentage of wealth invested in risky assets usually has a V-shaped pattern with respect to the growing of reference point level, and increases along with the rising lifespan. There are additional hedging components in the portfolio due to the salary and minimum performance constraint. The salary causes her to invest less aggressively in index bond due to the fact salary usually correlates positively with the inflation. While the minimum performance offsets the effect of salary. Furthermore, the results have some important implications for the management of a DC pension plan.

3 - Dynamic Portfolio Optimization with Loss Aversion Preference in Mean-Reverting Market
Jianjun Gao, Duan Li

In this work, we study the portfolio optimization problem with loss aversion utility function in mean-reverting market. Particularly, we use Kahneman and Tversky's S-shape utility function to characterize investor's preference and adopt CRI type of model to capture the mean-reverting phenomena of the stock return. We develop the semi-analytical portfolio policy of such a problem by using the martingale approach. Furthermore, numerical approach is proposed to compute the optimal wealth process and portfolio policy. The revealed portfolio policy is different from the one derived from the traditional CRRA utility model under mean-reverting market setting and also different from the one derived from portfolio optimization model with S-shape utility function and deterministic opportunity set. This result helps to explain some irrational behavior of the investor when the stock return exhibits mean-reverting pattern.

4 - Optimally Manage Crash Risk
Wei Zhu

Crash of the financial market means that most of the financial assets suddenly lose a certain part of their nominal value, which implies almost all the assets become perfectly correlated in a crash. The diversification effect of portfolios in a typical markets condition and the corresponding risk measures do not work any longer in a crash situation. Thus the performance measures (risk and return) and the managerial point of view under a crash should be distinguished from the traditional ones under the normal conditions. In this paper, we integrate crash risk into portfolio management and investigate the performance measures, hedging and optimization of portfolio selection while involving crash risk. A convex programming framework based on parametric method is proposed to formulate the problem as a tractable one. Comprehensive simulation and empirical study are performed to test the proposed approach. This is a joint work with Shushang Zhu, Xi Pei and Xueting Cui.

■ MD-41

Monday, 14:30-16:00 - Building WE, 2nd floor, Room 209

Finance and OR 1

Stream: Financial Mathematics and OR
Chair: *Azar Karimov*
Chair: *Gerhard-Wilhelm Weber*
Chair: *Suhan Altay*

1 - Stochastic Optimal Control of Systems with Regime Switches, Jumps and Delay - in Finance, Economics and Nature
Gerhard-Wilhelm Weber, Emel Savku, Yeliz Yolcu Okur

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

2 - Modelling Operational Risk using Skew t-copulas and Bayesian Inference
Betty Johanna Garzon Rozo, Jonathan Crook

Operational risk losses are heavy tailed and are likely to be asymmetric and extremely dependent. We propose a new methodology to assess, in a multivariate way, the asymmetry and extreme dependence between severities and to calculate the capital for operational risk. This methodology simultaneously uses (i) several parametric distributions and an alternative mixture distribution (the Lognormal for the body of losses and the Generalized Pareto Distribution for the tail) using a technique from extreme value theory, (ii) the multivariate skew t-copula applied for the first time across severities and (iii) Bayesian theory to estimate the skew t-copula parameters. This paper analyses a new operational loss data set, SAS' Operational Risk Global Data, to model operational risk at international financial institutions. Our approach substantially outperforms symmetric elliptical copulas, demonstrating that modelling dependence via the skew t-copula provides a more efficient allocation of capital charges up to 56% smaller than what the standard Basel model would state.

3 - Investor motivations and decision criteria in equity crowdfunding
Tomi Seppala, Anna Lukkarinen, Jyrki Wallenius, Hannele Wallenius

Equity crowdfunding is a fast-growing form of financing that enables large groups of people to invest in early-stage companies. Due to the nascent nature of the field, little is known about the motivations and criteria underlying equity crowdfunding investors' financing decisions. We have conducted a survey of equity crowdfunding investors that yielded 911 usable responses. The results give rise to three main findings. First, a factor analysis of decision criteria reveals five main factors: i) campaign specifications, ii) target attractiveness, iii) investors' familiarity with the target company, iv) campaign scale, and v) investors' personal acquaintances. Second, a cluster analysis of motivations reveals that investors can be grouped into three clusters: donation-oriented supporters, return-oriented supporters, and pure investors. Third, investors' motivations are related to their decision criteria, as shown by ANOVA. Campaign specifications and target attractiveness are most important to pure investors, whereas familiarity is most important to donation-oriented supporters. Campaign scale is less important to donation-oriented supporters than to other investors, while personal acquaintance is relevant solely to return-oriented supporters. The results highlight that equity crowdfunding investors are a heterogeneous group that consists of people with different backgrounds, motivations, and decision criteria.

■ MD-42

Monday, 14:30-16:00 - Building WE, 1st floor, Room 120

Applications and Computational Methods in Game Theory

Stream: Game Theory, Solutions and Structures
Chair: *Elisenda Molina*

1 - Computing power in influence decision models
Maria Serna, Xavier Molinero

We consider two collective decision-making models associated with influence games, the oblivious and non-oblivious influence decision models. The difference is that in oblivious influence models the initial decision of the actors that are neither leaders nor independent is never taken into account, while in the non-oblivious it is taken when the leaders cannot exert enough influence to deviate from it. We consider the power measure, for an actor in a decision-making model. Power is ascribed to an actor when, by changing its inclination, the collective decision can be changed. We show that computing the power measure is #P-hard in both oblivious and non-oblivious influence decision models. We present two subfamilies of (oblivious and non-oblivious) influence decision models in which the power measure can be computed in polynomial time.

Acknowledgements: First author was partially funded by Grants TIN2013-46181-C2-1-R and 2014SGR1034, the second one by Grant MTM2015-66818-P.

2 - Solving Fuzzy Games for Players with Different Risk Levels
Yesim Koca, Ozlem Muge Testik

In this study, a decision problem with two conflicting rational and intelligent decision makers is considered and the problem is modeled as a two player zero sum game. Since payoff values in the game cannot always be defined as exact (crisp) values in practice, fuzzy logic is implicated in the model. Various solution methods for fuzzy games are proposed in literature, where the results are mostly presented in terms of efficient strategy mix probabilities and their respective alpha cut values. However, acceptable risk levels for players in the game are not taken into consideration. The aim of this study is to propose a solution method which can be generalized for each player's different risk levels. Therefore, after determining the risk levels, efficient strategy mix probabilities are calculated simultaneously by using multi-objective linear programming. Proposed methodology and the results are discussed through a numeric example.

3 - Improving Polynomial Estimation of the Shapley Value Based on Stratified Random Sampling with Optimum Allocation
Elisenda Molina, Juan Tejada, Javier Castro, Daniel Gomez Gonzalez

In this communication we propose a refinement of the polynomial method based on sampling theory proposed by Castro et al. (2009) to estimate the Shapley value for cooperative games. Besides analyzing the variance of the former estimation method, we propose to rely on stratified random sampling with optimum allocation in order to reduce it. We examine some desirable statistical features of the stratified approach and provide some computational results for analyzing the gains due to stratification, which are around a 30% on average, and more than a 80% in the best case.

■ MD-43

Monday, 14:30-16:00 - Building WE, ground floor, Room 18

Optimization in Renewable Energy Systems 1

Stream: Optimization in Renewable Energy Systems
Chair: *Serap Ulusam Seckiner*

1 - Modelling of Wind Speed and Generated Power of a Wind Turbine by Using Particle Filtering to Monitor a Wind Farm
Yunus Eroglu, Serap Ulusam Seckiner

Renewable energy resources are clean and local energy production alternatives. Thus, they also have become important instruments for energy policies of countries. One of the most common used renewable energy resources is wind energy. While wind energy technologies increase day by day; investment, operation, and maintenance costs of wind energy sector are decrease. Therefore, wind farms have become more popular all over the world. Wind energy is also very popular instrument for Turkey by its high potential. The future of wind energy looks like a bright area for Turkey in both short and long term. While the value of installed wind power plants increases, monitoring and optimization of current wind energy sites becomes an emerging area. If a wind farm could be monitored dynamically and correctly, the anomalies in the system would be detected even before it occurred. Thus, in this study, a particle filtering approach is modeled to monitor wind power of a wind turbine, which gives many messages about health of wind turbine. Wind speed and wind power data, which were gathered from the SCADA system within 10 minutes intervals, were used as modeling parameters. The generated wind power was monitored by proposed Particle Filtering algorithm where the wind speed used as a predictor measurement for the generated wind power of a wind turbine. The proposed model was tested on a real data of a wind farm in Turkey.

2 - Performance Analysis of Wind Turbines
Serap Ulusam Seckiner, Harika Akalin, Yunus Eroglu

Renewable energy sources are getting importance for sustainable energy development and environmental protection. Wind energy is one of the most explicit renewable energy sources in the world, nowadays,they become widespread. Among the renewable sources, Turkey has very high wind energy potential. The future of wind energy looks bright area for Turkey in both short and long term. The wind energy potential on land and sea of Turkey is more than many European countries. Although the fact that the value of installed wind power plants increases day by day,optimization of current wind energy sites becomes an emerging area.Feasibility analysis and potential analysis of wind energy areas have lost importance in all over the world. In the current literature, the main focused subjects on wind energy researches are related with "How a wind farm can be managed with its most efficient parameters and optimum power generation strategies". This can be achieved by monitoring and improving the performance of wind turbines. Wind farms should be investigated and analyzed in order to improve the farm electricity generation efficiency by using performance analysis. Thus, the aim of this study is to investigate the performance of a wind farm by using efficiency analysis. In our study, Stochastic Frontier Analysis was used to calculate efficiency of each wind turbine to compare and to determine whole wind farm efficiency. The proposed approach was tested by using real data of a wind farm in Turkey.

3 - Wind Turbine Placement in Wind Farms Using Brute Force Algorithm
Melike Sultan Karasu Asnaz, Kadriye Ergün

Optimal placement of wind turbines in wind farms has a great importance for energy production. Several studies related to turbine placement have been conducted in order to find the best location of turbines in wind farms considering energy production maximization and total cost minimization. Various heuristic approaches, especially artificial intelligence technology, have been implemented to find optimum solution to the wind turbine placement problem. In this study, the authors discuss an existing problem assuming single type of turbines usage, and a square-shaped flat space wind farm area that has unidirectional wind with a uniform wind speed. Wake effect is also considered in calculations of wind turbine performance. Brute Force algorithm is used to check all possible turbine positions in the area, and the same process is repeated to the candidate locations by applying recursive process in order to find the best configuration in wind farm.

■ MD-47

Monday, 14:30-16:00 - Building WE, 1st floor, Room 115

Stochastic Modeling and Simulation in Engineering, Management and Science 3

Stream: Stochastic Modeling and Simulation in Engineering, Management and Science
Chair: *Gerhard-Wilhelm Weber*
Chair: *Paresh Date*

1 - Impact of Knowledge Sharing-Based Online Customer Complaint Handling on Enterprise Product Sales - A Simulation Analysis
Siyu Luo, Shuqin Cai, Shimiao Jiang

Online complaints are frequently published and disseminated on the Internet. The traditional service-personnel based complaint handling method can no longer handle such massive online complaints in time.To solve online complaints timely and effectively, enterprise can make use of the knowledge sharing behavior of knowledgeable users in the virtual community. As positive and negative power has influence on customer's satisfaction, knowledge sharing and online complaints affect customer's willing of purchase, and finally product sales. We construct a multi-agent concept model simulating the dynamic process of user's behaviors, such as purchasing, spreading word-of-mouth, complaining and sharing knowledge. This paper explored the ability of knowledge sharing in weakening the impact of online complaints and lifting the amount of product sales. Results show that knowledge-sharing behaviors do have the ability to effectively weaken the negative influence of online complaints, and this ability was positively influenced by the knowledge sharing intention and knowledge sharing quality of overall virtual community. Once the ability rises to a certain degree, there would be a big jump in product sales. But this ability is also limited, even with its maximum ability, knowledge sharing cannot completely solve online complaints and totally offset the negative impact of online complaints. (This research was supported by the National Natural Science Foundation of China under Grant 71371081.)

2 - Effects of Transfer Policies and Layout Structures in Automotive Body Shops Considering Multi-products
Dug Hee Moon, Yeseul Nam, Yang Woo Shin
The function of body shop in an automotive factory is to assemble various parts produced in press shop using welding processes. Generally, the body shop is divided into 15 20 sub-assembly lines and there is no buffer in sub-assembly lines. However the decoupled sub-lines are connected with the conveyor systems and the functions of conveyor are transportation and buffer space. Another important feature of automotive body shops is that two or more sub-assemblies are assembled together. In the designing phase of body shops, we should select one of the two different layout concepts based on welding methods, and they are layered build method and modular build method. The transfer policy in sub-assembly lines is an important decision in the designing phase, and they are synchronous transfer policy and asynchronous transfer policy. Recently, it is popular that multi types of cars are produced in a body shop by changing welding jigs, and the cycle times in welding stations are different with the types of cars. In this study, we investigate the effects of layouts and transfer policies on the performance measures such as production rate and flow time, when multi-types of cars are produced in a same manufacturing system. The behaviors of system performances are compared and the guidelines for system design are suggested by various simulation experiments.

3 - Application of a New Method for Sampling from Partially Specified Distributions in the Assessment of Indeterminate Power Systems
Paresh Date, Mohasen Mohammadi, Gareth Taylor
This paper presents a new method for generating scenarios from partially specified probability distributions. The method generates a set of vectors and the associated probability weights that match a given target mean vector and a target covariance matrix exactly. A crucial difference between existing moment matching methods and the new method is that, the algorithm generates a unimodal distribution with the mode coinciding with the mean. The probability weights of the sample vectors in the new method decrease as the vectors move 'further' away from the mean in terms of the inner product, whereas the existing moment matching methods generate sample vectors with equal probability weights. Additional 'free' parameters in the algorithm can be used to match higher order moments approximately. We demonstrate the use of this method for probabilistic assessment of small-disturbance stability of an indeterminate power system. The presence of uncertainty in operating conditions and parameters results in variations in the damping of critical modes and makes probabilistic assessment of system stability necessary. For such assessments, the conventional Monte Carlo approach is computationally demanding for large power systems and is often impractical for use in a realistic timeframe. Furthermore, unlike the proposed method, conventional methods that currently use point estimate techniques do not account for correlations between the indeterminate system operating conditions.

■ MD-48

Monday, 14:30-16:00 - Building WE, 1st floor, Room 116

Portfolio optimization

Stream: Decision Making Modeling and Risk Assessment in the Financial Sector
Chair: *Adam Krzemienowski*

1 - Dynamic portfolio choices by simulation-and-regression: revisiting the issue of value function vs portfolio weight recursions
Jean-Guy Simonato, Michel Denault

Simulation-and-regression methods have been recently proposed to solve multi-period, dynamic portfolio choice problems. In the constant relative risk aversion (CRRA) framework, the "value function recursion vs. portfolio weight recursion" issue was previously examined in van Binsbergen and Brandt (2007) and Garlappi and Skoulakis (2009). We revisit this issue in the context of an alternative simulation-and-regression algorithmic approach which does not rely on Taylor series approximations of the value function. We find that, in this context, the portfolio weight recursion variant of the algorithm provides very precise results, is more reliable, and should be preferred to the value function recursion variant, especially for problems with long maturities and large risk-aversion levels.

2 - Stress-testing of pension fund ALM models with stochastic dominance constraints
Sebastiano Vitali, Milos Kopa, Vittorio Moriggia

The main goal of a pension fund manager is sustainability. We propose an ALM model structured as a multi-stage stochastic programming problem adopting a discrete scenario tree and a multi-objective function. Among other constraints, we consider second order stochastic dominance with respect to a market portfolio. Moreover, we introduce a contamination on the scenario tree with a sample of price shock scenarios to compare optimal solutions under stress-testing. To protect the pension fund from shocks we test also the inclusion of hedge financial contracts in the form of put options. Numerical results show that we can efficiently manage the pension fund satisfying liquidity, return, sponsor's extraordinary contribution and funding gap targets. Such targets, thanks to the use of the protection contracts, are fulfilled also in case of shock.

3 - Portfolio selection based on the worst-case distribution
Adam Krzemienowski

The basis of portfolio selection is to determine the share of each financial asset. This is a typical optimization problem solved by the Markowitz method which maximizes the expected rate of return and minimizes the risk. The assumptions of the Markowitz model should ensure that the optimal portfolios are stable over time, i.e., they should be characterized by the absence of fluctuations in their shares. In practice, these assumptions are never met. To solve this problem, one may determine an optimal portfolio with respect to a certain time-invariant distribution bounding the stochastic process of portfolio returns from below. This distribution is called the worst-case distribution and is based on the relation of first-order stochastic dominance and concordance ordering. The approach is illustrated with the results of a computational experiment conducted on the real-life financial data.

■ MD-51

Monday, 14:30-16:00 - Building PA, Room D

Optimality Conditions, Regularity and Related Topics

Stream: Mathematical Programming
Chair: *Goran Lesaja*

1 - P-regularity Theory and Optimization Problems
Alexey Tretyakov, Agnieszka Prusińska

We present methods for solving degenerate constrained and unconstrained nonlinear optimization problems. The optimality conditions for equality- and inequality-constrained optimization problems will be formulated and corresponding numerical methods will be presented.

2 - A Method of Meeting Paths for Linear Exchange Model and Generalizations
Vadim Shmyrev

New development of original approach to the equilibrium problem in a linear exchange model and its variations is presented. The conceptual base of this approach is the scheme of polyhedral complementarity. The idea is fundamentally different from the well-known reduction to a linear complementarity problem. It may be treated as a realization of the main idea of the simplex-method of linear programming. In this way, the finite algorithms for finding the equilibrium prices are obtained. The whole process is a successive consideration of different structures of possible solution, that are analogous to basic sets in the simplex-method. The approach reveals a decreasing property of the associated mapping whose fixed point yields the equilibrium of the model. The basic method was generalized for some variations of linear exchange model, in particular, for the model with production, parametric exchange model. The presented consideration deals with its generalization on the piecewise linear exchange model. The author was supported by the Russian Foundation for Basic Research (project no. 16-01-00108).

References: 1. Shmyrev V. I.: Polyhedral complementarity and equilibrium problem in linear exchange models - Far East Journal of Applied Mathematics, vol. 82, Number 2, 2013, pp. 67-85. 2. Shmyrev V. I.: A method of meeting paths for the linear production-exchange model - J. Appl. Indust. Math., vol. 6, Number 4, 2012, pp. 490-500.

■ MD-52

Monday, 14:30-16:00 - Building PA, Room C

Global Optimization

Stream: Global Optimization
Chair: *Ahmet Sahiner*
Chair: *Fatih Ucun*

1 - Lipschitz Global Optimization
Yaroslav Sergeyev

Global optimization is a thriving branch of applied mathematics and in this talk the Lipschitz global optimization problem is considered. It is supposed that the objective function can be "black box", multiextremal, non-differentiable, the Lipschitz constant is unknown, and evaluation of the objective function at each point is a time-consuming operation.

The main attention in this talk is dedicated to two types of methods: (i) algorithms using space-filling curves in global optimization; (ii) diagonal global optimization algorithms. A family of derivative-free numerical algorithms applying space-filling curves to reduce the dimensionality of the global optimization problem is discussed. An efficient adaptive diagonal partition strategy is described and global optimization algorithms using it are introduced and broadly tested.

References: [1] Ya.D. Sergeyev, R.G. Strongin, and D. Lera, Introduction to Global Optimization Exploiting Space-Filling Curves, Springer, NY, 2013. [2] Ya.D. Sergeyev, D.E. Kvasov, Diagonal Global Optimization Methods, FizMatLit, Moscow, 2008. [3] R.G. Strongin, Ya.D. Sergeyev, Global Optimization with Non-Convex Constraints: Sequential and Parallel Algorithms, Kluwer, Dordrecht, 2000, 2d ed. 2013, 3rd ed. 2014, Springer. [4] Ya.D. Sergeyev, D.E. Kvasov, "Lipschitz global optimization", in J.J. Cochran et al., (Eds.), Wiley Encyclopedia of Oper. Res. and Manag. Sci., John Wiley & Sons, NY, 4:2812-2828, 2011.

2 - Generalized convexity concepts and their role in optimization
Pál Burai

The main goal of this talk is to introduce two generalized convexity notions, to examine their properties and their use in optimization theory, in particular, to deduce necessary and sufficient first order conditions.

3 - A global method for operation optimization problem
Lianjie Tang, Lixin Tang

This paper studies a global method for the general operation optimization problem of N stands in a hot or cold rolling production process. In order to express the practical problem, the problem may be written as the generalized geometric programming (GGP) model in which the objective and constraints are signomial functions. We will attempt to establish a link between (GGP) and convex programming so that for the general operation optimization problem it can be obtained easily the global optimal solution. Although such constraints do not seem convex at first sight, the inherent convexity of the constraint functions can be found based on convex analysis theory. Thus, under some conditions, the primal problem can be equivalently transformed into a convex optimization problem. Our numerical experiments demonstrate that this method is effective for solving a class of practical problems by using convex optimization tools.

■ MD-53

Monday, 14:30-16:00 - Building PA, Room A

Panel: European Study on OR/MS Education

Stream: Initiatives for OR Education
Chair: *Marco Laumanns*
Chair: *Joao Miranda*

1 - European Study on OR/MS Education: Brief Results and Preliminary Trends
Jeroen Belien, Hans W. Ittmann, Marco Laumanns, Joao Miranda, Ana Paula Teixeira, Margarida Vaz Pato

In the light of recent improvements in OR/MS Education, a survey was conducted amongst European universities and other higher education institutions (ec.europa.eu/eusurvey/runner/ORMSeducation), from June to October 2015. The survey and related activities correspond to the first phase of the "European Study on OR/MS Education" and the study purpose is to obtain detailed insight into the current state of OR/MS Education in Europe. The survey dissemination had good support from OR/MS communities and the total number of responses was significant: 191 respondents, of these about 30% can, at least partially, be identified from the institution from which they originate. Five relevant subjects were addressed: A) Enrollment of students; B) 1st-Year students; C) Restructuring procedures (e.g., Bologna); D) Teaching practices; and E) Labor Market. Based on an in-depth analysis of the survey results, a general view of the current situation of OR/MS Education in EURO countries is presented. Together with the brief results, preliminary trends are identified, important issues are discussed, and suggestions for improvements are made. In this way the main elements for a general and broader discussion, on future developments and OR/MS Education enhancements, are provided.

2 - Panel Discussion on OR/MS Education: Countries' Differences within a Shared European View?
Jeroen Belien, Kseniia Ilchenko, Joao Miranda, José Fernando Oliveira, Kenneth Sörensen, Ariela Sofer, Marijana Zekic-Susac

The "European Study on OR/MS Education" was primarily about OR/MS Education in Europe. As some countries were fairly well represented in the survey some additional research opportunities arose. Based on the survey results, the purpose is to provide those involved in OR/MS Education with pointers of what is happening at the European level, in order to enable them making informed decisions. The main goal for this panel discussion is to better understanding of the differences between OR/MS Education in different European countries. The starting point for the discussion is the survey appreciation, which was primarily focused on getting a general view on OR/MS Education in Europe. Secondly, there might be country specific issues, or demands, that can influence what OR/MS educators decide in terms of how they interpret and use the European survey results. From the discussion, it is expected to gain a sense of the differences between OR/MS Education within a specific country versus that of the rest of Europe. Important differences between the national situation and the European situation might lead to follow-up studies; for instance through interviews with survey respondents, it will be possible to investigate whether the survey results can be confirmed, but also how these can be explained. The panel discussion contributes to this by providing a useful insight in the way higher education institutions from different European countries present, offer, and handle OR/MS Education.

■ MD-54

Monday, 14:30-16:00 - Building PA, Room B

Large scale structured optimization 1

Stream: Convex Optimization
Chair: *Silvia Villa*
Chair: *Saverio Salzo*

1 - A Dual Method for Minimizing a Nonsmooth Objective over One Smooth Inequality Constraint
Ron Shefi, Marc Teboulle

We consider the class of nondifferentiable convex problems which minimizes a nonsmooth convex objective over a smooth inequality constraint. Exploiting the smoothness of the feasible set and using duality, we introduce a simple first-order algorithm proven to globally convergence to an optimal solution with a sublinear rate. The performance of the algorithm is demonstrated by solving large instances of the convex sparse recovery problem.

2 - Acceleration of iterative regularization algorithms by delta-convex minimization
Claudio Estatico, Fabio Di Benedetto, Flavia Lenti

In this talk we focus on the solution of functional equations characterized by an ill-posed operator mapping the unknown object to the data. The conventional variational regularization approach involves the minimization of a Tikhonov-type functional defined as the sum of a fitting term, which controls the residual, and a penalty term, which stabilizes the problem. We first discuss some Tikhonov-type functionals whose penalty term is model-dependent. More specifically, the penalty term is not a-priori defined but rather it depends explicitly on the operator characterizing the functional equation. Then, this model-dependent penalty term allows us to introduce a delta-convex (i.e., representable as a difference of two convex terms) Tikhonov-type functional, which is useful for speeding up the convergence of iterative gradient minimization algorithms. We call this acceleration technique as irregularization, which is especially useful for large scale equations where the computational complexity of gradient minimization algorithms is generally high. Moreover, some extensions of the irregularization technique to special Banach space settings is discussed and numerically analyzed in the context of image deblurring problems.

3 - Convergence analysis of a stochastic majorize-minimize memory gradient algorithm
Jean-Christophe Pesquet, Emilie Chouzenoux

Stochastic approximation techniques play a prominent role in solving many large scale problems encountered in machine learning or image/signal processing. In these contexts, the statistics of the data are often unknown a priori or their direct computation is too intensive, and they have thus to be estimated online from the observations. For batch optimization of an objective function being the sum of a data fidelity term and a penalization (e.g., a sparsity promoting function), Majorize-Minimize (MM) methods have recently attracted much interest since they are fast, highly flexible, and effective in ensuring convergence. The goal of this work is to show how these methods can be successfully extended to the case when the data fidelity term corresponds to a least squares criterion and the cost function is replaced by a sequence of stochastic approximations of it. In this context, we propose an online version of an MM subspace algorithm and we establish its convergence by using suitable probabilistic tools. We also provide new results on the convergence rate of such kind of algorithm. Numerical results illustrate the good practical performance of the proposed algorithm associated with a memory gradient subspace, when applied to both non-adaptive and adaptive linear system identification scenarios.

■ MD-56

Monday, 14:30-16:00 - Building CW, 1st floor, Room 122

Turning Research into Collaborative Cloud Applications

Stream: Workshops and roundtable
Chair: *Susanne Heipcke*

1 - Turning Research into Collaborative Cloud Applications
Susanne Heipcke, Sebastien Lannez

Optimization models are more and more frequently deployed as distributed, multi-user solutions within company networks or in cloud-based environments. We discuss the impact of these trends on modelling tools, including aspects such as data handling, support of concurrent and distributed computing, or internationalization as well as requirements on solver technology and integration with analytic tools like R. Making research models available to other users, raises a number of challenges and pitfalls. We cover strategies to overcome these and present how optimization or analytic models and solutions combining both can be rapidly deployed as collaborative, web-based applications.

■ MD-58

Monday, 14:30-16:00 - Building CW, Room 024

Mentoring Session 1

Stream: Mentoring Sessions

1 - Mentoring Session 1
Galina Andreeva

Have you ever thought of talking to someone outside your normal circle of work colleagues and friends for help with solving a problem? The mentoring session is the perfect opportunity to do just that. EURO2016 mentoring enables you to sign up for a 20 minute one-to-one session with an experienced OR professional. It is designed to help you with the issues you might be facing in your practice, career or development. You may use it to gain valuable advice; to help you identify the skills and expertise you need, and where to go for information; to see new perspectives; and to build your network. You must sign up in advance to talk to a specific mentor. Details of how to do this, and the latest mentor line-up, can be found on the EURO2016 website, at: http://www.euro2016.poznan.pl/mentoring/ To get the most from the session, please prepare in advance: what is the problem you'd like help and advice on, what would you like to know from your mentor. Be ready to ask the questions!

Monday, 16:30-17:30

■ ME-01

Monday, 16:30-17:30 - Building CW, AULA MAGNA

Plenary Dimitris Bertsimas

Stream: Plenary, Keynote and Tutorial Sessions
Chair: *Daniele Vigo*

1 - Machine Learning and Statistics via a Modern Optimization Lens
Dimitris Bertsimas

The field of Statistics has historically been linked with Probability Theory. However, some of the central problems of classification, regression and estimation can naturally be written as optimization problems. While continuous optimization approaches has had a significant impact in Statistics, mixed integer optimization (MIO) has played a very limited role, primarily based on the belief that MIO models are computationally intractable. The period 1991-2015 has witnessed a) algorithmic advances in mixed integer optimization (MIO), which coupled with hardware improvements have resulted in an astonishing 450 billion factor speedup in solving MIO problems, b) significant advances in our ability to model and solve very high dimensional robust and convex optimization models. In this talk, we demonstrate that modern convex, robust and especially mixed integer optimization methods, when applied to a variety of classical Machine Learning (ML) / Statistics (S) problems can lead to certifiable optimal solutions for large scale instances that have often significantly improved out of sample accuracy compared to heuristic methods used in ML/S. Specifically, we report results on 1) The classical variable selection problem in regression currently solved by Lasso heuristically. 2) We show that robustness and not sparsity is the major reason of the success of Lasso in contrast to widely held beliefs in ML/S. 3) A systematic approach to design linear and logistic regression models based on MIO. 4) Optimal trees for classification solved by CART heuristically. 5) Robust classification including robust Logistic regression, robust optimal trees and robust support vector machines. 6) Sparse matrix estimation problems: Principal Component Analysis, Factor Analysis and Covariance matrix estimation.

In all cases we demonstrate that optimal solutions to large scale instances (a) can be found in seconds, (b) can be certified to be optimal in minutes and (c) outperform classical approaches. Most importantly, this body of work suggests that linking ML/S to modern optimization will lead to significant advantages.

Tuesday, 8:30-10:00

■ TA-01

Tuesday, 8:30-10:00 - Building CW, AULA MAGNA

Keynote José Fernando Oliveira

Stream: Plenary, Keynote and Tutorial Sessions
Chair: *Erik Demeulemeester*

1 - Waste Minimization: the Contribution of Cutting and Packing Problems for a More Competitive and Environmentally Friendly Industry
José Fernando Oliveira

Cutting and Packing problems are hard combinatorial optimization problems that arise in the context of several manufacturing and process industries or in their supply chains. These problems occur whenever a bigger object or space has to be divided into smaller objects or spaces, so that waste is minimized. This is the case when cutting paper rolls in the paper industry, large wood boards into smaller rectangular panels in the furniture industry, irregularly shaped garment parts from fabric rolls in the apparel industry, but also the case when packing boxes on pallets and these inside trucks or containers, in logistics applications. All these problems have in common the existence of a geometric subproblem, which deals with the small object non-overlap constraints.

The resolution of these problems is not only a scientific challenge, given its intrinsic difficulty, but has also a great economic impact as it contributes to the decrease of one of the major cost factors for many production sectors: the raw-materials. In some industries raw-material may represent up to 40% of the total production costs. It has also a significant environmental repercussion as it leads to a less intense exploration of the natural resources from where the raw-materials are extracted, and decreases the quantity of garbage generated, which frequently has also important environmental impacts. In logistics applications, minimizing container and truck loading space waste directly leads to less transportation needs and therefore to smaller logistics costs and less pollution.

In this talk the several Cutting and Packing problems will be characterized and exemplified, based on Gerhard Wäscher's typology (2007), allowing non-specialists to have a broad view over the area. Afterwards, as geometry plays a critical role in these problems, the geometric manipulation techniques more relevant for Cutting and Packing problems resolution will be presented. Finally, aiming to illustrate some of the most recent developments in the area, some approaches based on heuristics and metaheuristics, for the container loading problem, and based on mathematical programming models, for the irregular packing problem, will be described.

■ TA-03

Tuesday, 8:30-10:00 - Building CW, 1st floor, Room 13

Preference Learning 1

Stream: Preference Learning
Chair: *Salvatore Corrente*

1 - Axiomatization of the Choquet integral and some aspects of its behavioural analysis
Mikhail Timonin

We propose an axiomatization of the Choquet integral model for the general case of a heterogeneous product set X = X1*...*Xn. In MCDA elements of X are interpreted as alternatives, characterized by criteria taking values from the sets Xi. Previous axiomatizations of the Choquet integral have been given for the particular cases Xi = Y or Xi = R for all i. However, within multicriteria context such identicalness, hence commensurateness, of criteria cannot be assumed a priori. This constitutes the major difference of this work from the earlier axiomatizations. In particular, the notion of comonotonicity cannot be used in a heterogeneous structure, as there does not exist a built-in order between elements of sets Xi and Xj. However, such an order is implied by the representation model. Our approach does not assume commensurateness of criteria. We construct the representation and study its uniqueness properties. We also revisit some popular indexes used to analyse behavioural properties of the model, such as the Shapley value and the interaction index. We demonstrate the difficulties with using these tools in cases when some criteria of the model do not exhibit interaction with the others.

2 - UTA-splines: additive value functions with polynomials
Olivier Sobrie, Nicolas Gillis, Vincent Mousseau, Marc Pirlot

UTA is a multiple criteria decision disaggregation procedure designed to learn an additive utility function model on basis of statements emitted by a decision maker. The method takes as input a set of pairwise comparisons of the form "alternative 'a' is preferred/indifferent to alternative 'b'" and the performances of 'a' and 'b' on the set of attributes involved in the decision problem. UTA uses linear programming in order to learn the additive utility functions. In an additive value functions model, these functions have to be monotone. In UTA this constraint is met by using piecewise linear functions. However using piecewise linear functions limits the interpretability of the model and its flexibility. In UTA-splines, we replace these piecewise linear functions by splines. The method uses semidefinite programming in order to infer an additive value function model. We present experimental results on artificial and real datasets.

3 - Interval UTA methods under different confidence levels of preference information
Masahiro Inuiguchi, Tomo Sugiyama, Roman Slowinski, Salvatore Greco

We consider Interval UTA, an extension of the ordinal regression method UTA to take into account robustness concerns. Interval UTA is an intermediate approach between the original UTA method and the robust ordinal regression methods UTA-GMS and GRIP. We extend the Interval UTA so as to handle different confidence levels of the preference information. We treat the following types of preference information: (A) "a is better than b with strong confidence", (B) "a is better than b with normal confidence" and (C) "a is better than b with weak confidence" and (D) "a and b are indifferent with strong confidence". The different confidence levels of preference information are represented by a nested set of interval utility function models. The nested set is composed of inner, middle and outer interval utility function models. We investigate the way of obtaining a nested interval models from given preference information. We identify the inner model by all preference information, the middle model by all preference information except type A, and the outer model by types C and D of preference information. We propose three ordinal regression approaches to build the nested interval UTA model: from inner to outer, from outer to inner, and simultaneous identification. In those ordinal regression approaches, we solve linear programming problems with constraints related to the nested structure among inner, middle and outer interval models. By a numerical experiment, we compare the 3 approaches.

4 - Robust decisions under risk & uncertainty
Roman Slowinski, Salvatore Corrente, Salvatore Greco, Benedetto Matarazzo

In order to learn Decision Maker's (DM) preferences and make robust decisions under risk and uncertainty, we apply Robust Ordinal Regression (ROR). This technique was originally proposed for multiple criteria decision aiding (MCDA) with the aim of taking into account the whole set of instances of a chosen type of preference model, which are compatible with preference information supplied by the DM in terms of holistic preference comparisons of some alternatives. ROR results in two weak preference relations, necessary and possible, in the whole set of alternatives; the necessary weak preference relation holds if an alternative is at least as good as another one for all instances compatible with the DM's preference information, while the possible weak preference relation holds if an alternative is at least as good as another one for at least one compatible instance. To apply ROR to decision under risk and uncertainty we reformulate this problem in terms of MCDA. This is obtained by replacing an uncertain outcome of a decision problem on a set of alternatives (e.g., a gain on investment) by a set of quantiles of the outcome distribution, which are meaningful for the DM. These quantiles become evaluation criteria of a deterministic MCDA problem, equivalent to the decision problem under risk and uncertainty. We solve the MCDA problem using a ROR method, like GRIP or ELECTRE-GKMS. We illustrate our proposal by solving an example of the famous newsvendor problem.

■ TA-04

Tuesday, 8:30-10:00 - Building CW, ground floor, Room 6

On some developments in game theory and OR situations

Stream: Recent Developments on Optimization and Some Results on Game Theory
Chair: *Mariusz Kaleta*

1 - What can experiments tell us about strategic behaviour in two-person, non-zero-sum games?
Alan Pearman, Ken-Ichi Shimomura, Barbara Summers, Simon McNair

Game theory has provided a rich source of insights for seeking to understand how individuals should and, to some extent, how they do behave in a variety of competitive situations. Although the immediate settings may be quite simplified or abstract, they are close enough to real life to offer worthwhile additions to complementary alternative perspectives, such as those from decision research or from other models of competition in economics. In this paper, we further develop a continuing series of computer-based experimental investigations into how subjects identify a strategy for competing against an opponent in a series of two-person, non-zero-sum games. The primary focus is descriptive - what people actually do - as opposed to prescriptive - what they should do in order to be seen to be acting rationally. We explore whether and how their strategies evolve over time, how effective they are, and how participants' behaviour correlates with verbal reports from the players describing what thought processes they were implementing at the time in order to decide on their strategic approach. We explore using measures of individual psychological difference to elaborate our descriptive account. We consider the influence of the complexity of the game on their exhibited behaviour and, unusually, investigate how behaviour patterns respond to sudden and unexpected changes in the game itself, a possibility not uncommonly met in real-life competitive situations.

2 - A Location-Based Train Performance Analysis for Passenger Trains.
Sofia Villers

On an average weekday there are 22,000 passenger train services running in the UK. Around 3,000 of those train services run through the Great Western area. On average only 2.5% of these 3,000 train services arrive more than 10 minutes late at their destination. The current performance measure is based only on the lateness at destinations. However, around 12% of the 3,000 train services arrive more than 5 minutes late at some timetable-locations in their journey. This work presents a different performance analysis based on train lateness at all locations in their journeys. This train performance analysis tries to answer questions like, 'are there specific train services that are almost always delayed at intermediate locations?', 'if the train starts its journey with a delay will it recover the time?', 'is a train's delay mainly caused at its stopping stations?', 'if a train becomes late at some point in its journey will it just keep getting later?'. This work presents the results of this train performance analysis using passenger train movement data.

3 - Cost reduction through the analysis of Sigma level: Case Study Automotive Industry
Amanda Mendes, Eliane Christo

Quality is a key factor for any company, as this always seeks to satisfy the needs and desires of customers. The work aims to analyze failures in the automotive electric glass mechanism cars during the warranty period granted by dealerships. Through the number of vehicles manufactured and the amount of defective was obtained a ratio of defective vehicles. Using Minitab software has been found values of the CPK and PPK values for the process in 2010 which was the period in which the vehicle presented more defects. Note that the company is in the sigma level of about 2.28, with 308,537 defects per million opportunities, which compromises 30 to 40% of the cost. Conducting another capability analysis for the years 2009 and 2011, periods in which vehicles had lower quantity of defects. It was observed that in normal times it operates in a sigma level 3.09, or 66,807 defects per million opportunities, compromising a lower part of the cost, 20 to 30%. About level of cost, if analyzed every year we have an average cost of EUR repairs 1645.73 / month. However for the years 2009 and 2011, there is an average cost of EUR 495.79 / month. This shows that if the company maintains the sigma level of the process 3.09 would reduce about 70% of the costs spent on repairs. This suggests a defect tracking, so the company can plan preventive actions to avoid that this situation generates criticality.

4 - Networked auctions and Price of Fairness
Mariusz Kaleta

We consider an auction design problem under network flow constraints. In many practical cases the commodities are associated with some elements of a network model, e.g. elements of telecommunication network, power transmission network or transportation network. Transactions are allowed only if the infrastructure, modeled as a network, is able to serve them. We introduce a class of network winner determination problems (NWDP), which can be used for choosing the winning transactions, and we analyze the computational challenges in solving the problems in NWDP set. We show that some versions of the network winner determination problems can be solved in polytime even in multi-item case. The sharp edge of tractability is designated by multi-item, binary (all-or-nothing) case.

We also focus on pricing mechanisms that provide fair solutions, where fairness is defined in absolute and relative terms. The absolute fairness is equivalent to 'no individual losses' assumption. The relative fairness can be verbalized as follows: no agent can be treated worse than any other in similar circumstances. Ensuring the fairness conditions makes only part of the social welfare available in the auction to be distributed on pure market rules. The rest of welfare must be distributed without market rules and constitutes so called Price of Fairness. We prove that there exists the minimum of Price of Fairness and that it is achieved when uniform unconstrained market price is used as a base price.

■ TA-05

Tuesday, 8:30-10:00 - Building CW, 1st floor, Room 8

Human Aspects in Multiobjective Optimization

Stream: Multiobjective Optimization
Chair: *Alena Otto*
Chair: *Dmitry Podkopaev*

1 - Interactive Multiobjective Methods: on the Measurement of the Achieved Decision Accuracy in the Laboratory Setting
Alena Otto

Interactive multiobjective optimization methods (IMOMs) assist decision makers (DM) in selecting their most preferred alternative step by step. Thereby the (possibly infinite) set of alternatives is unknown and alternatives get computed at each interaction step based on the preferences expressed by the DM. If the submitted partial preference information, such as reference directions or a reference point, was insufficient (e.g. when no efficient alternative with the desired characteristics exists), the DM may input new information on his/her preferences in the next interaction step. Theoretically, we expect DMs to perform enough iterations to select their most preferred alternative. However, in practice we observe cyclicality (i.e. DMs return to the visited alternatives) as well as concerns have been raised that DMs may quit their search prematurely. Overall, it is difficult to assess, when IMOMs indeed assist DMs to achieve their most preferred solution, because we neither have complete information on the DM's preferences nor know the whole set of efficient alternatives. In this talk, we will discuss possible ways to control for DM's preferences in a laboratory setting by externally imposing a valuation function on the criteria space and thus making decision accuracy directly measurable. We discuss research questions that can be addressed in such experimental setting and how they allow us to compare different design elements of the IMOMs.

2 - Multiple Criteria Decision Analysis: Method Centric or Human Centric?

Ignacy Kaliszewski

In the presentation we attempt to diagnose the limited response from OR practitioners to Multiple Criteria Decision Analysis methods. We hypothesize several reasons for that, such as: narrow time windows for actual decision making, the high mental cost of absorbing any MCDA method requiring an active participation of the Decision Maker in the decision making process, or the underestimated role of learned intuition, which precludes its explicit use as the preference carrier. In more general terms, we hypothesize that the lack of popularity and publicity of the perspective MCDA offers has its grounds in method centricity of MCDA methods, with human centricity being their desirable trait. As a remedy, we present and discuss a simple, intuitive variant selection mechanism which seems to be free on any above mentioned MCDA method deficiencies. This mechanism is reverse engineered from the Decision Maker explicit preferences expressed in the most natural terms. As a validation of the viability of our approach, we present a few problems solved with it and also the experience gathered from teaching MCDA courses.

3 - Towards Human-oriented Development of Multiobjective Optimization Methods

Dmitry Podkopaev

The research field of multiobjective optimization (MOO) has been shaped mainly by mathematical and computer scientists. This influences the role the decision maker (DM) has in MOO methods. First, the methods are developed in the form of algorithms, usually represented as flowchart schemes or pseudocode. Such a form dictates that the DM plays the passive role of a function returning preference information, called when needed. Second, the DM is mainly communicated with in mathematical (rather than human) language. A short description of method-specific parameters the DM is asked to provide, in our opinion can hardly characterize the solution derivation mechanism, weakening the link between the DM and "the solution corresponding to DM's preferences".

In contrast to MOO, the field of software engineering provides many instruments for developing programs in human-oriented (or at least user-friendly) manner; and there are examples of MOO methods implemented in such way. The event-driven approach to programming makes the user an active part of initiating all the interaction. Various graphical tools greatly ease human-machine communication. We propose to adjust the process of developing MOO methods to the opportunities the software industry provides for implementing them, namely using event-driven architecture, UML-based method description, and supplementing it with human-friendly preference modeling. We demonstrate how existing MOO methods can be re-engineered in this way.

■ TA-06

Tuesday, 8:30-10:00 - Building CW, ground floor, Room 2

Risk, Uncertainty, and Decision 1

Stream: Risk, Uncertainty, and Decision
Chair: *Veronica Roberta Cappelli*

1 - Bounded Rationality and Decision Analysis

Rakesh Sarin

Decision Analysis requires coherent judgments on beliefs and preferences and uses expected utility as a criterion for optimization. Bounded rationality recognizes that because of cost of processing information and cognitive limitations people may not be able to optimize even if they intend to do so. I will use two examples - one from investment and one from marketing - to illustrate how bounded rationality can be modeled within the framework of Decision Analysis.

2 - Sources of Uncertainty

Simone Cerreia Vioglio, Veronica Roberta Cappelli, Fabio Angelo Maccheroni, Massimo Marinacci

There is by now solid empirical evidence on the dependence of risk attitudes of decision makers on the risk source they are facing (Heath and Tversky, 1991, Fox and Tversky, 1995, Slovic, 1999). For example, human casualties generated by different catastrophic events (such as earthquakes, epidemics, terror attacks, nuclear accidents) may be evaluated in very different ways by policy makers taking prevention measures. Analogously, consumption at future dates is obviously discounted in different ways, but an investor may also take into account the fact that in different future dates he will be more on less affected by outcomes' variability (older people are more vulnerable to consumption shocks than younger ones).

In this paper, we provide a framework to describe decisions depending on several sources and we obtain a general axiomatic foundation for the representation of preferences in this framework. Specifically, alternatives depending on different sources are represented by vectors of source dependent prospects, and we characterize the evaluation of these alternatives by means of a two stage process: in the first stage, decision makers compute the certainty equivalents of the different components of the vector using source- specific utility functions, probability measures, and probability distortion functions; in the second stage, they take a a quasiarithmetic mean of these certainty equivalents.

3 - Testing Biseparable Preferences

Veronica Roberta Cappelli, Fabio Angelo Maccheroni, Giorgia Romagnoli

A large body of empirical evidence shows violations of expected utility. In response, decision theory and behavioral economics have provided a large variety of non-expected utility theories. However, the existing evidence does not clearly discriminate among such theories. Many of the most well-known non-expected utility models belong to the class of biseparable preferences, which includes Rank Dependent Utility models (Choquet Expected Utility, Prospect Theory and Choice-Acclimating Personal Equilibria), models of Disappointment Aversion, Maxmin Expected Utility and its Alpha-maxmin extension. Biseparable preferences satisfy the minimal behavioral restrictions that allow to separate tastes (as captured by a utility function on outcomes) and beliefs (as captured by the willingness to bet on events, often a distorted probability). In this paper we derive a non-parametric procedure for testing the biseparability of preferences hypothesis and we apply it to the results of a preliminary lab experiment. In the data we find little support for the separation of utility and beliefs as characterized by biseparable preferences. On the other hand, the observed behavior can be accommodated by alternative models, such as Smooth Ambiguity and Source Dependent Expected Utility.

■ TA-07

Tuesday, 8:30-10:00 - Building CW, 1st floor, Room 123

ROADEF/EURO OR Challenge presentation (II)

Stream: EURO Awards and Journals
Chair: *Eric Bourreau*
Chair: *Vincent Jost*
Chair: *Safia Kedad-Sidhoum*
Chair: *David Savourey*
Chair: *Marc Sevaux*
Chair: *Jean André*
Chair: *Michele Quattrone*
Chair: *Rodrigue Fokouop*

1 - GRASP Approach for Inventory Routing Problem
Tamara Jovanovic

The inventory routing problem that is considered in this paper is proposed by AIR LIQUIDE within the ROADEF/EURO challenge 2016 in the qualification phase. The suggested method consists of feasibility and improvement phase. The first phase involves a constructive heuristics (greedy) for obtaining a good quality feasible solution. This first phase is followed by the randomized adaptive search as an improvement. The greedy routine for obtaining a first feasible solution is based on the principal "deliver as late as possible". Delivery decisions are made according to the priority functions, which are defined based on the statistical analysis of customer properties. The improvement phase consists of repetitively removing customers from the current solution, improving the partial solution with different transformation functions, and finally scheduling back the dropped customers. Scheduling back is done by running the same greedy algorithm from the first stage on the set of dropped customers. The results of this method are confirmed in the qualification phase of the challenge.

2 - A heuristic for the Air Liquid Inventory Routing Problem
Pedro Munari, Aldair Alvarez, Maria Gabriela Furtado, Pedro Luis Miranda, Amélia Stanzani

We describe a solution strategy proposed for the Air Liquide Inventory Routing Problem of the ROADEF/EURO 2016 Challenge. The strategy is based on a heuristic that analyses the consumption of the product at customers through the time horizon and then ranks the customers according to product shortage. For each feasible time window regarding drivers and trailers availability, the heuristic solves a resource constrained shortest path problem to determine shifts that satisfy all requirements stated by the company. At the end of the method, the best routes are combined to generate a final solution for the problem. The results of computational experiments using real-life data provided by the company indicate that the proposed strategy is able to find reasonably good solutions in very short running times, which is a desirable feature in practice. Also, the quality of the solutions can be improved by allowing longer running times.

3 - ROADEF/EURO Challenge 2016 : Final Results announcement
Eric Bourreau, Vincent Jost, Safia Kedad-Sidhoum, David Savourey, Marc Sevaux, Jean André, Michele Quattrone, Rodrigue Fokouop

We present the results of the ROADEF/EURO 2016 challenge, an international optimization contest propose jointly by EURO, the French OR society (ROADEF) and an industrial partner (Air-Liquide). Many prizes are available. Air Liquide propose 2500 euros for the first team in junior category, 7500 euros for the first in senior category and 5 000 euros for a special award. Intermediate qualification results (available since february 2016 on http://challenge.roadef.org/) have already shown that the competition is very tight, but after all these presentations, the suspense will be over as the winners will be revealed.

■ TA-08

Tuesday, 8:30-10:00 - Building CW, 1st floor, Room 9

Workshop on Spatial-Multi Criteria Evaluation Decision Support System

Stream: Workshops and roundtable
Chair: *Valentina Ferretti*
Chair: *Luc Boerboom*

1 - Workshop on Spatial-Multi Criteria Evaluation Decision Support System
Luc Boerboom, Valentina Ferretti

The ILWIS geographic information system (GIS) is the only raster-based and free and open source GIS, which offers spatial multi-criteria evaluation (SMCE) inspired by decision science software. Rather than using a simple GIS notion of overlays to perform SMCE, it uses a value tree, has value functions and weighting options. Decision alternatives can be pixels within a map and spatial plans. Criteria can be spatial, spatial metrics, or non-spatial. A new client-server architecture allows web-based SMCE for a vast range of developments and applications. The workshop addresses (junior) researchers and software developers/practitioners in decision sciences. No experience with GIS is required, but basic understanding of Multi-Attribute Decision Making is. Participants will gain: 1) Hands-on experience and theoretical grounding of SMCE to identify problem locations, design solutions and evaluate alternative plans. 2) Application opportunities by seeing examples of national parks delineation, regional reconstruction after war, implementation of national urban policies, or transition to biogas. 3) R&D opportunities in the new ILWIS client-server architecture, through connectors to Python, R, and Java. Participants can freely take software, tutorial, and example data but will be required to bring their own laptop.

Content 15 minutes: Introduction to ILWIS-SMCE and looking ahead into client-server based ILWIS-SMCE 10 minutes: Download, installation of software and data. 30 minutes: Tutorial of ILWIS - SMCE with a case of national park design and choice, based on accompanying peer reviewed journal publication. 30 minutes: Explore complex example cases of regional reconstruction after war, implementation of national urban policies 5 minutes: Closing remarks

Output. Participants can freely take software, tutorial, and example data.

Practical requirements. BYOL (Bring Your Own Laptop) and BYOB (beer). This Windows software also runs under Wine on Linux or Parallels on Mac.

■ TA-09

Tuesday, 8:30-10:00 - Building CW, 1st floor, Room 12

Modeling software

Stream: Mathematical Programming Software
Chair: *Robert Fourer*

1 - Recent progress in CPLEX for Quadratic models
Xavier Nodet

IBM Decision Optimization released two versions of CPLEX in 2015. We will review new features and performance improvements that these releases bring, with a specific emphasis on Quadratic models.

2 - Cloud services for optimization modeling software
Robert Fourer

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

3 - Mosel: Modelling and more
Susanne Heipcke

Xpress-Mosel, originally designed as a modelling, solving and programming language for working with the solvers of the FICO Xpress Optimization suite, has gradually been extended to support parallel and distributed computing, going along with a host of new data connectors (including the possibility to act as HTTP client or server), new interfaces to tools such as the analytics suite R, the definition of metadata via annotations and most recently, internationalization. The deployment options (cloud, physical network, desktop) of Mosel programs via the web-based multi-user interface provided by FICO Optimization Modeler including visualizations find increasing use from non-optimization users, some examples of which will be presented here.

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

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

■ TA-10

Tuesday, 8:30-10:00 - Building CW, ground floor, Room 1

AHP Applications 1

Stream: Analytic Hierarchy Process / Analytic Network Process
Chair: *Josef Jablonsky*

1 - Energy Resource Selection Using Analytic Hierarchy Process: Case of Black Sea Region in Turkey
Ata Çırak, Didem Cinar

Selection of a suitable resource for energy generation is crucially important especially for developing countries who depend on foreign energy resources to fulfill their needs. In this study, analytical hierarchy process is used to determine the best energy resource in terms of technical, economic, environmental, social, and political attributes. This paper is mainly concerned with the differences between the decisions of various partners about the suitable energy resources. Thus, energy companies, academicians, and people living nearby the sources are taken into account as the decision makers. The main factors affecting both overall and group decisions are investigated. Preliminary results are obtained for Black Sea Region of Turkey which has a growing economy and a high potential of domestic energy resources.

2 - Choose a medium-sized warship to be built in Brazil: a multicriteria approach
Marcos Santos, Rubens Oliveira, Sergio Baltar Fandino, Ernesto Rademaker Martins, Jonathan Ramos, Glauco da Silva

Purpose: To base the choice of a medium-sized ship, ie, 2,000 to 3,000 tonnes, to be built in Brazil, showing the hierarchical way options. Methods: Among the many tools of Multi-Criteria Decision Aids, the AHP method is used. The criteria will be listed and their respective weights are assigned to the light of the National Defense Strategy, the Strategic Program of the Navy and interviews with some Navy officers with more than twenty year career. To list the criteria we used the technique of critical incident. Contribution for practice: Although the AHP is a consecrated by the American School method and widely used by the scientific community, the Brazilian Navy does not have records that this method has been applied in the Staff Studies aiming the acquisition and / or construction of war ships. Being a hierarchical and compensatory method in much fits the culture of Brazilian Navy. Contribution to society: The Principle of Economy and of Parsimony in Public Administration require you to spend the least amount of resources in order to give maximum return on each dollar invested. With this, the use of AHP method in selecting the unit to be built is presented as a transparent and clearly scientific bias way for Brazilian society have the perception that the best option of the three models presented ships was made.

3 - AHP model for quality of life analysis: A case of Czech administrative regions
Josef Jablonsky

Measuring the quality of life of given units (cities, urban regions, countries etc.) is the task that is quite often discussed by researchers and independent organizations. The result of the analysis usually leads to a composite index that allows ranking of the units. The problem itself is multiple criteria decision analysis (MCDA) problem. This kind of problems is often solved by simple approaches that need not lead always to correct results. The main aim of the paper is to develop an AHP model with absolute measurement for evaluation of quality of life in 14 administrative regions in the Czech Republic based on 3 main groups of totally 24 criteria and compare its results with official methodology. This methodology is based on equal importance of all criteria and a quite unacceptable MCDA technique is applied. The results given by the AHP model are compared to the ones derived by official methodology, by several MCDA methods (SAW, TOPSIS, PROMETHEE), and by a data envelopment analysis model without explicit inputs.

4 - Stakeholder Prioritization using AHP: A Sustainability Marketing Perspective
Vinod Kumar

The researchers have not reached to any consensus even after introducing several stakeholder classification schemes in the area of sustainability marketing. Therefore, the present research aims to introduce a new and simplified model for classifying and prioritizing stakeholder in relation to sustainability marketing. The model is based on empirical research, carried out on Business Standard 1000 Indian companies. The data is collected using a web generated structured questionnaire that has resulted in 153 valid responses. These responses are then analyzed to classify and prioritize the identified stakeholders using Exploratory Factor Analysis (EFA) and Analytical Hierarchy Process (AHP) techniques respectively. The new model proposes to classify stakeholders on the basis of dimensions of sustainability i.e., environmental stakeholders, social stakeholders and economic stakeholders. Moreover, the economic stakeholders found to be given more importance over environmental stakeholders and social stakeholders. The individual stakeholder groups are also prioritized to facilitate managers and practitioners for effective stakeholder management.

■ TA-11

Tuesday, 8:30-10:00 - Building CW, 1st floor, Room 127

Discrete and Global Optimization 3

Stream: Discrete and Global Optimization
Chair: *Gerhard-Wilhelm Weber*
Chair: *Vahid Eghbal Akhlaghi*

1 - A Global Approach for Storage Location Problems in a Distribution Center
Jung-Fa Tsai, Ming-Hua Lin

This study considers a storage location problem in a distribution center which discusses about how to place goods on a set of locations with minimized total moving distance and costs in order-picking operations in a distribution center. The formulated problem is a quadratic integer programming problem and hard to be solved for finding a global optimal solution. Although various heuristic algorithms have been developed to treat this problem, the solution obtained cannot guarantee the global optimality. This study integrates the efficient linearization approach and enhanced SOS1 expression to reformulate the storage location problem as a linear mixed-integer program for finding a global optimal solution. The proposed model is more computational efficient by reducing the number of binary variables and can treat large scale problems. Numerical examples are presented to demonstrate that the proposed method can effectively obtain a global optimal solution and assign goods to locations to reduce moving distance and costs in order-picking operations in a distribution center.

2 - The Two-Echelon Freight Transportation Network in City Logistics
Mohammad Saleh Farham, Haldun Sural, Cem Iyigün

We consider a two-echelon distribution network at the context of City Logistics. In the first echelon, freight is carried from external facilities to the inner-city facilities by large trucks. External facilities are City Distribution Centers (CDCs) located on city boundaries. In the second echelon, goods are loaded into environment-friendly vehicles to be distributed to the customers in urban areas. We consider strategic planning of the two-echelon freight transportation as one of the challenging problems in city logistics. The problem seeks location of facilities and routing of vehicles at minimum transportation cost. We basically consider a simple variant of the problem containing one CDC and several candidate satellite locations in the second echelon. No routing decisions are made in the first echelon. We present mixed integer programming formulations of the problems under satellite and vehicle capacities and customer time windows. Set partitioning formulation of the problem is provided and a branch-and-price algorithm is developed to solve the problem where the sub-problem is an Elementary Shortest Path Problem with Resource Constraints. The ESPPRC is solved by means of dynamic programming and several improvements are done to boost the performance of the algorithm. Problem test instances applicable to city logistic framework are generated for the computational purposes and we report extensive computational results. This research is supported by TUBITAK Grant No: 113M121

3 - Comparison of CRM and k-Unit Cycles in Robotic Cells with Multiple Parts
Vahid Eghbal Akhlaghi, Hakan Gultekin, Betul Çoban

In this paper, we consider the robotic cell scheduling problem where multiple parts are produced in a flowshop environment. An industrial robot performs the transportation of the parts between the machines and the loading/unloading of the machines. If the robotic cell produces different types of parts, we refer to it as a multiple part-type cell (in contrast to single part-type cells), in which parts have different processing times on the machines. We consider the cyclic scheduling of the robot moves. A cycle is specified by a repeatable sequence of robot moves designed to transfer a set of parts between the machines for their processing. A cycle in which k parts are produced is called a k-unit cycle. In other words, the robot takes k parts from the input device and whenever all the robot activities are repeated exactly k times and the robot returns to its initial state of the cycle, the k-unit cycle is completed. Exactly k parts are produced at the end of the cycle. On the other hand, Concatenated Robot Move Sequences (CRM sequences) is the repetition of the same 1-unit cycle repeated k times to produce k parts. The objective in both cases is to determine the optimal robot move cycle (either 1-unit or k-unit) and the part sequence to maximize the long-run average throughput rate. We develop a mixed integer programming formulation and heuristic algorithms for both cases. We compare the performances of CRM and k-unit cycles through an extensive computational study.

4 - Integer Programming Formulations and Benders Decomposition for Maximum Induced Matching Problem
Betül Ahat, Tinaz Ekim, Z.Caner Taskin

In this study, we investigate Maximum Induced Matching problem (MIM), finding an induced matching having the largest cardinality. The problem is NP-hard for general graphs. We develop an IP formulation with less decision variables compared to other formulations in the literature. Then, we introduce vertex-weighted and edge-weighted versions of MIM and call them Maximum Vertex-Weighted Induced Matching problem (MVWIM) and Maximum Edge-Weighted Induced Matching problem (MEWIM), respectively. We adapt previous formulations to solve MVWIM and MEWIM instances. In Maximum Weight Induced Matching problem (MWIM), we assume both vertices and edges have weights. We give a QP formulation for MWIM and its linearization. We implement Benders decomposition approach to partition the problem into smaller problems and add some valid inequalities to our formulation to improve the efficiency of our algorithm. By testing the performance of our methodology on random graphs with different densities, we see that our approach solves instances with medium and large densities significantly faster than other methods in the literature.

■ TA-12

Tuesday, 8:30-10:00 - Building CW, ground floor, Room 029

VeRoLog: Crossdocking

Stream: Vehicle Routing and Logistics Optimization
Chair: *Fabien Lehuédé*

1 - Shipment Consolidation and Dispatching with Cross-Docks
Sinem Tokcaer, Ahmet Camcı, Ozgur Ozpeynirci

Long haul and international freight transportation is a highly competitive market, where freight forwarder companies have to deliver the best service with low prices. In order to meet this challenge, the freight forwarders mostly establish their own consolidation systems to achieve economies of scale and efficient use of the owned and rented vehicles. Additionally, most of the freight forwarders use cross-dock terminals in the visited country in order to provide additional services, and reduce the traveling time of the vehicles. In this study, we introduce shipment consolidation and dispatching problem (SCDP). We develop a mathematical model that decides on consolidation of orders, departure date and route of the vehicles and the intermediate stops on the routes by allowing the orders to be delivered either by vehicle or using a cross-dock. We also develop two lower bound algorithms (LB1 and LB2), and test mathematical model and two lower bound algorithms on randomly generated instances. The experiments show that, there is no significant difference between LB1 and LB2 algorithms in terms of CPU time; yet, LB2 is significantly better than LB1 in terms of solution quality. * This research is supported by TUBİTAK, Grant No: 214M195.

2 - Integrated optimization for material flow and placement problem in cross-docking
Ilker Kucukoglu, Nursel Ozturk

Cross-docking system, which is one of the lean logistics strategy, has become a practice concerned by many companies in order to increase the efficiency of the material flow. This paper addresses the integrated material flow and placement problem in cross-docking centers where products are transferred from suppliers to customers through cross-docking facilities without storing them for a long time. The problem is formulated using mixed integer programming which aims to find best product transshipment and placement plan that minimize total transportation cost in supply chain network. Because of the complexity of the problem a simulated annealing (SA) meta-heuristic algorithm is proposed to solve large scale problems. The proposed SA is performed for several randomly generated examples and results show that this approach exposes effective and efficient solutions in acceptable computational times. As a result of this study, the proposed algorithm can be applicable to find a material flow and placement plan from suppliers to customers for real life cross-docking operations.

3 - A large neighborhood based matheuristic for the vehicle routing problem with cross-docking and dock resource constraints
Fabien Lehuédé, Michel Gendreau, Philippe Grangier, Louis-Martin Rousseau

The Vehicle Routing Problem with Cross-Docking (VRPCD) is a variant of the Pickup and Delivery Problem with Transfers with one compulsory transfer point: vehicles start by collecting items, then return to the cross-dock where they unload/reload some items and eventually visit delivery locations. The VRPCD has been proposed to model the routing part of the cross-docking distribution strategy, whict has been largely used since 1980s and is known to help reducing delivery costs compared to traditional distribution systems. In the VRPCD, it is assumed that a truck undergoes consolidation operations as soon as it arrives at the cross-dock. However, in real life the processing capacity of the cross-dock is a limiting factor, and as such several recent articles have outlined the need for a model that would take it into account in the routing problem. To that end, we introduce an extension of the VRPCD in which the number of vehicles that can simultaneously be processed at the cross-dock is limited. We call it the Vehicle Routing Problem with Cross-Docking and Dock Resource Constraints (VRPCD-DR). To solve it, we adapt a recently proposed method for VRPCD that relies on large neighborhood search and periodic calls to a set partitioning based problem. In particular we focus on feasibility tests in the reinsertion part of the LNS, as the capacity constraints at the cross-dock makes the scheduling subproblem NP-Hard. Our method has been tested on instances adapted from the VRPCD.

4 - Design and Analysis of a Proposed Nested Genetic Algorithm to Solve a Vehicle Routing Problem with Cross Docking
Mahdi Bashiri, Ali Baniamerian

Implementation of an appropriate distribution strategy in order to manage the physical flow of materials is one of the most important factors in the success of the companies. Cross docking is an efficient distribution strategy which todays is practically used by many companies to improve their servicing in the lower cost with the high level of customer satisfaction. In this paper because of the NP_hardness of the problem a nested Genetic algorithm is designed to solve a vehicle routing problem with cross docking and time windows. Review on the literature of cross docking shows that at most one part solution representations in different algorithms were proposed to the problem. The length of one part solution representations in the larger instances leads to high computational time to search which is an important issue in the evolutionary algorithms. In the proposed algorithm we introduce a two part solution representation and an efficient approach to search the solution space called nested approach. A good feasible solution of delivery part is obtained in the first phase and the best pickup part solution is created according to the obtained delivery part in the second phase. The consolidation operations are then added to the complete solution. In order to evaluate the performance of the proposed algorithm of this paper, different examples of a real data set from small to large sizes are solved and analyzed.

■ TA-13

Tuesday, 8:30-10:00 - Building CW, ground floor, Room 3

VeRoLog: Routing In Practice 1

Stream: Vehicle Routing and Logistics Optimization
Chair: *Sameh Haneyah*

1 - Departure Time Optimization in Real-life Vehicle Routing Problems
Gerben Groenendijk, Leendert Kok

Optimizing departure times in vehicle routes is a crucial step in developing efficient vehicle route schedules. For Real-life vehicle routing problems in particular, this is a challenging task. On the one hand, customers request more extensive vehicle routing models to better fit their business. On the other hand, problem sizes grow, while the urge of quickly finding the optimal departure time grows as well. Optimized departure times are highly valued in practice. Not only in order to reduce costs by a better utilization of resources, but it is also required to find feasible schedules with respect to driving and working time legislation. Although literature contains some research on departure time optimization, the combination of restrictions that needs to be taken into account for Real-life vehicle routing problems isn't considered yet. In this talk, we illustrate some of the restrictions that need to be taken care of in practice and we describe how we try to cover them in our vehicle routing solutions. Next, we disclose recent trends in logistics that challenge our model and that may serve as an agenda for future research.

2 - Solving Integrated Vehicle Routing and Resource Assignment Problems from Practice
Sameh Haneyah, Leendert Kok

We address a problem from practice on vehicle routing and resource assignment. Our solution approach decomposes the problem into two phases. The first phase constructs trailer routes by solving a capacitated vehicle routing problem with time windows, driving legislation, and congestion. The second phase assigns trailer routes to resource shifts, i.e., truck and driver combinations, by solving a scheduling problem. To provide greater flexibility and better utilization of resources, we may divide trailer routes into segments and assign the segments to resource shifts. The latter case increases the complexity due to dependency issues when segments of the same trailer route are assigned to different resource shifts. Currently, we have a software product that uses column generation, where complete trailer routes are assigned to resource shifts (columns), but this approach is not fully applicable with segments, because then the columns are no longer independent. In literature, we see few papers on this problem where limitations are introduced on the segments resulting from the first phase, to make them independent in the second phase. However, we need a solution method that handles the dependencies, because circumventing them diminishes the benefits of planning with segments. Moreover, we need a method that works well in practice. In this talk, we discuss the different solution methods we developed and propose the suitable method to use for a difficult case from practice.

3 - Practical Ways to Solve Real-life Extensions to Routing Problems
Bryan Kuiper

Vehicle routing problems in practice appear with many restrictions such as capacities, time windows, calendar openings, forbidden or required capabilities, drivers' working and driving regulations, etc. At ORTEC we have a generic software product that employs state-of-the-art algorithms to solve different variants of such problems. However, we are often encountered with new requirements from special business cases that the generic framework cannot immediately handle. In some cases, it is sensible to extend the framework to cover the new requirements, but in other cases it makes more sense not to extend the algorithms and increase their complexity considerably only to cover a fraction of customer cases. For the latter cases, we develop some procedures that can complement the main algorithmic framework in order to solve certain sub-problems or complicated business restrictions. In this talk, we first describe the existing algorithmic framework in general, and second present few customer cases with requirements not fully covered by the generic framework. Finally, we present procedures and tricks implemented to handle the additional requirements. A main example comes from a customer case where combinations of pallets and large doors need to be transported in trailers with flexible floors. The construction of flexible floors depends on the assignment of doors and pallets to be transported, and this changes for every optimization call.

4 - Properties of Good Solutions for the Vehicle Routing Problem
Florian Arnold, Kenneth Sörensen

The Vehicle Routing Problem (VRP) is probably the most-studied problem in Operations Research. However, in the race for faster algorithms and better solutions, few research has been performed to shed light on the problem itself. Even though problem-specific knowledge is an important ingredient in the design of heuristics, such knowledge is rare for the VRP. As an example, it is proven that in the Traveling Salesman Problem does no optimal solution contain intersecting edges. Even though such a statement is not true for the VRP, it should be possible to deduct general guidelines such as: "In general, solutions can be improved by removing intersections". In this presentations, we take a first step in this direction and use data mining techniques to identify properties that distinguish optimal from non-optimal solutions. Those properties describe the geometrical nature and relations of routes. We combine them with instance characteristics to derive findings that are independent of the specific problem instance. With the help of a classification learner we are able to predict with a relatively high percentage from the defined properties whether a certain solution for any instance is optimal or not. Moreover, we extract rules that explain why a solution is not optimal. Finally, we demonstrate how these rules can be used in the design of heuristics. We implement a local search technique that uses a rule-database to determine the most-promising moves in each step.

■ TA-14

Tuesday, 8:30-10:00 - Building CW, 1st floor, Room 125

Optimal decisions

Stream: Mixed-Integer Linear and Nonlinear Programming
Chair: *Giuseppe Bruno*

1 - An optimization model for the check-in service
Giuseppe Bruno, Antonio Diglio, Andrea Genovese, Carmela Piccolo

In an airport terminal, the check-in service consists in processing and accepting passengers arriving at designated desks. Even if many companies introduced online procedures to reduce the impact of these operations, the need for an efficient management still arises due to the increasing air passengers' traffic and to a concurrent necessity of cutting costs for airlines and third party providers. These concomitant issues frequently lead to congestions of the terminal infrastructures and long waiting times and queues at check-in desks. We propose an optimization model for airports check-in services. The aim is to decide the optimal number of active check-in gates, in such a way to balance the operative costs of the service and the passengers' waiting time at the terminal. In particular, the model addresses simultaneously a staff-scheduling problem for the desk-operators, i.e. the problem of deciding how many employees have to begin work in any period of the day in such a way to satisfy the demand at minimum cost, and a passengers-scheduling problems, i.e. the problem of deciding how many passengers have to be accepted in each time period. This way, the model find a trade-off solution between the cost incurring for the desk-operators and the service-level provided to users, defined in terms of waiting times. The model was tested on real-data related to different Italian airports and the results show its capability of solving istances of different size.

2 - Distance-based methods of group classification
Mariya Naumova

Given a finite number of learning samples from several populations (groups) and a collection of samples from the union of these populations, it is required to classify the entire collection (not a single sample) to one of the groups. Such problems often arise in medical, chemical, biological and technical diagnostics, classification of signals, etc. We consider different methods of solving the problem based on distance formulas and make comparison of their quality based on numerical results. We give an illustrative example with real data to demonstrate the effectiveness of the classification methods.

3 - Intelligent Decision Support Systems in Supply Chain Management
Sahar Validi

Increasingly complex supply chains have to adapt to the uncertain and dynamic environment in which they operate. Efficient decision-making in such an environment is a necessity and affects the supply chain performance significantly. Research shows that conventional approaches to decision-making are no-longer an efficient way of dealing with problems in supply chains. Artificial Intelligence or Knowledge-Based techniques are used increasingly as efficient alternatives to more conventional techniques to decision making.

Use of Decision Support Systems and Artificial Intelligent techniques has a long history in management of Information Systems, yet literature review reveals limited use of AI techniques in decision making and managing supply chains. AI techniques are recognised as complex and dynamic approaches through which complicated situations can be dealt with. Ideally, a Knowledge-based decision support system within the supply chain should behave like a smart (human) consultant; gather and analyse data, identify problems throughout the supply chain, find and evaluate the solutions and propose and monitor actions.

This paper is based on an ongoing interdisciplinary research on the applications of Artificial Intelligence techniques in Supply Chain Management. The focus of this paper is specifically on Decision Support Systems and the contribution of AI in this field to efficient management of supply chains.

4 - Maximization Problems with Half-Product Objective Function
Vitaly Strusevich, Hans Kellerer, Rebecca Sarto Basso

We address the Boolean programming problem of maximizing a half-product function, with and without a linear knapsack constraint. Maximizing the half-product can be done in polynomial time, since the objective is supermodular. Adding a knapsack constraint makes the problem non-approximable within a constant factor, provided that the coefficients in the linear part of the function are negative. For maximizing a function with positive coefficients in the linear part we develop a fully polynomial-time approximation scheme.

■ TA-15

Tuesday, 8:30-10:00 - Building CW, 1st floor, Room 126

Modeling Uncertainties in Gas Network Optimization

Stream: Optimization of Gas Networks
Chair: *Sidhant Misra*

1 - The Passive Gas Network Nomination Problem: Handling of Physical Uncertainties
Denis Aßmann, Frauke Liers, Michael Stingl

In this talk, we focus on the impact of uncertainties in the operation of gas networks. A well-known example is the roughness value of the pipe that influences the friction of the gas and thereby effects the pressure loss between the endpoints of the pipe. However, the roughness depends on the contamination of the pipe and can only be measured with great effort. Our goal is the generalization of mathematical optimization models for gas network operation such that the solutions are protected against a predefined uncertainty set. The robustification of the mentioned problem leads to mixed- integer linear, conic quadratic or positive semidefinite optimization problems, depending on the given uncertainty set and the occurrence of the uncertain data. In this talk, we present a static mixed-integer linear and a two-stage mixed-integer positive semidefinite robust optimization approach, together with preliminary computational results.

2 - Monotonicity in Dissipative Networks and Applications to Robust Optimization
Marc Vuffray, Sidhant Misra

We consider transient flows of a commodity transferred throughout a network, where the flow is characterized by density and mass flux. The dynamics on each edge are represented by a general system of PDE that approximates subsonic compressible fluid flow. The commodity may be injected or withdrawn at any nodes, and is propelled throughout the network by compressors. A canonical problem requires to operate compressors such that time-varying withdrawals are delivered and the density remains within strict limits while an economic cost objective is optimized. We consider the case where withdrawals are uncertain, but bounded within prescribed time-dependent limits. We prove that general dynamic dissipative network flows possess a monotonicity property that renders tractable optimization problems in which the solutions must be robust with respect to withdrawal uncertainty. We illustrate this result with the example of the natural gas network.

3 - Optimization of integrated gas-electric systems under uncertainty
Line Roald, Sidhant Misra

Electricity generation from gas fired power plants is increasing in many parts of the world. Gas-fired generators have the capability to ramp quickly and are often utilized by grid operators to balance the intermittent energy production from renewable energy sources. While the electric systems depend on this flexibility, the resulting gas withdrawals are both time-varying and unpredictable. Without proper scheduling that accounts for the dynamic properties of the gas systems, pressure violations and supply disruptions which increase risk in both gas and electric systems might occur.

To address this problem, we formulate an integrated optimization problem which minimizes cost of electricity generation and gas compression subject to constraints from both the electric and gas systems. We base the gas system constraints on a dynamic representation, where the gas flows are modelled using partial differential equations, reflecting the fact that gas systems typically do not reach steady state in intra-day operation. To account for uncertainty from renewables, we enforce the constraints in the electric system using chance constraints, which ensure a high probability of constraint satisfaction and provide probabilistic bounds on the gas withdrawals. Based on those bounds, we formulate a robust gas problem based on monotonicity properties of the gas flows. In a case study, we show that the method provides solutions which are feasible for both systems and robust to uncertainties.

■ TA-16

Tuesday, 8:30-10:00 - Building CW, 1st floor, Room 128

Home healthcare

Stream: Healthcare Logistics
Chair: *Tomas Eric Nordlander*

1 - A heuristic rolling horizon approach for home care routing and scheduling in a dynamic setting
Daniela Guericke, Leena Suhl

Home care is a growing sector in health and social systems. In contrast to other care institutions, clients receiving services stay at their own homes. Hence, the home care providers face a complex routing and scheduling task to plan their services. For application in practice, skill requirements and legal labor regulations must be considered. Most publications in literature consider a static planning for a given set of clients and nurses. However, regular changes in demands of clients and availability of nurses occur and lead to a dynamic setting. Therefore, we propose a heuristic solution approach to incorporate these changes in a rolling planning horizon while preserving continuity between planning periods. The consideration of continuity avoids changes in assignments of nurses to clients and aims at preserving similar time schedules. Both aspects are essential for client satisfaction and need to be joined with the economical objective function of minimizing travel times. We use our numerical results for several analyses to show the computational efficiency of the proposed method and quality of the solutions. We further investigate the influence of different continuity metrics on the resulting schedules and the trade-off between maximizing continuity and minimizing travel time.

2 - Homecare planning, a challenging optimization task.
Tomas Eric Nordlander, Leonardo Lamorgese

The planning of homecare services is a complex process that involves: 1) allocating personnel among shifts, 2) assigning staff members to patients, 3) routing staff visits and 4) scheduling treatments while considering, for example, required competences, patient and caregiver preferences, labour laws, union regulations, organisational policies and temporal precedence of activities within a limited budget. Homecare planning is primarily done manually even though optimisation techniques have aided in solving similar problems in other domains. Efficient homecare planning requires optimisation techniques and optimised homecare can deliver significant savings for municipalities, regions and hospitals. From the patient's perspective, higher-quality homecare services provide higher living standards. Improved service quality results in better treatments (assignment of staff members with the appropriate competences), higher continuity of care (less rotation of staff members for the same patient) and fulfilment of patient preferences. More efficient homecare services allow treating more patients at home, which patients indicate is their preferred place of care. However, homecare planning is still mostly performed manually. Researchers need to address the integrated optimisation problem to obtain efficient, global solutions. Existing research has focused on planning on the operational level, but attention also needs to be placed on the strategic and tactical levels.

3 - Integrated Home Health Care Optimization via Genetic Algorithm and Mathematical Programming
Ly Nguyen, Roberto Montemanni

In this study we address an integration of interrelated optimization problems for home health care: rostering, assignment, routing, and scheduling in multi-period workforce planning under uncertainty in nurse availability. Our new model explicitly handles the constraints related to workload balancing and multi-period planning, and the principles of robust optimization approach are followed to find a robust solution. We also introduce a matheuristic algorithm that works based on a genetic algorithm mechanism to tackle four optimization problems sequentially but interactively. Two nested genetic algorithms are integrated. Steady-state reproduction is carried out based on two replacement strategies: replacing solutions at random and replacing the worst solutions. Experiments are conducted on instances based on real historical data from a company operating in Lugano, Switzerland. The obtained results show that, in genetic algorithm, the strategy of replacing the worst solutions outperforms the strategy of replacing solutions at random in our case. Addressing the four optimization problems in a unified approach results in a more efficient solution. In addition, the proposed algorithm: i) is able to handle large instances and to provide a weekly workforce planning solution in a reasonable time, which is reliable against uncertainty in nurse availability; ii) can be used to efficiently support managers in evaluating the trade off between the robustness and the cost of a solution.

4 - Alternative transport modes for home health care staff - logistical challenges and the question of sustainability
Patrick Hirsch, Christian Fikar, Klaus-Dieter Rest, Jana Voegl

The traffic situation in densely populated areas causes various challenges (e.g., congestions and limited parking space) for home healthcare (HHC) service providers performing tasks at client's premises. Up to now, the HHC staff uses mainly individual cars. In this talk, we investigate the optimization of different alternative transport concepts for a major Austrian HHC provider. These include trip sharing with walking-routes as well as routing and scheduling with bikes and public transport. The concepts lead to challenging optimization problems due to synchronization constraints, interdependencies between different routes, and time-dependencies. Moreover, we present sustainability criteria to evaluate the concepts, which were identified based on extensive desk research and interviews with HHC staff. The results show substantial potential to reduce the number of required vehicles, to save travel time, and to enable more sustainable operations.

■ TA-17

Tuesday, 8:30-10:00 - Building CW, ground floor, Room 0210

Assortment and Portfolio Management

Stream: Demand and Supply Management in Retail and Consumer Goods
Chair: *Alexander Hübner*

1 - A dynamic clustering approach to data-driven assortment personalization
Fernando Bernstein

A retailer faces heterogeneous customers with unknown product preferences. The retailer can personalize the assortment offering based on the customers' profile information. Given the abundance of customer and product attribute data, this may be computationally intensive. At the same time, customers with different profiles may have similar preferences for products. Thus, the retailer can benefit from aggregating information among customers with similar preferences. We propose a dynamic clustering approach that adaptively adjusts customer segments and personalizes the assortment offering to maximize cumulative revenue.

2 - An integrated assortment- and shelf-space optimization model
Kai Schaal, Alexander Hübner

Retailers must select the assortment to offer to their customers and decide about the shelf space each item included in the assortment is allocated. If shelf space is limited, both decisions are interdependent. For example, offering broader assortments leaves less space for single items and may induce out-of-stock situations. Smaller assortments leave more space for single items but may result in out-of-assortment situations. We develop an integrated optimization model which supports retailers in optimizing assortments and planograms when shelf space is limited. Our model accounts for all relevant demand effects, i.e. stochastic and space-elastic demand as well as out-of-stock and out-of-assortment substitution. To solve the resulting non-linear optimization problem, we develop a heuristic that efficiently yields near-optimal results, even for large-scale instances. Applying our model to two case studies and simulated data sets, we show that both, space-elasticity and substitution effects have a significant impact on profits and planograms and that both effects reinforce one another.

3 - Retail category optimization: methodology and application
Marina Karampatsa, Evangelos Grigoroudis, Nikolaos Matsatsinis

Retail category management (RCM) aims to provide the shoppers and consumers with what they want, where they want it, and when they want it. RCM can be characterized as a multi-perspective same-time decision problem, where a series of questions have to be solved jointly: what to list (assortment planning), how to put the products into the shelves (shelf planning) and how much to order (inventory planning). Despite the longstanding recognition of its importance, no dominant methodology for RCM exists and scientific models address only some of the factors that make assortment, shelf space and inventory planning so challenging. In this paper, we describe an innovative approach by integrating assortment, shelf space and inventory planning problems. First, a mathematical model for this integrated problem is provided. Second, we apply our model at a supermarket chain in Crete, Greece and compare the recommendations of our model with the existing assortments. Third, we present a methodology for estimating the parameters which form the backbone of the proposed optimization model such as the substitution probabilities and the basic demand of products that may be included in the assortment; including the products that enter the market for the first time.

4 - Economies of scope in service production
Guenter Fandel, Jan Trockel

Firms have to choose their market positions. Suppliers can offer a wide range of services as generalists or they act as specialists by offering a small range of services. In this paper based on Chatain/Zemsky (2007) and Chatain (2011) we analyse how supplier-specific economies of scope generated by investments can compensate the loss occurring by a non-optimal organisational structure (resource configuration) of production. These considerations are modelled by a non-cooperative game with one buyer and two suppliers. We show how the buyer can gain from supplier-specific economies of scope. In this case, the buyer will never split the orders to both suppliers. But, if the investment costs of the suppliers are very high and/or the gains of the buyer are rather low, the pure strategy combination "no investments" for the two suppliers will become the unique Nash equilibrium, whereby the buyer places the two orders each to the supplier who is the specialist for it. Additional Nash solutions are dependent on the specific economies of scope. If the buyer has to place two different services he should order one supplier, if the tasks have similar characteristics and the investment costs of a supplier result in higher specific economies of scope relevant to the choice of the buyer.

■ TA-18

Tuesday, 8:30-10:00 - Building CW, ground floor, Room 023

Sustainability 2

Stream: Production and Operations Management
Chair: *Mina Faragallah*

1 - Multi-manufacturer pricing and quality management strategies in the presence of brand differentiation and return policy
Balaji Roy

In this paper, we consider multiple manufacturers' handling a single product selling through a common retail channel. Demand at retailer's end depend on retail price and quality of the product. Each manufacturer customizes their product to differentiate it from the other manufacturers' products. Manufacturers' compete with each other over price and quality in the presence of brand differentiation. In this set up we assume two scenarios, (i) the usual case when customers do not have the facility of return and refund and (ii) when customers do have the facility of return and get full refund. We analyse the pricing and quality management strategies of the manufacturers' and the retailer in each scenario for centralized and decentralized systems. Through our study we find that brand differentiation increase retail price and quality of the products. We also see that to make full refund policy more profitable than no return, reservation price has to be set higher. Using revenue sharing mechanism we coordinate the decentralized system and make it a win-win situation for each party involved. Finally, through a numerical example we analyse the effect of various parametric values on the decision making strategies of our model.

2 - Multicriteria Model to Evaluate the Green Logistics
Edilson Giffhorn, Maria do Socorro dos Santos Giffhorn

This paper presents the construction of a multicriteria model to evaluate the performance of organizations with regard to Green Logistics. To this was applied a process to identify the representative references that provided the fundamental data to perform a bibliometric study that revealed the growing importance of the subject and the development opportunities in relation to performance evaluation of Green Logistics. Through the MCDA-C multicriteria methodology were identified, organized and measured performance criteria considered relevant to organizations, to society and according to the literature. Once built the model was possible to trace the impact profile of industries belonged to different sectors that revealed its alignment with the concepts of Green Logistics and was possible to propose customized actions of improvement for each case study carried.

3 - Optimization of Integrated Batch Mixing & Continuous Flow in Glass Tube & Fluorescent Lamp Production Process
Mina Faragallah, Abdelghani Elimam

This paper deals with the production planning of in-series continuous flow, and discrete production plants. The paper is applied to glass and fluorescent lamp industry, where raw materials are mixed in batches, charged to a continuous furnace to produce glass tubes, and then assembled into discrete lamps. A non-linear programming model was formulated for the production processes from the raw material mixing stage the production of fluorescent lamps. The formulation consists of three integrated sub-models. The first is developed to optimize the raw material mix, while satisfying the desired properties of produced glass. The second provides the optimum glass pull rate from the furnace, which determines the production amounts of glass tubes. An important factor in the continuous flow process is the broken glass (cullet) ratio added to the furnace, which reduces the amount of raw material, and natural gas consumed when increased. The third sub-model determines upon the optimum production, and inventory levels for the discrete lamps assembly plant. In order to solve the integrated model, separable programming methods and linear approximations were used to transform the non-linear terms with a percentage error of maximum 1.5%. Results are validated versus actual production data from a local Glass & Lamp factories, and the model proved it's an efficient tool of integrating the whole process flow of fluorescent lamp production at minimum cost.

■ TA-19

Tuesday, 8:30-10:00 - Building CW, ground floor, Room 021

Network design

Stream: Telecommunications and Network Optimization
Chair: *Jean-Sébastien Tancrez*

1 - Optimizing Fiber To The Home cabling schemes
Vincent Angilella, Matthieu Chardy, Walid Ben-Ameur

Several billion euros are currently spent each year for the deployment of fiber to the home technologies. It is the solution chosen by many telecommunication operators to satisfy the increasing demand in bandwidth. Although an abundant literature deals with this problem, especially regarding network design and facility location, few papers tackle the cabling related issues. This work focuses on a sub problem of the global FTTH network design which consists in optimizing FTTH cabling schemes in tree networks while considering the different cable separation operations. It takes into account separation costs and engineering rules from a telecommunication operator. We prove the problem to be NP-complete and propose several integer programming approaches. The different approaches are compared according to different scenarios. We assess the models on real-life instances.

2 - Benders Decomposition for the Multi-Layer Telecommunication Network Design Problem
Inci Yüksel-Ergün, Haldun Sural, Ömer Kirca

Practical telecommunication networks involve more than one technology represented by virtual network layers. Each virtual layer corresponds to a single type of technology using a single granularity of flow, i.e., single type of facility. The multi-layer network design problem is to design telecommunication networks that account for the multi-facility and multi-technology characteristic of real life applications. We develop a tailored algorithm based on Benders decomposition to solve the large multi-layer network design problems that cannot be handled by general solvers. Consolidating the available test problem instances in the literature, we perform extensive computational experiments on these instances, including three and five-layer instances, with the algorithm and present favorable results.

3 - Benders Decomposition and Column Generation for the Discrete Cost Multicommodity Network Design Problem
Imen Mejri, Safa Bhar Layeb, Farah Mansour Zeghal, Mohamed Haouari

Multicommodity Network Design problems arise in the strategic and tactical planning processes and have many applications mainly in the fields of telecommunication and logistics. Thus, solving this challenging NP-hard problem is crucial for the profitable business of network operators. In this work, we focus on the Discrete Cost Multicommodity Network Design Problem (DCMNDP), with multiple discrete facilities to be installed on the edges. Each facility is bidirectional and has a known discrete capacity and a fixed cost. Given point-to-point commodity demands, the DCMNDP requires installing at most one facility on each edge such that all the demands can be routed while minimizing the total fixed cost. To solve the DCMNDP to optimality,we investigate a tailored Benders decomposition approach that we apply to two different formulations: the commonly used arc-node formulation and the arc-path formulation. We notice here that the latter formulation requires the use of a column generation approach to derive the Benders cuts. The comparison of the two formulations on real-world instances and randomly generated instances shows that the Benders decomposition approach is more efficient when applied to the arc-path formulation.

4 - A Multi-Hub Express Shipment Service Network Design Model with Flexible Hub Assignments
Jose Miguel Quesada, Jean-Charles Lange, Jean-Sébastien Tancrez

The express carriers offer overnight, door-to-door delivery of shipments, within regions as large as the US, Europe or the Middle East. For ensuring the reliability and efficiency of their service, they need to determine a set of feasible routes that enable the transportation of shipments from their origins to their destinations, a problem known as the Express Shipment Service Network Design (ESSND) problem. For reaching economies of scale, the express integrators first consolidate the shipments by moving them from their origin to hubs, where the shipments are sorted by destination, and then they are transported from the hubs to the destinations.

Most of the existing approaches for solving multi-hub version of this problem rely on a fixed hub assignment, i.e. the allocation shipments to hubs is an input of the problem. In this research, we develop an optimization model for addressing the ESSND for the next day deliveries within a region, with multiple hubs and with flexible hub assignment. The flexible hub assignment incorporates the hub allocation decision of the shipment to the network design model. We provide a reformulation that improves the LP relaxation and reduces the number of variables and constraints compared to existing models in the literature, and that includes complex route structures. Our model is tested using extensive numerical experiments to show the value added in terms of efficiency and effectiveness, based on instances in the European region.

■ TA-20

Tuesday, 8:30-10:00 - Building CW, ground floor, Room 022

Facility Location

Stream: Location
Chair: *Masashi Miyagawa*

1 - Optimizing hierarchical facility location and service zones with multiple distance constraints: Exploring the problem on one route

Mohsin Nasir Jat, Luc Muyldermans

Many service systems provide multiple types or levels of services, often through a hierarchy of service facilities. Emergency service and Information Technology (IT) equipment support services are examples where the responses are provided within certain time windows and the services are differentiated on this bases. Locating facilities for such services is commonly dealt with as a covering problem. However, service operations such as IT equipment maintenance and highway maintenance also require maintaining inventories of parts and materials that are required for providing the services at the demand points. This adds another dimension to the problem as inventory cost can also influence the optimum location pattern and service area configurations. We study the trade-off between inventory and transportation costs when determining the setup of facilities and service areas for time (distance) constrained services. We present a Mixed Integer Nonlinear Programming (MINLP) model to study the optimum locations of hierarchical facilities and their service zones for two time-based services. The model considers the minimum number of facilities of each type and the fraction of demand associated with each time-based service type. This multifaceted problem is explored on a line segment, which can be related to serving uniformly distributed customers on one road, to highlight the operational issues and generate insights for more complex situations.

2 - Ranking based heuristic algorithm for discrete competitive facility location problems

Julius Žilinskas, Algirdas Lančinskas, Pascual Fernandez, Blas Pelegrin

The research is focused on solution of the discrete Competitive Facility Location Problems for an Entering Firm which is aimed at selection of optimal locations for a set of new facilities subject to maximization their market share. The new heuristic algorithm for selection of the optimal locations based on random search with ranking of candidate locations is proposed. The real data of near 7000 demand points in a geographical area have been used for the experimental investigation of the proposed algorithm considering different models of customer behavior.

3 - A Facility Location Model Using DEA

Adel Hatamimarbini, Mehdi Toloo, Per Agrell

In general, facility location problems target at finding the optimal location among a set of candidate facility locations (e.g., plants and warehouses) where the objective is to minimize the total cost of the siting configuration in line with fulfilling the demands. Since facility location decisions normally have significant and long-term impact on the entire supply chain, we require to consider a number of, often conflicting, objectives. In this study, we develop a new facility location model using data envelopment analysis (DEA) with the aim of locating the facility as well as determining its optimal capacity. To validate the proposed model, we prove some theorems and provide an illustrating example.

■ TA-21

Tuesday, 8:30-10:00 - Building CW, ground floor, Room 025

Planning of rapid transit systems

Stream: Public Transportation
Chair: *Eva Barrena*

1 - Determination of frequencies, vehicle capacities and passenger assignment in dense Railway Rapid Transit networks

David Canca, Eva Barrena, Alicia De Los Santos Pineda, Jose luis Andrade

We propose an optimization model in order to determine optimal line frequencies and train capacities in dense railway rapid transit networks in which several lines share open tracks. Moreover, the assignment of passengers to lines is simultaneously considered. Given a certain passenger demand matrix, the MILP model determines the most appropriate frequency and train capacity for each line taking into account infrastructure capacity constraints and allocating lines to tracks while assigning passengers to lines. The proposed approach takes the service provider and the user points of view into consideration. From a users' perspective, the model selects the most convenient set of frequencies and capacities, routing passengers from their origins to their destinations while minimizing the average trip time. From the service provider perspective, the model minimizes operation, maintenance and fleet acquisition costs. Due to the high number of variables and constraints appearing in real size instances, a preprocessing phase determining the best k-paths for each origin-destination pair is followed in order to solve such kind of instances. Then, best path information is used to dene sparse index sets in order to significantly reduce the size of the problem. The modelling approach is applied to the real case of Madrid Metropolitan Railway network.

2 - Passenger Demand considerations in Rapid Transit Networks Timetabling

Eva Barrena, David Canca, Francisco A. Ortega Riejos

We study the effect of passenger demand in the design and optimization of train timetables for a rail rapid transit line adapted to a dynamic demand environment. The objective is to minimize the average passenger waiting time at the stations, thus focusing on passenger welfare. Since passenger demand can be of different nature, we analyze the effect of different passenger demand considerations in the resulting train timetables. For that aim, we focus on static, time-dependent and elastic demand. The first considers a constant origin-destination matrix for the planning horizon and assumes that passengers arrive to stations at constant time intervals. The second considers a time dependent origin-destination matrix, whose elements are therefore a function of the time. The third considers that passengers arrive to stations with the intention of boarding a train, and choose an alternative transportation mode if the train delays more than a certain time. Results show the effect of each of these considerations and the suitability of each of them according to the network properties.

3 - A public transit network design model considering redistribution of services and depot location during disruptions

Luis Cadarso, Esteve Codina, Laureano Fernando Escudero, Ángel Marín

A model for designing a public transit network is presented in this paper. The model combines a conventional approach of demand spatial coverage and the recovery of breakdowns due to limited reliability of the transportation units. The aging of the units is taken into account by the rate of services that may be affected by a breakdown. A bimodal scenario is assumed where users may choose between the transit system and an alternative transport system following a logit choice model. The design model takes into account construction costs and users' travel times in both modes of transportation by a two stage decision process. At a first stage of decision, construction of infrastructure is considered and in the second, user travel costs and recovery action costs depend on a set of scenarios associated with a set of possible disruptions. Two types of scenarios are considered: a) the scenarios of normal operation and b) disruption scenarios which are associated to network link's breakdown. The recovery from disruptions considers by a proper modelling, the topology of the lines and the depot adequate location. The novelty of this approach is the introduction of risk aversion in the network design. In the approach that has been followed, the type of risk under consideration is the level of impact of different disruptions in the network operation the operator is willing to accept.

■ TA-22

Tuesday, 8:30-10:00 - Building CW, ground floor, Room 027

Large Scale Optimisation in Transportation and Production

Stream: Combinatorial Optimization
Chair: *Francois Soumis*

1 - Constraints Aggregation for Large-Scale Pairing Problems
Francois Soumis, Mohammed Saddoune, François Lessard

The crew-pairing problem is generally modeled as a set partitioning problem, the flights have to be partitioned in pairings. A pairing is a crew path starting at a base covering many flights during few days of works and finishing at the same base. For large-scale problems a first difficulty is the exponential number of feasible pairing (number of variables). Columns generation permits to deal with it. However solving a master problem of 40 000 constraints at each of the thousands iterations of the column generation request to much time. To reduce the solution time some airlines use a Rolling-Horizon heuristic (RH) that divides the horizon into overlapping time slices. For example two days slices with an overlap of one day. However solving 30 problems of 3000 flights (two days time slices) requires many days and the quality of solutions in not so good because the optimisation is too myopic (the windows are narrow). The Dynamic Constraints Aggregation method (DCA) developed by (Elhallaoui et al. 2005) speed-up the master problem by reducing the degeneracy. This method also produces better dual variables and reduces the number of column generation iterations. Furthermore the LP solution is less fractional and it reduces the number of nodes to explore in the branch and bound. This permits to solve a weekly window of 10 000 flights in few hours. The RH with weekly windows produces solution improved by up to 5% on salaries and reduces the number of deadheads by up to 40%.

2 - Simultaneous Optimization of Personalized Integrated Recovery for Pilots and Copilots
Mohammed Saddoune, Francois Soumis, Atoosa Kasirzadeh

The airline crew scheduling problem involves assigning a group of crew members to scheduled flights over a planning horizon while respecting safety rules and regulations. In a context of perturbation at the operational level, this paper proposes a new heuristic algorithm that solves the integrated scheduling problem for the pilots and copilots simultaneously in a single step based on column generation and dynamic constraint aggregation. All results are conducted on a set of real instances from a major US carrier and show that the integrated approach helps to provide more robust schedules by increasing the number of common pairings for pilots and copilots.

3 - Multi-model assembly line balancing with limited resources. A case in the textile industry
Jordi Pereira

Assembly lines are a widespread production method used to manufacture high volumes of goods. Line balancing deals with one of the problems that need to be tackled in order to efficiently design an assembly line; that is, the division of operations that need to be performed to the goods among the workstations that constitute the assembly line. In this work we consider a line balancing problem found in the textile industry in which the balancing process must jointly consider the balancing of operations for multiple goods as well as the limited availability of machinery. In order to solve the problem, lower and upper bounds are proposed and the quality of the proposed algorithms is studied.

4 - Multi-criteria ambulance service scheduling problem - A case study of Hong Kong
King-Wah Anthony Pang

Emergency Ambulance Service (EAS), refers to the immediate response, assessment and treatment of the sick and injured prior to the conveyance to hospital; it impacts lives of global citizens significantly owing to the increasing demand around the globe. In the light of the increasing importance of EAS, responsive and sustainable EAS system that minimizes risk of failure is required. Hence, this study mainly focuses on improving the EAS scheduling system, especially the process of how the call centre handle emergency requests and allocate existing resources, such as ambulance, to conveyance of patients to hospitals. In this study, multiple criteria are considered when the call dispatcher arranges the ambulance to reach the caller's location, i.e., availability of ambulance at different depots, distance from the depots to the caller's location, critical level of the patient. After the ambulance reaches the patients, similar considerations are made to determine which hospital to sent the patient to. A multi-criteria optimization model has been developed in order to find the best allocation of medical resources such that the patients' weighted average waiting time is minimised. A case study of the Hong Kong EAS system is analysed and simulation result shows the proposed scheduling approach can significantly reduce the weighted waiting time.

■ TA-23

Tuesday, 8:30-10:00 - Building CW, ground floor, Room 028

Networks and Graphs

Stream: Graphs and Networks
Chair: *Frits Spieksma*
Chair: *Anna Nagurney*

1 - Heuristics for Analyzing Infeasibility in Flow Networks
Imke Joormann

We study means to repair infeasibility in network flow problems with supplies and demands, where we concentrate on the NP-hard Minimum Irreducible Infeasible Subsystem Cover problem (minIISC, the smallest subset of constraints that must be dropped to obtain a feasible system). With the help of some observed characteristics, we develop a number of heuristics and investigate their effectiveness together with some specialized versions of approaches known from minIISC on general linear systems.

2 - Observation and Analysis of the Braess Paradox in a Macroscopic Electrical Network
Ladimer Nagurney, Anna Nagurney

The Braess Paradox is the counter-intuitive phenomenon in a user-optimized network system where adding an additional link to the network increases the cost for every user. While primarily identified with traffic networks, the Braess Paradox has also been observed in telecommunications networks and in mechanical spring, fluid flow and nanoscale networks. The purpose of this work is to show that the Braess Paradox can be observed in macroscopic electric networks consisting of resistors and diodes. We first identify the electrical quantities that correspond to the flow and the cost on the network and illustrate the mapping of the cost functions to ideal electrical components. By writing Kirchoff Law nodal equations for the electrical network, we illustrate how, by appropriate choice of component values, the Braess Paradox can be observed in the network. We show how the classic Braess Paradox examples can be cast into a form where they can be implemented as real electric circuits. We exploit the nodal equations to show that networks with more general link cost functions can also exhibit the Braess Paradox. We construct several macroscopic electric circuits out of real physical components and demonstrate, by making voltage measurements, that the voltage across the circuit increases as another link is added showing that the Braess Paradox can occur in real circuits. We conclude this work with the extension of this analysis and measurements to cases where the demand is varied

3 - Balanced Optimization with Vector Costs
Frits Spieksma, Annette Ficker, Gerhard J. Woeginger

We investigate the complexity and approximability of so-called balanced optimization problems. Informally, balanced optimization problems are problems where the objective is to minimize the difference between a largest cost element, and a smallest cost element in the solution. We identify a large family of problems that admit a 2-approximation in polynomial time, and we show that for many problems in this family this approximation factor 2 is best-possible (unless P=NP).

Motivated by a practical application, we pay special attention to the balanced assignment problem with vector costs: we prove lower-bounds on the approximability of this problem, even in the highly restricted case of sum costs.

■ TA-24

Tuesday, 8:30-10:00 - Building BM, 1st floor, Room 119

Project Scheduling 1

Stream: Project Management and Scheduling
Chair: *Arik Sadeh*

1 - Use of the Mathematical Models in the EVM
Tomas Subrt, Jan Bartoska, Petr Kucera

Earned Value Management (EVM) is a successful tool for project progress tracking and project indicators evaluation. Even though in EVM there are some shortcomings and it is possible to propose new extensions. One of the possible expansion is the use of mathematical models to calculate additional parameters of EVA. Although different work schedules for allocating resources have been used for many years, they have not yet treated with the impact of human factors, for instance in the form of Student Syndrome. To express work schedule involving the Student Syndrome using mathematical model in EVM is therefore a directly offer. One of the most commonly mentioned EVM lack is a declining credibility of EV (BCWP - Budgeted Cost of Work Performed) index while approaching the end of the project. The assumption of linearity of PV (BCWS - Budgeted Cost of Work Performed) in EVM can lead to incorrect conclusions about the development of project time and cost indicators and to mistakes in project progress reporting. PV value, whether atomic or aggregate, should be as close as possible to the real work effort of allocated resources. Human resources tend to have different shape and top of their work efforts due to individual character traits. Our contribution aims to precise these parameter estimates using adequate mathematical models.

2 - Optimal Overlapping Strategies for Projects with Interdependent Activities
Gregory Gurevich, Baruch Keren, Zohar Laslo, Yossi Hadad

Overlapping is one of main techniques for project time compression. This is a schedule compression technique in which activities normally performed in sequence are performed in parallel. A decision if a specific degree of overlapping is desirable can be made on the basis of a trade-off between its positive and negative impacts. This paper analyzes a simple project with two activities. The activities can be executed in a serial mode (separately), in a parallel mode (overlapping), or in a mixed mode (partly in a serial mode and partly in a parallel mode). There is an interdependence between the activities and the duration-budget tradeoffs functions of the activities are defined differently if the activities are executed separately or in a parallel mode or in a mixed mode. The paper presents a deterministic duration-budget tradeoffs model that takes into account the interdependence between the activities. The proposed model allows determining the optimal execution-mode and the budget distribution between the project activities in the context of different objective functions. A stochastic extension of the proposed model is also considered. In the stochastic context, the activities durations are random variables where the expected values of the durations are a result of the budget that is invested in the activities. The presented analysis aims to help practitioners to choose the optimal overlapping strategy.

3 - Measuring Projects' Success According to Their Characteristics
Cristina Feniser, Arik Sadeh

Projects' success and the causes to their success are very attractive to be measured. In an ongoing study the success of projects was measured and reported using several variables, by project managers and or stack holders. The projects are classified according to the diamond approach suggested by Shenhar and Dvir (2007). The diamond approach considers projects in four dimensions: (i) the level of project's novelty, (ii) the complexity of projects from the management point of view, (iii) the level of technological uncertainty at the beginning projects, and (iv) the pace of completion of projects. In the context of the diamond approach the four dimensions are commonly abbreviated to NTCP. The characteristics of 400 projects were measured according to these four dimensions where each dimension has 3 to 4 ordinal values. The success level of those projects was statistically analyzed with respect to those four dimensions.

■ TA-25

Tuesday, 8:30-10:00 - Building BM, ground floor, Room 19

Links between behavioural sciences and OR

Stream: Behavioural Operational Research
Chair: *Konstantinos Katsikopoulos*

1 - Behavioral Anomalies in Consumer Wait-or-Buy Decisions and Their Implications for Markdown Management
Manel Baucells, Nikolay Osadchiy, Anton Ovchinnikov

A decision to buy an item at a regular price or wait for a possible markdown involves a multi-dimensional trade-off between the value of the item, the delay in getting it, the likelihood of getting it and the magnitude of the price discount. Such trade-offs are prone to behavioral anomalies by which human decision makers deviate from the discounted expected utility model. We build an axiomatic preference model that accounts for three well-known anomalies, and produces a parsimonious generalization of discounted expected utility. We then plug this behavioral model into a Stackelberg-Nash game between a firm that decides the price discount and a continuum of consumers who decide to wait or buy, anticipating other consumers' decisions and the resultant likelihood of product availability. We solve the markdown management problem and contrast the results of our model with those under discounted expected utility. We analytically show that accounting for the behavioral anomalies can result in larger markdowns and higher revenues. Finally, we calibrate our model via a laboratory experiment, and validate its predictions out-of-sample.

2 - Decision Analysis in the Nuclear Sector
K. Nadia Papamichail, Simon French, Duncan Shaw

Decision Analysis approaches have been shown to structure and analyse complex societal problems in the face of uncertainty and conflicting objectives. Despite numerous applications to critical areas, such as the nuclear sector, Decision Analysis adoption has not been widespread. This paper presents a critical review of the literature on Decision Analysis in the nuclear sector. The work highlights Decision Analysis tools, applications and challenges both from an academic and practitioner perspective. A survey is being conducted, as part of an ongoing Delphi-style process, to explore Decision analysis practices in the nuclear sector and identify under-researched topics in the literature that are of interest to practitioners. Preliminary results will be presented, together with guidelines for stronger Decision Analysis practices and suggestions for academic research priorities that reflect the practical challenges of applying Decision Analysis. Finally, the work will explore how behavioural sciences can inform and compliment Decision Analysis initiatives.

3 - Statistical properties of decision environments
Ozgur Simsek

There is evidence that people often make decisions by using simple rules, such as lexicographic heuristics or unit weighting. These decisions can potentially have low accuracy because they use few pieces of information and do not try to combine the information optimally. Surprisingly, empirical studies have shown the opposite: simple rules often perform almost as well as or better than statistical decision methods.

Several properties of the decision environment can explain this finding, including for example, dominance relationships among decision alternatives and noncompensatoriness in the environment. When these properties are present, the decision problem becomes easy in the sense that many methods (simple and complex) yield the same decision, eliminating the need to find an optimal trade-off between the various cues that are available. For instance, a single cue, or a simple tallying of the cues, may suffice to make the correct decision.

I will review statistical properties of the decision environments that make the decision problem easy. I will then examine how often we encounter these properties in a large, diverse collection of natural environments. The main results is that these properties are highly prevalent, making it possible for simple rules to reach (and even exceed) the predictive accuracy of statistical models, using less information and less computation. I will also discuss uses of these properties in sequential decision problems such as Tetris.

4 - Simple Models for Decision Analysis and Support? A Synthesis of the Results
Konstantinos Katsikopoulos, Ian Durbach

This talk considers decision problems sufficiently structured so that they can be analyzed and supported by quantitative models. These models tend to be cognitively challenging in the sense that they require the elicitation and combination of quantities such as probabilities, utilities, and weights. We discuss three strands of work which have asked if and how should these decision models be simplified. There is not much communication among the strands and they have reached different conclusions: Research on the preference strand shows that simple models sometimes approximate well the more complex models; the inference strand has put forth conditions under which simple models are more effective than the more complex models; and some forecasters have proposed that simple models should be preferred. We argue that the differences can be reconciled by noticing that (1) preference research assumes a model of the data, which is typically complex, and evaluates the loss that simplifications incur relative to this model, while (2) inference and forecasting work evaluate complex and simple models on predicting the data directly. We point out that the ultimate goal is to find out when do simple models perform better than complex models, and when not. We outline various useful results provided so far, but also note that no general results are yet available. We conclude by discussing if and how should decision research and practice change, with respect to using simple models.

■ TA-26

Tuesday, 8:30-10:00 - Building BM, 1st floor, Room 109D

Machine Learning for Analytics

Stream: Business Analytics and Intelligent Optimization
Chair: *Sebastian Maldonado*

1 - Credit Scoring with Support Vector Machine (SVM) considering Feature Selection via a Budget Constraint
Juan Perez, Sebastian Maldonado, Cristian Bravo

We analyze the acquisition costs related to business analytics problems by proposing an MIP version of the SVM to incorporate different costs for different feature subsets in a budget constraint. Our aim is to construct a classifier that constrains or minimizes acquisition costs (fixed and variable) while classifying adequately. In the context of a MIP-SVM model, we include a budgetary constraint on the fixed costs addition, and the attributes acquisition variables, which restricts the amount of money given to those effects. Then, by running several analyses on the budget value, we construct multiple classifiers, each one of them according to different budgets, which we analyze regarding their classification power related to the total cost incurred that is restricted by the budget. The results, besides of allowing to make cost-profit analysis of a classifier regarding its forecast power and the total cost of feature acquisition, also let us make a regulation according to the cost-effectiveness of including additional attributes in as much as the budget varies. In the database analyzed and compared to Recursive Feature Elimination and Fischer, the results regarding the classification are quite similar. However, in relation to the total costs implied by the acquisition of features, the proposed methodology entails substantial improvements, obtaining much lower costs.

2 - Time series feature selection with SVR- an empirical evaluation for electric load forecasting
Sebastian Maldonado, Sven F. Crone

Forecasting high-frequency time series of electricity demand remains a preeminent area for research and practice in time series prediction due to its importance to the short-term management of power systems. However, for machine learning approaches of ANN and SVR a major challenge remains to specify an adequate and parsimonious input vector of time series features. In this work we extend the Kernel-Penalized SVR (KP-SVR) algorithm for embedded feature selection towards simultaneous autoregressive time series lag selection and time series estimation via SVR. The extended approach performs a backward elimination of variables by iteratively adjusting the widths of an anisotropic Gaussian kernel. A penalization function for the use of covariates is included in the algorithm in order to minimize the non-zero widths.

The proposed method has appealing advantages for high-frequency data: first, it constructs sparse models automatically, avoiding a time-consuming model specification step. Secondly, it achieves superior performance than alternative approaches for automatic time series due its capacity to model nonlinear. Finally, the method allows the correct specification of exogenous variables together with the automatic lag selection. Experiments on the Great Britain's electricity demand forecasting dataset demonstrate the effectiveness of our approach in terms of predictive performance and selection of the adequate seasonal patterns.

3 - Data driven sustainable mobility indicators
Sheida Hadavi, Wouter Verbeke, Cathy Macharis

Mobility is an aspect of growing relevance. Numerous studies have demonstrated the major contributions of transportation to air pollution, congestion, climate change etc. In order to preserve the liveability of urban environments, the mobility system needs to evolve to be more sustainable and various local policy measures are required. Determining whether a city is moving towards sustainable development is a great challenge. A competent monitoring tool enables authorities to adequately address the pressing impact areas, evaluate progress, and avoid grounding policy measures on an insufficient knowledge base. In this era that a lot of knowledge can be derived from data, cities should take the necessary steps in using relevant IT technologies to monitor cities' progress to sustainability. Moving from the current mobility model to a Smart City sustainable model, raises a number of non-trivial challenges, among which is identifying the underlying factors in mobility dynamics. In this research, looking into available open data related to mobility, a cloud of structured and interlinked information elements will be established. The data meta-model will be produced by identifying relevant databases and other resources. Development of an indicator framework driven from the data and the meta-data model will be investigated. A dashboard demonstrating sustainable mobility indicators for different aspects is the aim to help evaluate city's sustainable development.

4 - A model tree for mixed type data classification
Chi-Hyuck Jun, Su-Dong Lee

To handle mixed types of variables, we propose a hybrid approach that combines a decision tree and logistic regression models, which work well with categorical and numerical variables, respectively. To perform a split search of the decision tree, we propose an algorithm for finding an optimal multiway split using comprehensive and scalable criteria specialized for the given problem. By using group lasso logistic regression and an ensemble of intermediate models, we are able to overcome problems due to local learning with reduced samples in partitioned data spaces. The performance of our proposed method has been investigated on the University of California, Irvine (UCI) data sets, indicating that our proposed method is an effective approach for improving classification performance of mixed type data classification problems.

■ TA-27

Tuesday, 8:30-10:00 - Building BM, ground floor, Room 20

Dynamic Programming 2

Stream: Dynamic Programming
Chair: *Lidija Zadnik Stirn*

1 - A hierarchical, multi-criteria and dynamic model of collaborative resource management
Lidija Zadnik Stirn, Janez Krč, Vasja Leban, Petra Groselj, Špela Pezdevsek malovrh

Prior approaches to resource management decisions that were for decades determined/chosen foremost with regard only to economic attitudes and within exclusive demand of one or a few individuals, but now they must be made with substantial public input (participatory processes) while achieving economic, ecological and social objectives. In order to pursue these intents we generated a decision support model (DSM) of resource management that explicitly takes into account sustainability, biodiversity, long time horizon, and above all includes the interests and preferences of the public, which benefits from several amenity values of that resource. In the DSM, the decision process is defined in terms of time periods, states, decisions and weighted values of criteria. As such, the presented DSM employs SWOT analysis, group analytic hierarchy process and analytic network process to evaluate objective functions of several decision makers. Finally, because resource management is necessarily an ongoing process, the model is placed within a recursive decision framework of Bellman-s type. To illustrate the problem and developed DSM some computational experiences are presented where we deal with the management of a rural area which lies in the western part of Slovenia. The area is important for the owners, experts, scientists and general public. The treated decisions are competitive and only one of them could be selected in one time period.

2 - A Semi-Markov Decision Model for routing aircrafts to two runways.
Constantinos Karamatsoukis

A Semi-Markov Decision Model is formulated for the optimal routing of arriving aircrafts to two runways of an airport. One of the main factors that determines the runway throughput is the required separation time between two successive aircrafts during landing procedure. The problem of assigning runways to a given set of approaching aircraft to an airport is the well-known Aircraft Landing Problem (ALP). Due to its complexity, it is hard to find the optimal policy in the most of the realistic cases. Our study presents a new stochastic dynamic programming approach to find the optimal routing of aircrafts to two runways. The aim is to minimize the total delay costs for all aircraft landings while respecting the required separation times. It is assumed that the type and the arrival time of the next incoming aircraft are stochastic.

3 - Performance Analysis for Cold-rolling Inventory Model via Markov Decision Processes
Jing Wu, Lixin Tang

In this paper, we provide the multi-echelon single inventory model in cold-rolling production . This is a stochastic dynamic programming based on Markov Decision Processes. We analyze some properties of the value function in state variables, such as monotonic, convexity and supermodular. These results are used to characterize how the properties will change with changes in model parameters. We find that the optimal unit production is determined by the optimal level of inventory order.

4 - Preference elicitation in dynamic social networks
Przemyslaw Szufel, Marcin Czupryna, Bogumił Kamiński, Grzegorz Koloch

In the paper we consider a scenario where public administration is using a on online social platform as a tool for providing citizen data and collecting their preferences. However, only a part of the population (i.e. sub-population) uses the platform. Hence, the opinions of the subpopulation present online may not be representative. This may cause the bias problems not only due to the fact that the social attributes distribution in subpopulation may differ from the distribution in entire population but also due to restricted to the subpopulation information diffusion process and the interactions among citizens. Hence, the goal of the paper is tackle this problem by developing a method for elicitation of preferences from online network data to the entire population.

For each online social platform user the available data includes personal attributes (e.g. gender, age, social status, employment), position in the social networks and opinions on various issues discussed in the online platform. The social network is represented as an undirected graph where nodes represent citizens and the edges represent social connection. Moreover, census data for personal attributes on the entire population is available. We have constructed an agent-based simulation model that takes into account personal attributes distribution, social network data and opinion diffusion dynamics and we test various preference elicitation algorithms.

■ TA-30

Tuesday, 8:30-10:00 - Building BM, 1st floor, Room 110

Recent Advances in Dynamics of Variational Inequalities and Equilibrum Problems 1

Stream: Recent Advances in Dynamics of Variational Inequalities and Equilibrum Problems
Chair: *Patrizia Daniele*

1 - A network model for organ transplants
Patrizia Daniele, Valeria Caruso

Many organs such as kidney, liver, pancreas, intestine, heart, as well as lungs, can be safely transplanted. Sometimes organ transplantation is the only possible therapy, for instance for patients with end-stage liver diseases, and the preferred treatment, for instance for patients with end-stage renal diseases. As a consequence, the demand of organs has greatly exceeded the offer and has become a key tool to cure deseases. In many coutries the costs to receive an organ, which are often very expensive, are all charged by the National Health Service. We aim at presenting a mathematical model, based on networks, which allows us to minimize the total costs associated with organ transplants. We find the related optimality conditions and the variational inequality formulation. Some existence and uniqueness results are stated and some numerical examples are studied.

2 - A Supply Chain Network Game Theory Model of Cybersecurity Investments with Nonlinear Budget Constraints
Anna Nagurney, Patrizia Daniele, Shivani Shukla

In this paper, we develop a supply chain network game theory model consisting of retailers and demand markets with retailers competing noncooperatively in order to maximize their expected profits by determining their optimal product transactions as well as cybersecurity investments subject to nonlinear budget constraints that include the cybersecurity investment cost functions. The consumers reflect their preferenc es through the demand price functions, which depend on the product demands and on the average level of cybersecurity in the supply chain network. We identify the supply chain network vulnerability to cyberattacks as well as that of the individual retailers. We demonstrate that the governing Nash equilibrium conditions can be formulated as a variational inequality problem and provide a novel alternative formulation, along with the accompanying theory. We propose an algorithm for the alternative formulation, which yields, at each iteration, closed form expressions in product transactions, security levels, and Lagrange multipliers associated with the budget constraints. We apply the algorithm to compute solutions to a spectrum of numerical supply chain network cybersecurity investment examples. The examples broaden our understanding of the impacts of the addition of retailers, changes in budgets, demand price functions, and financial damages, on equilibrium product transactions and cybersecurity investments, and on retailer and supply chain vulnerability.

3 - Service Provisioning Problem in Cloud and Multi-Cloud Systems
Mauro Passacantando, Danilo Ardagna, Anna Savi

Cloud computing is a new emerging paradigm that aims to streamline the on-demand provisioning of resources as services, providing end users with flexible and scalable services accessible through the Internet on a pay-per-use basis.

This paper aims to study the hourly basis service provisioning problem through a generalized Nash game model. We take the perspective of Software as a Service (SaaS) providers that want to minimize the costs associated with the virtual machine instances allocated in a multiple Infrastructures as a Service (IaaS) scenario while avoiding incurring penalties for execution failures and providing quality of service guarantees. SaaS providers compete and bid for the use of infrastructural resources, whereas the IaaSs want to maximize their revenues obtained providing virtualized resources.

We propose a solution algorithm based on the best-reply dynamics, which is suitable for a distributed implementation. We demonstrate the effectiveness of our approach by performing numerical tests, considering multiple workloads and system configurations. Results show that our algorithm is scalable and provides significant cost savings with respect to alternative methods (5% on average but up to 260% for individual SaaS providers). Furthermore, varying the number of IaaS providers means an 8%-15% cost savings can be achieved from the workload distribution on multiple IaaSs.

■ TA-31
Tuesday, 8:30-10:00 - Building BM, 1st floor, Room 111

Sports Analytics

Stream: OR in Sports
Chair: *Lidia Angulo-Meza*

1 - Duckworth-Lewis Method and Optimization of the Projected Score Formula
Rishikesh Parma, Viraj Phanse

In this project, we have modified the Duckworth-Lewis (D/L) method to make it more robust and accurate. We have further optimized the modification by devising the "Parma-Phanse-Sahu Equation" to help calculate the projected score in truncated cricket matches.The D/L method is used to calculate a projected score in truncated one day (ODIs) cricket matches, affected by inclement condition such as rain. A margin of victory in runs is created using par scores. Previous research has found limitations in the D/L method. In the first part of the paper, we have modified the D/L method by analyzing the data from more than 75 ODIs played between January 2014 to September 2015 from cricinfo. Our modification was primarily based on the averages of more than 45 batsmen who were batting at different positions. In the second part, we have further optimized the obtained modified formula and have devised the "Parma-Phanse-Sahu Equation". We evaluated the equation by considering factors such as number of wickets, the number of over bowled and run rate at certain instances. We implemented the equation at different stages of matches and have obtained satisfactory results. A factor named faith factor was defined to evaluate efficiency of batsmen. We observed that the projected score calculated by using the "Parma-Phanse-Sahu Equation" and results obtained from the modified D/L are nearly the same, and felt the optimization is valid.

2 - Wicket Clustering in Cricket
Ajith Kumar, Uday Damodaran, Suresh R P

The fall of a wicket of the batting team in the game of cricket is akin to a failure in survival analysis. A simple pattern of the fall of wickets would be a uniform one with wickets falling at equally spaced intervals. However, a popular belief is that there are frequent and significant departures from this uniform pattern. Commentators of the game frequently refer to the phenomenon of wickets 'falling in a heap', that is, a clustering of the fall of wickets. An extreme case of such clustering is the phenomenon of 'choking' when a team in a strong position finally loses the game after wickets fall in close succession. This study tests whether wicket clustering actually exists in cricket and if so, examines what explains the phenomenon. Failure clusters are first identified using standard algorithms and outlier tests. The distance between failures is measured using metrics of runs scored and balls faced. Data of the One Day Internationals played by cricket playing nations is used to do this. Various factors that could explain the clustering phenomenon are examined, like the identity of the team, the batting order (whether the team was batting first in the game or second), the location of the cluster (whether it is at the beginning of an innings, in the middle or towards the end) and the performance pressure faced by batsmen while chasing a run rate that is significantly higher than the run rate at that instant.

3 - Distributing Financial Resources for Olympic Sports Using Parametric DEA and Variable Returns to Scale
Lidia Angulo-Meza, João Carlos Soares de Mello, Renato Pescarini Valério, Juliana Quintanilha da Silveira

The so-called parametric DEA was introduced to solve problems of resource distribution using constant returns to scale. Such models include the spherical, hyperbolic and ellipsoidal DEA. In this work, we want to redistribute financial resources for Brazilian Olympic sports taking into account the funds previously received by each sport as an input and the three outputs are the ratio between the medals won by the medals offered by each sport. As we used ratios as outputs it is mandatory to use variable returns to scale models. For that we introduce an extension of the parametric models, the parabolic model which allows taking into account different returns to scale. The results obtained with the parametric parabolic model are compared with the non-parametric Zero Sum Gains DEA model. The models proposed herein are an alternative to the arbitrary financial resources granted by the Agnelo/Piva Law, from the national lotteries, among Olympic confederations in Brazil. All sports but soccer are included in this study. Soccer is not included because of other sources of financial income (it is the most popular sport in Brazil), and the Agnelo/Piva Law explicitly excludes soccer from the financial distribution.

4 - Strategy Optimization in Sports - A Two-Scale Approach via Markov Decision Problems
Susanne Hoffmeister, Jörg Rambau

We present a paradigm to model sports strategy optimization via Markov Decision Problems (MDPs). If one employs a detailed model, optimal policies can be prohibitive to compute. If one chooses a rather aggregated model, input probabilities can be impossible to determine. We suggest a way-out: To answer questions about optimal policies, we employ an accessible aggregated model. Its critical input parameters are estimated by simulations in a detailed model whose input parameters can be derived from observations during training hours. As an example, we characterize when risky play is better than safe play in beach volleyball.

■ TA-33

Tuesday, 8:30-10:00 - Building BM, 1st floor, Room 113

Emerging Applications of Data Mining and Computational Statistics 5

Stream: Computational Statistics
Chair: *Pakize Taylan*
Chair: *Gerhard-Wilhelm Weber*
Chair: *Georgios Marinakos*

1 - Direct Marketing Analytics for Term Deposits Attraction
Georgios Marinakos, Sophia Daskalaki

Attracting deposits constitutes a crucial objective for all banks in order to retain viable levels of liquidity. Direct marketing campaigns are therefore common practice for the attraction of depositors. In this paper a data analytics practice is applied on a Portuguese bank's large customer analytic record, aiming to reveal how effective and informative can be the output of each step of the applied data mining process. The product under promotion is a term deposit program and each customer is a valuable target. The dataset is characterized by class imbalance and different scaling for the numeric and categorical variables. The data preprocessing procedures comprised of outlier detection, rescaling practices and also resampling techniques. Towards this we propose a newly designed undersampling technique in order to handle imbalance and increase classification predictive power. Statistical and non parametric algorithms are applied to create classifiers that may recognize potential depositors, while their evaluation is based on the financial performance of the produced models and also on their implications on needed resources by the bank to launch each model driven campaign. The empirical analysis reveals that the proposed resampling technique combined with non parametric classification leads to the most profitable outcome. Alteratively Synthetic Minority Oversampling combined with parametric classification leads to the best possible outcome in case of limited resources.

2 - Feature Extraction of Time-varying Process Data Based on Factor Analysis
Kyuchang Chang, Seung Hwan Park, Jun-Geol Baek

The more facilities in manufacturing process become complex, the more sensors collect data from the facilities. Consequently, extracting meaningful information from the data in real time is becoming more difficult. It is important to reduce data dimensionality considering various characteristics of the data before applying data mining or machine learning algorithms. This study aims to construct efficient methodology for extracting features of time-varying process data from a wide variety of sensors. This study uses industrial data equipped with several sensor systems including engineering variables which are multi-variate and time sequential. This study applies factor analysis as dimensionality reduction method. While PCA(Principal Component Analysis) uses total variance, factor analysis uses common variance. Factor analysis evaluates inter-connectivity between variables and extracts common factors which represent the total state. It classifies sensors which have similar pattern and reduces the number of variables and simplifies the fault detection model. The better classification performance for fault detection is expected.

3 - Decision Tree Classification to Predict Effect of JPEG Compression on Images
Jevgenij Tichonov, Olga Kurasova, Ernestas Filatovas

Though modern digital image processing tools enable to select the most suitable parameters in the JPEG algorithm for a particular image, however the images of different quality and sizes are obtained after compression even in the case of the same values of the parameters. It is difficult to determine in advance how the values of the parameters in the JPEG algorithm will influence a certain image. In this research, the image classification has been investigated, where the goal is to classify images in order to predict the effect of JPEG algorithm on images. This information is useful to select optimal parameters of the JPEG algorithm for each class of images. We aim to determine which features describing the original images have to be used, when classifying into three classes - images with high, middle and low quality after compressing them by the JPEG algorithm. Quality of images after compression is estimated by a Structural Similarity (SSIM) index and Peak Signal-to-Noise Ratio (PSNR). In this work we have used Decision Tree classification with hierarchical learning and investigated various options for sets of features: the means and the standard deviations for each RGB component of images pre-processed by various filters, as well as ratio between amounts of pixels of the original images and their sizes in bytes. The most accurate classification results have been obtained when the images are pre-processed by edge detection filters and thresholding.

■ TA-34

Tuesday, 8:30-10:00 - Building BM, 1st floor, Room 116

Scheduling and Applications

Stream: Supply Chain Scheduling and Logistics
Chair: *Malgorzata Sterna*

1 - Heuristics for Solving the Berth Allocation Problem
Jakub Wawrzyniak, Maciej Drozdowski, Jakub Marszałkowski, Eric Sanlaville, Xavier Schepler

Container shipping plays important role in the contemporary logistics. Port container terminals have key importance in global trade as transshipment points where modes of transportation change. Due to growing competitiveness between ports a port authority must take into account significant factors attracting maritime traffic. One of them is vessel turnaround time. Vessel turnaround time is determined by the allocation and sequencing of ships and cranes at the berths. Hence, Quay Crane Assignment Problem (QCAP), Quay Crane Scheduling Problem (QCSP), and Berth Allocation Problem (BAP) were considered in the literature. In this presentation we consider Berth Allocation Problem. BAP is usually solved before QCAP, QCSP because ships are most valuable and least flexible element of the harbor logistics. Consequently, assigning vessels to berths in the port is one of the most critical actions undertaken by the port manager. BAP is defined by a set of ships and berths. The optimality criteria are mean weighted flow time and mean weighted stretch. BAP can be solved to optimality only for small instances and very short time horizons. Long time horizons are more typical when estimating limits of port throughput. We introduce a bunch of heuristics, which can be used for solving big instances of BAP emerging when time horizon of months and years come into consideration. Performance of the heuristics is analyzed with respect to quality of solutions and runtime.

2 - Daily Pattern Formulation and Valid Inequalities for the Curriculum-based Course Timetabling Problem
Niels-Christian Bagger, Guy Desaulniers, Jacques Desrosiers

The Curriculum-based Course Timetabling Problem was formally described in the second international timetabling competition in 2007 (ITC2007). The goal is to generate weekly schedules by assigning courses to time periods and rooms while minimizing some associated penalties. Only a few of the studies in the literature have been focusing on the lower bounds which is the focus in this work. This is done by considering only the assignment of the courses to the time periods, thus ignoring the assignment to rooms, and to develop a mixed integer programming model based on enumerating patterns for each course and each day. The formulation enables us to derive valid inequalities and to remove some patterns from the model by showing that any solution containing these patterns is infeasible. This results in the improvement of four currently best known lower bounds on the 21 data sets from ITC2007 and closes the gap between the best know solution and the lower bound for one of these four instances.

3 - System Supporting Text Analysis
Grzegorz Fenrich, Malgorzata Sterna

We are living in the world, where access to various kinds of publications, more generally speaking to information, is very simple. Analyzing and comparing texts become more and more important, but also more and more difficult because of the amount of available information. We propose a set of tools which will support and automate these actions. The presented system supporting text analysis is multi-leveled, and divided into several modules. It allows determining the subject of the text being analyzed, building database of related texts selected from different sources, and, finally, comparing it to texts gathered in this database with use of library of combinatorial optimization algorithms supporting the text comparison phase. The system was devoted mainly to managing documents generated by students during their academic education, but it can be used also widely.

4 - Supply Process Optimization in Charitable Organizations
Malgorzata Sterna, Mateusz Cichenski, Mateusz Jarus, Jaroslaw Szymczak

We investigated the problem of minimizing the cost of supply process in charitable organizations. This process consist of ordering and delivering goods, which might be either donated or bought at different locations. Charitable institutions are interested in minimizing the total cost, which consists of the prices at which particular products are bought and the cost of their transportation. We formulated the mathematical model of the problem, which is NP-hard. Then we proposed list heuristics and the genetic algorithm solving it. The efficiency of implemented methods was checked in extensive computational experiments. The genetic algorithm was integrated with the software system, web service, which may serve charitable organizations. The system is designed to allow registered users exchanging information on offered products and demanded goods and to suggest efficient solutions optimizing supply process.

■ TA-35

Tuesday, 8:30-10:00 - Building BM, ground floor, Room 17

Supporting Wet Lab Experiment

Stream: Computational Biology, Bioinformatics and Medicine
Chair: *Andrzej Swierniak*

1 - Sensitivity Analysis in Biological Experiment Planning
Małgorzata Kardyńska, Jaroslaw Smieja

Due to rapid advances in experimental techniques, our knowledge about biological processes affecting cell behavior and fate is continuously expanding. Unfortunately, the efforts to uncover the structure of regulatory mechanisms governing them are hampered by high costs of experiments, uncertainty of measurements and enormous complexity of the systems under consideration. This is why new computational and analytical methods are required to assist experimental work and analyze available data. In recent years standard sensitivity methods have been applied to analysis of biological systems models. While sensitivity methods proved to be helpful in analysis of various pathways, they were focused on simulation results whose units were clearly determined (as concentration units). Unfortunately, in most cases available data, though quantitative, is relative (fold change instead absolute values). Taking into account that signaling pathways are investigated in the context of their responses to step or impulse excitations, we propose to use normalized step response as the most fundamental dynamic characteristics of the system. Its frequency distribution provides valuable information about qualitative system behavior that can be subsequently used to build sensitivity parameter rankings. They, in turn, indicate experiments that should be performed in order to estimate parameter values. Moreover, they may provide additional hints concerning the choice of time points for measurements.

2 - Method for Identification of Components of Secondary Metabolites Based on Mass Spectra
Marcin Borowski

Man has always been interested in the world around, eager to know what constitutes its surroundings. Getting to know them, he gradually expanded the boundaries of horizons. Step by step, it became possible to determine the qualitative and quantitative composition of surrounding environment. This involved developing a number of physical, chemical and computer science methods of studied systems. Our study has been focused on secondary metabolites. Commonly, to identify secondary metabolites one can use mass spectrometry. The elements observed in the mass spectra are identified by database searching algorithms. As a result the algorithm returns a list of potential chemical compounds. The aim of this work was to develop, implement and test the combinatorial algorithm which allows to determine the chemical composition of the test compound, based on data from the mass spectrometer. Given mass of the particle (mass to charge ratio of the fragmentation ion is converted to molecular weight) and a particular set of elements (plus their masses and valency), the algorithm tries to determine the molecular formula for this particle. This backtracking algorithm finds all (or some) solutions to the above defined problem (constraint satisfaction problem), incrementally builds candidate solutions, and abandons each partial candidate as soon as it determines that potential solution cannot possibly be completed to a valid one.

3 - Brain Magnetic Resonance Image Processing
Krzysztof Psiuk-Maksymowicz, Damian Borys

The aim of this work was to develop image processing methodology necessary for creation of complete vascular network of the human brain. For this purpose a set of magnetic resonance images, including non-contrast enhanced angiography, was analyzed. The angiograms were obtained by means of Time of Flight Angiography and Phase Contrast Angiography. Segmenting both type of images enabled for extraction of the arterial and venous trees. The images with characterized vessel centroids and diameters were then exploited to create a model of two type of vessel trees. In order to connect both trees synthetic model of capillaries was applied. Created model of full vascular network of the brain was necessary to simulate pathologies, such as tumor development. It included angiogenesis and remodeling of the network in a course of time. Angiogenesis is a process of growth of new blood micro-vessels from existing vasculature under the hypoxic conditions. It is a fundamental step in the transition of tumors from benign to the malignant type. Additional outcome of this work was preparation of probability maps for different brain structures. Maps were created from normalized, segmented magnetic resonance images from representative group of 99 healthy volunteers. This kind of probability maps are especially valuable for diagnostic purposes. This work was supported by NCN grant 2011/03/B/ST6/04384 (DB) and NCBiR grant PBS3/B3/32/2015 (KPM).

4 - Machine Learning Methods as Tools in Drug Discovery Research: Application in Ligand-based Virtual Screening
Agata Kurczyk

Virtual screening (VS) is an important approach in the drug discovery process. Methods used in VS can be divided into two classes: structure- or ligand-based techniques. Machine learning (ML) procedures were often successfully applied in VS protocols. The most common practical ML usage is to classify or prioritize databases of molecules in terms of biological activity. Yet another ligand-based approach for VS is the concept of privileged structures (PS). The PS concept is based on the assumption that certain structural features produce biological effects more often than others.

In a search for new anti-HIV-1 chemotypes, we developed a multi-step ligand-based VS protocol combining ML methods with PS concept. The performances of various ML methods and PS weighting scheme were evaluated and applied as VS filtering criteria. Finally, a database of 1.5 million commercially available compounds was virtually screened using a multistep ligand-based cascade, and 13 selected unique structures were tested by measuring the inhibition of HIV replication in infected cells. This approach resulted in the discovery of two novel chemotypes with moderate antiretroviral activity, that, together with their topological diversity, make them good candidates as lead structures for future optimization.

This work was partially supported by the National Centre for Science, Poland, project DEC-2012/04/A/ST7/00353.

■ TA-36

Tuesday, 8:30-10:00 - Building BM, ground floor, Room 18

Scheduling in Healthcare 4

Stream: Scheduling in Healthcare
Chair: *Sharon Hovav*

1 - MRI Block Scheduling at a Norwegian Hospital
Anders N. Gullhav, Marielle Christiansen, Bjørn Nygreen, Mats M. Aarlott, Jon Erik Medhus

The process of scheduling patients to MRI (magnetic resonance imaging) scanners at hospitals is typically done in multiple stages. On a tactical decision making level, the hospital in this study develops a block schedule that is used as a guide in the appointment scheduling on the operational level. The block schedule is a weekly recurring schedule that specifies an assignment of patient groups, which is defined according to medical characteristics, to the different heterogeneous MRI scanners at different time slots during a week. The block schedule must satisfy various technical and staffing requirements, such as change of coils and available personnel. In this work, we suggest using mathematical programming to create appropriate block schedules, and propose a mixed integer linear programming (MILP) formulation of the problem. The MILP is solved using a commercial solver on test data obtained from a major Norwegian hospital.

2 - Workforce Management for Integrated Healthcare Between Hospitals and Community: a Case Study on Chronic Kidney Disease
Fang He

People with chronic health conditions are most intensive users of healthcare services because their treatment needs are usually longterm, and more complex than those with acute diseases. An estimated of 15 million people in England have at least one longterm condition with the prevalence of cancers, chronic kidney disease and diabetes, rising most quickly in recent years. As an example, the mean annual expenditure of NHS to treat a renal patient on peritoneal dialysis (PD) was '21,655 in 2008 in U.K. Individual patients with chronic kidney disease (CKD) need a range of care services from multidisciplinary workforce such as specialist consultants, surgeons, general practice, clinic nurses and community nurses, etc. The care pathways for patients with CKD vary, and cross several sections in the healthcare system. The care pathways need to be carefully and thoroughly reviewed and optimised within the healthcare system to establish cost effective integrated management without compromising the quality of care. This study is conducted jointly with Sheffield Kidney Institute. In this initial study, we examine and understand the clinical care pathways and the way the workforce are assembled inside and outside hospital for the care of patients with CKD.

3 - Stochastic Scheduling of Vaccine Deliveries in Large-scale Vaccination Supply Chains
Sharon Hovav, Ilya Levner

We consider a problem of multi-echelon scheduling of the mass delivery of vaccine batches in the nation-wide influenza vaccination supply chain (IVSC) under uncertain (stochastic) demand and varying environment conditions. The problem is treated in two echelons: first, the delivery from the manufacturers to the distribution center (DC) and, second, the delivery from the DC to the network of clinics and efficient distribution of vaccines in the network. The vaccine demand during the vaccination season is stochastic and assumed to be normally distributed. IVSC is a challenged supply chain with the following properties: 1. The vaccine fits for and can be used only during a unique season. 2. The distribution of demand in each clinic over the months of the vaccination season are stochastic with its distribution assumed to be known. 3. The total amount of vaccines should be set several months before the influenza season starts and cannot be changed during the season. 4. The benefit of vaccination is different per sub-groups of population and decreases over time.

Given a forecast of weekly orders, the problem is to define how many vaccines are to be produced and how they should be scheduled for efficient delivering to the retail (clinics) in each month. We describe the mathematical model of the problem and suggest an efficient solution algorithm based on a sequential solving of a series of modified newsboy problems.

■ TA-38

Tuesday, 8:30-10:00 - Building BM, 1st floor, Room 109M

Health Care Management 1

Stream: Health Care Management
Chair: *Penka Petrova*

1 - Applications of Operations Research and Intelligent Techniques in the Health Systems. A Bibliometric Analysis
Marek Lubicz

Operations research and quantitative methods, including the ones based on artificial or computational intelligence, have been applied in health care for decades. Looking at areas of applications as well as evolution of techniques one can notice trends, emerging problem areas, and also international disparities in the application-oriented research. In particular, despite huge advancements in applied health operational research published in major scientific journals, papers demonstrating modelling approaches applied for Eastern European health care systems are very rare. One could argue that substantial progress in applied research could possibly reflect general status of processes in a health care system. This paper explores this idea by means of analysis of the research results presented in the period 1985-2015 at annual conferences of the EURO Working Group Operational Research Applied to Health Services (ORAHS) and confrontation of trends in broad-European ORAHS research with those published by Polish authors. The technical background for this research is a bibliometric analysis based on SciMat - a Science Mapping Analysis software Tool, developed at the University of Granada. Conclusions concerning relationships between distinctive features of the health systems versus the needs and the capabilities for quantitative support of health care decision making are also discussed.

2 - The Relationship Between the Efficiency of Hip Fracture Surgeries and Patients Socio-Economic Index Using Two Stage Network DEA: the Case of Israel
Zilla Sinuany-Stern, Simona Cohen Kadosh

This study examined the relative efficiency of orthopedic wards in Israeli acute hospitals (20 hospitals) by using Data Envelopment Analysis (DEA) which demonstrates multiple inputs and outputs. In our study we examined the relative efficiency of a specific operation, Hip Fracture, within orthopedic wards based on quality measures of care such as medical process indicators and outcomes measures. In this part of our research we have developed two-phase network model suited to the medical process of analyzing the Hip Fracture operation with 2 inputs that reflect the condition of the patient: the fracture type and Charleston Index, and two intermediate variables reflecting the medical process: surgery within 48 hours and the rate of using a drain for one day, and finely 2 outputs: the death rate after surgery and the rate of infection. A two stage DEA network has been adapted to the output oriented and variable return to scale version, using additive weighted efficiencies of the two stages. In addition, we examined the relationship between Socio-Economic Index (SEI) of patients operated versus the relative efficiency scores of the Hip Fracture two stage operations. Furthermore, we tested the effect of the hospitals location in terms of peripheral geography on efficiency scores. We found no statistically significant correlation between the efficiency and SEI, and nor between the efficiency and the geographical periphery status.

3 - Medical Care Within an OLG Economy with Realistic Demography
Stefan Wrzaczek, Ivan Frankovic, Michael Kuhn

We study the role of a health care market within a continuous time economy of overlapping generations subject to endogenous mortality. The economy consists of two sectors: final goods production and a health care sector, selling medical services to individuals. Individuals demand health care with a view to lowering mortality and morbidity over their life-cycle. We derive the age-specifc individual demand for health care based on the value of life as well as the resulting aggregate demand for health care across the population. We then characterize the general equilibrium allocation of this economy, providing both an analytical and a numerical representation. We study the allocational impact of a medical innovation both in the presence and absence of anticipation; and a temporary baby boom. We place particular emphasis on disentangling general equilibrium from partial equilibrium impacts.

4 - INN Prescribing or INN Substitution: A Hybrid Modelling Approach to Optimal Pharmaceutical Policy Decision Making
Ross Kazakov, Penka Petrova

The paper describes pharmaceutical markets being complex adaptive socioeconomic systems with changing properties made out of agents and agents' interactions, including doctors, patients, pharmacists, pharmaceutical companies and regulators, and evolving in an environment with limited resources like medicines budget and information. A hybrid system dynamics and agent-based modelling experiment is conducted in order to explore and compare the benefits and shortcomings of two competing healthcare policies related to International Non-proprietary Name /INN/ prescribing and INN substitution, which the government in a CEE country is intending to implement. The aim of the experiment is to explore and compare the effect of the above two competing policies on the pharmaceutical market, in regards to key policy indicators like widening access to medicinal treatment and improving utilization of medicines budget, while having in mind that the market will need to change from a state of one with brand name prescribing by doctors and no medicinal substitution allowed in the pharmacies to one with INN prescribing or INN substitution. No matter which of the two policies would the government try to implement, a major change would be brought to the market in relation to agents' behaviour, medicine expenses and information availability.

■ TA-39

Tuesday, 8:30-10:00 - Building WE, 1st floor, Room 107

Pricing and Revenue Management

Stream: Advances in Revenue Management
Chair: *Luce Brotcorne*

1 - Dynamic pricing in the vehicle ferry industry
Christopher Bayliss

We will present an optimisation approach for vehicle ferry pricing and packing, where we allow for different ferry configurations (e.g. movable decks). When demand is high, the optimal prices we derive should regulate demand so as to encourage the most profitable vehicle mix and deck configuration. Optimal packing solutions are firstly derived for all vehicle mixes; these vehicle mixes define the ferry's capacity envelope, and the optimal packing solutions correspond to its Pareto front. Allowing for different ferry configurations enlarges the capacity envelope. The vehicle mixes are used as the states of a dynamic program, which is solved to determine the optimal price points for each vehicle type at each level of remaining capacity and time interval during the selling season. The proposed approach is based on ferries which use a lane based approach for loading on departure day. As an extension, we also evaluate the revenue impact of relaxing the strict lane-width constraint by making lane-width a decision variable of the model, leading to a 2-dimensional rectangular packing problem. We use simulation to compare the revenue obtained using the optimal static booking limit solution with the optimal dynamic pricing solution and pricing solutions obtained using heuristic packing algorithms. We will present computational results on generated instances based on data from commercial partners, which highlight the revenue impact and computational cost of the proposed approach.

2 - Revenue Management and Demand Side Management in the Energy Field
Luce Brotcorne, Sezin Afsar, Patrice Marcotte, Gilles Savard

Pricing models for demand side management methods are traditional used to control electricity demand which became quite irregular recently and resulted in inefficiency in supply. We propose bilevel models to explore the relation and between energy suppliers and customers who are connected to a smart grid. This approach enables to integrate customer response into the optimization process of supplier who aims to maximize revenue or minimize capacity requirements. Numerical results are given.

3 - Dynamic Programming Algorithms for Optimal Upgrading
David McCaffrey

We present a dynamic programming approach to optimal management of upgrades in multi-compartment aircraft. We review an algorithm which is known to give an exact solution in a feasible runtime to the 2-dimensional problem (i.e. 2 compartment aircraft). We discuss sufficient conditions for this algorithm to also give exact solutions to the 3- and 4-dimensional problems. We present estimates based on numerical investigations of the potential financial benefit from this dynamic approach to managing upgrades compared to current static approaches

■ TA-40

Tuesday, 8:30-10:00 - Building WE, 1st floor, Room 108

Mathematical Models in Macro- and Microeconomics 1

Stream: Mathematical Models in Macro- and Microeconomics
Chair: *Vadim Strijov*
Chair: *Gerhard-Wilhelm Weber*

1 - The Application of Time Series Models to a Data-driven Approach in the Newsvendor Problem
Davood Pirayesh Neghab, Gabor Rudolf

The vital point concerning problems of operations research and management science is that a good prediction is not going to be a good decision, necessarily. On the other hand, in many various fields like Finance, the auxiliary data are recording simultaneously with main data range from a low order to high one. These predictor variables can be very imperative because of the inevitable dependency, and also very accommodating because of being easy to measure in many cases. Considering some characteristics of big data like volume, variety, and velocity we should try to reduce the complexity of problems to gain the parameters. So, nonparametric approaches lead to bring accurate results in a short time. In this regard, regression and econometrics models like AR and MA can help us to achieve many forecasting goals.

In this study, we consider the newsvendor problem and its cost function for performance examination of a decision which is to be minimized. We apply the autoregressive models to this type of problems. The final function includes time series parameters which the coefficients are obtained by optimization methods. This approach is going to capture the different lags correlation of different predictor variables and bring them to a single linear combination. Then, the decision of order quantity is made directly without any need to predict the demand. The results are shown in details compared to the classic approach.

2 - The Added Value of Social Media in Sentiment Analysis
Matthijs Meire, Dirk Van den Poel

The mass increase in UGC (e.g., reviews, Facebook posts, tweets) has sparked interest in sentiment analysis during the last decade. Despite this evolution, the information used in sentiment analysis models remains limited to the content itself. However, on social media, such as Facebook, not only the focal post's content is available, but, taking into account the time of a posting, there is also leading and lagging information. Leading information is available even before content is posted. On the other hand, lagging information is generated a posteriori, after the content was posted. The purpose of this study is therefore to (1) assess the added value of information available before and after the focal post's creation time in sentiment analysis of Facebook posts, (2) determine which predictors are most important, and (3) investigate the relationship between top predictors and sentiment. We build a sentiment prediction model, including leading information, lagging information, and traditional post variables. We benchmark Random Forest and Support Vector Machines using cross-validation. The results indicate that both leading and lagging information increase the model's predictive performance. The most important predictors include the number of uppercase letters, the number of likes and the number of negative comments. To the best of our knowledge, this study is the first to assess the added value of leading and lagging information in the context of sentiment analysis.

3 - The core regression for valuating real estate in Poland
Rafał Zbyrowski

The main purpose of this article is to concentrate on the problem of statistical valuating real estate in Poland. Nowadays the development of the data analysis in the real estate market can be observed. It seems that the mathematical Shepard's method called "core regression" is appropriate to solve many practical problems connected with the valuating on the real estate market. The very important advantage of this method is focusing the estimation on a small group of objects that are noticeable similar to the valuating one. I think an empirical analysis of this case could be vital from the economy point of view and moreover it would be useful for professionals linked with decision making on the real estate market. A review of the literature shows that the empirical usage of the Shepard's method is not so popular especially in Poland. My paper is focused on an empirical study of using Shepard's method in example of valuating flats in Warsaw. It is worth saying that in the USA this method of valuating is mentioned quite often in the area of decision making and supporting business.

■ TA-41

Tuesday, 8:30-10:00 - Building WE, 2nd floor, Room 209

Finance and OR 2

Stream: Financial Mathematics and OR
Chair: *Emel Savku*
Chair: *Gerhard-Wilhelm Weber*
Chair: *Mustafa Pinar*

1 - Selling Sunscreen Products, Come Rain or Shine
Xavier Brusset

Cool summers or warm winters affect sales of scores of products and wreak havoc with the best marketing and promotional efforts for all firms operating in consumer goods, food and beverages, apparel, cosmetics, tourism and many other industries. Each year, the cost of unseasonal weather exceeds $500 billion in the United States alone. The renewed interest in investigating the role of weather on business activity is prompted by more reliable weather data, the development of new risk mitigating tools, and rising weather variability creating increased risks. On the basis of an innovative and replicable methodology, we model the influence of weather on sales in a way that supports the implementation of risk mitigation instruments, using weather parameters as sole explanatory variables. Models developed with our methodology allow managers to better understand the role of weather on business performance, take real-time corrective actions, and protect sales as well as marketing efforts from the effects of adverse weather.

We analyze sunscreen 4 week-rolling sales data in France over 11 years (2003-2013). We construct and select the weather variables that display the highest correlation factor. We find that temperature and precipitation anomalies are the most influential variables, which we use to model changes in sales as a function of weather and promotions. We propose a new risk assessment indicator which measures the maximum potential loss. Mitigation policies can be set up.

2 - Startup Company Valuation Using a Product Growth Model
Pedro Pólvora

Startup companies are particular in many ways, such as in the fact that they provide much less financial information to investors and employees then mature companies that are traded in exchanges. We propose a model to value early stage startup companies based on the product growth and client acquisition models. We use existing deterministic models for the daily active users (DAU) of a web-based startup as a proxy to the product growth and relate it with the value of the company. We propose extensions to stochastic models and also present some numerical examples.

3 - Optimal Investment in a Stochastic Factor Model under the Existence of Private Information
Ioannis Baltas, Athanasios Yannacopoulos

In the present paper we study an optimal control problem for a general stochastic factor model under the existence of some private information. To be more precise, we consider an economic agent who has the possibility to invest part of her wealth in a financial market consisting of a riskless and a risky asset, whose coefficients depend on some external economic factor process. Moreover, we assume that the agent, from the beginning of the trading interval, possesses some private information concerning the evolution of the risky asset. This information is not precise but is subjected to some noise. The optimal investment decision is determined by the solution of an expected utility maximization problem, taking into account her enlarged information set. For a certain class of utility functions of CARA type and when the external factor process evolves according to an Ornstein-Uhlenbeck process, we are able to provide closed form solutions for the optimal investment decision and the optimal value function. Finally, by employing an Euler-Maruyama scheme, we numerically study the impact of the private information on the optimal investment strategy.

■ TA-42

Tuesday, 8:30-10:00 - Building WE, 1st floor, Room 120

Dynamic models in game theory

Stream: Dynamic Models in Game Theory
Chair: *Alessandra Buratto*

1 - HIV vs. the Immune System: A Differential Game
Alessandra Buratto, Rudy Cesaretto, Rita Zamarchi

A differential game is formulated in order to model the interaction between the immune system and the HIV virus. One player is represented by the immune system of a patient subject to a therapeutic treatment and the other player is the HIV virus. The aim of our paper is to determine the optimal therapy that allows to prevent viral replication inside the body, so as to reduce the damage caused to the immune system, and allow greater survival and quality of life. We propose a model that considers all the most common classes of antiretroviral drugs taking into account different immune cells dynamics. We validate the model with numerical simulations, and determine optimal structured treatment interruption (STI) schedules for medications.

2 - Optimal Solution in a Cooperative Differential Game of Pollution Control

Ekaterina Gromova

A particular class of linear-quadratic differential games of pollution control is considered. It is shown that the delta-characteristic function computed for this cooperative game is superadditive and that the Yeung conditions are satisfied without any additional restrictions on the parameters of the model. The Yeung conditions guarantee the irrational behaviour proofness in a cooperative differential game. Both the Shapley value and the corresponding imputation distribution procedure were obtained in the analytic form. This result guarantees a stable cooperation on the basis of the Shapley value taken as the cooperative solution. This leads to a substantial improvement as the cooperative solution implies a lower lever of pollution.

It is also shown that the Yeung conditions can be used to construct a strongly time-consistent core. Within this core there exists a supporting imputation which has the property that a single deviation from this imputation in favor of any other imputation from the core still leads to the payment from the core. The obtained results were formulated for the Shapley value taken as the supporting imputation.

3 - Slow and steady wins the race: approximating Nash equilibria in nonlinear quadratic tracking games

Dmitri Blueschke, Viktoria Blueschke-Nikolaeva, Ivan Savin

We propose a meta-heuristic approach for solving nonlinear dynamic tracking games. In contrast to more 'traditional' methods based on linear-quadratic (LQ) techniques, this derivative-free method is very flexible with regard to the model or objective function specification (e.g., to introduce inequality constraints or asymmetry in the penalties of the objective function). The meta-heuristic is applied to a three-player dynamic game and tested versus a derivative-dependent method in approximating solutions of different game specifications. In particular, we consider a dynamic game between fiscal (played by national governments) and monetary policy (played by a central bank) in a monetary union. Apart from replicating the results of the LQ-based techniques in a standard setting, we solve two 'non-standard' extensions of this game (dealing with inequality constraint in control variable and with asymmetric objective function), identifying both a cooperative Pareto and a non-cooperative open-loop Nash equilibria, where the traditional methods are not applicable. Our results demonstrate that using the proposed method one can apply a much more differentiated set of policy objectives which lead to a better macroeconomic outcome.

4 - A thorough analysis of dynamic oligopoly with sticky prices

Agnieszka Wiszniewska-Matyszkiel, Marek Bodnar, Fryderyk Mirota

In this paper we analyse a dynamic game modelling oligopoly with sticky prices. We calculate feedback Nash equilibria and open loop Nash equilibria, and compare resulting trajectories of price and production. Although our paper is not the first such model of oligopoly, it appears to be the first paper in which non-stationary open loop Nash equilibria were rigorously calculated. Therefore, our analysis allows us to study and compare feedback and open loop Nash equilibria which are not constant. We prove that feedback equilibrium production from some time instant on, is strictly greater than the open loop equilibrium production, with reverse inequality for prices. Moreover, equilibria are only piecewise differentiable. We also analyse behaviour of equilibrium price and production as functions of parameters of the model and we obtain, among others, monotone convergence of steady states of open loop Nash equilibrium price and production to analogous levels of the static Cournot-Nash equilibrium as the speed of adjustment tends to infinity, while for feedback equilibrium, convergence is to some nontrivial convex combination of the static Cournot-Nash equilibrium and the competitive equilibrium.

■ TA-43

Tuesday, 8:30-10:00 - Building WE, ground floor, Room 18

OR for Energy and Resource Efficiency

Stream: Optimization in Renewable Energy Systems
Chair: *Katharina Stahlecker*

1 - Multi-criteria evaluation of transition pathways towards a sustainable energy system

Katharina Stahlecker, Jutta Geldermann

In order to achieve the national target of reducing Germany's emissions by 80% by 2050 a transition of the energy system is required. German long-term energy policy targets envision an energy efficient system primarily based on renewable energies. This transition towards a sustainable energy system involves multiple conflicting criteria. Technically feasible options need to be assessed considering economic and social sacrifices and environmental impacts. Within the publicly funded project NEDS, researchers from different disciplines are developing feasible transition pathways towards a sustainable energy supply in 2050 for the German federal state of Lower-Saxony. The aim of this research project is to evaluate the sustainability of different scenarios and transition pathways. Multi-criteria decision analysis is used to simultaneously consider technological, economic, environmental and social criteria. Due to the long-term nature of the decision problem, the analysis needs to take uncertainties and path dependencies into account.

2 - Use of MCDA in Constructing Strategic Action Portfolios

Theodor Stewart

The concepts developed in this paper arose specifically in the context of national energy planning in developing countries, taking into consideration both reaction to and mitigation of climate change. The concepts undoubtedly apply equally to other strategic natural resource planning problems. Typically such strategic planning processes incorporate three phases: an initial identification of courses of action that can be implemented; an assembly of such actions into portfolios that constitute potential policies; and the evaluation of such policies to provide final recommendations.

Each phase can be viewed as a multiple criteria decision making problem, but different MCDA mechanisms will be appropriate to each. The first has a strong problem structuring element and discrete choice MCDA applied to a sorting problematique. The second is a multiobjective portfolio optimization problem, with the aim of generating a short-list for final consideration. The third phase is again a discrete choice problem aimed at choice or ranking of alternatives, often in the presence of important qualitative criteria. We shall trace the development and integration of MCDA thinking through these three phases.

3 - Modelling renewables mitigation options in the Colombian power system

Jose Lenin Morillo Carrillo, Mauricio Palma, Ricardo Delgado, Angela Ines Cadena

This paper examines the impact of the penetration of Non-Conventional Renewable Energy Resources (NC-RES) in the Colombian generation mix. The work makes use of an expert system to set the expansion portfolio, a Stochastic Dual Dynamic Programming method and the MARKAL models, to assess the impacts on electricity production and prices, fuel use and CO2 emissions. Several scenarios of generation with different levels of penetration of NC-RES, storage systems and energy efficiency targets were evaluated. Provision of firm energy is a major challenge for Colombia given the low regulations capabilities of the hydro-dominated power system. Seven scenarios were finally chosen to appraise cost and benefits. Two of the six scenarios consider the installation of batteries, three of them consider energy efficiency goals on the demand side and one of them considers the installation of more efficient thermal plants. Results show that a target of 30% of NC-RES in 2050, as proposed in a more ambitious intended National Determined Contribution, could be feasible if storage capabilities are installed. The system could benefit from the complementarity between wind and hydro resources as well as from decentralized photovoltaic systems that exchange power with the network. Different services and tariffs must be considered in the Colombian Power Market. MARKAL model was used to verify the net CO2 abatement within the entire energy system.

4 - Which is the optimal role that biomass and waste could play in a future energy system? - Linkage of biomass and waste supply models with energy models
Amalia Pizarro

Biomass and waste are foreseen to play an important role in achieving fossil-free societies. They can provide backup energy for fluctuating production, transport fuels or high value chemicals. They are precious feedstocks with competing uses, whose utilization must be optimized throughout their life cycle. Optimization of biomass use has traditionally been done with models that consider an infinite market approach, with unlimited demand for electricity, heat or fuels. However, in the future, biomass and waste might constitute more than 50% of the primary fuel consumption; thus,the impact of biomass and waste in the energy system might not be marginal and the energy system will be affected by the use of both. Therefore,a holistic approach between the agriculture, waste and the energy sector is needed. A spatial-temporal network model has been developed for this purpose,where nodes and arcs define the topology of the waste and biomass systems and their different usages. This model is iteratively soft-linked, with an energy system model, in order to evaluate the optimal use of biomass and waste within the boundary conditions of the surrounding energy system. The objective of the research is to develop decision-support tools that can help in using resources in the overall best possible way, integrating economic and environmental considerations, assisting decision-makers in strategic short and long-term planning,avoiding sub-optimization of the biomass,waste and energy systems.

■ TA-47

Tuesday, 8:30-10:00 - Building WE, 1st floor, Room 115

Advances in Stochastic Modeling

Stream: Stochastic Modeling and Simulation in Engineering, Management and Science
Chair: *Raik Stolletz*
Chair: *Massimo Di Francesco*

1 - Managing demand and supply uncertainty in Build-To-Order supply chains
Ton de Kok, Jaap Arts

We consider a real-life case study at a high-tech first tier supplier to an OEM. The supplier builds its product on order, implying that it promises a fixed delivery lead time to the OEM. However, after the OEM orders and the due date of the order has been agreed, the OEM changes its due date several times during the final assembly at the supplier. The supplier responds by delaying the assembly process or speeding up the assembly process dependent on the change in the due date. The final assembly process involves a considerable amount of testing. As the outcome of the test may or may not cause rework, the processing time of assembly is stochastic. We present a remarkably simple model that explains the empirical behaviour of this complex system. The simplicity of the model provides a fundamental understanding of the impact of customer order due date changes during a built-to-order assembly process.

2 - Dependence among Single Stations in a Production Line and the Second Moment Result of the Theory of Constraints
Kan Wu, Ning Zhao

Theory of constraints has been commonly applied in production systems to improve productivity. Under this scheme, people believe that the most effective place to improve the performance of a production line is to improve the performance of its bottleneck. Since the improvement on an upstream workstation may have an impact on its downstream servers, finding the true bottleneck is not trivial in a stochastic production line. Due to the analytical intractability of general tandem queues, we develop methods to quantify the dependence among stations through simulation. Dependence is defined by the contribution queue time at each station, and contribution factors are developed based on the insight from Friedman's reduction method and Jackson networks. In a tandem queue, the dependence among stations can be either diffusion or blocking, and their impact depends on the positions relative to the bottlenecks. Based on these results, we show that improving the performance of the system bottleneck may not be the most effective place to reduce system sojourn time. Sometimes, performance improvement from a front-end station of a production line can be a better choice. Rather than making independence assumptions, the proposed method points out a promising direction and sheds light on the insights of the dependence in practical queueing systems.

3 - Nonparametric Knowledge Gradient Procedure
Bogumił Kamiński

We consider a ranking and selection problem in simulation context. In this off-line learning setting we compare a finite number of parameterizations of stochastic simulation model and given a limited budget for performing simulations want to select the alternative that has the best performance. We focus our research on procedures using Bayesian methodology based on knowledge-gradient approach. In the existing literature this approach has been successfully applied in standard parametric belief models (Gaussian, Beta-Binomial, etc.). In this work we develop a knowledge-gradient policy that does not require parametric assumptions about distribution of simulated alternatives. We show that this can be achieved using the methodology assuming that prior beliefs are described using Dirichlet process. We propose algorithms that allow to execute knowledge-gradient and knowledge-gradient star policies. The proposed nonparametric approach is more demanding computationally than parametric knowledge-gradient procedures that are based on conjugate priors that are traceable analytically. We show how the required numerical procedures can be efficiently preformed using parallelized computations using two implementations: a) CUDA architecture, b) distributed computing in the cloud. In the presentation we compare the performance of the proposed procedure to parametric knowledge-gradient in different scenarios and report on the scalability of the considered algorithm parallelization methods.

4 - Optimizing simulation parameters for stochastic empty container repositioning
Massimo Di Francesco, Alexei Gaivoronski, Paola Zuddas

We face the stochastic empty container repositioning by a discrete event simulation model, which is based on lower and upper inventory thresholds at each port. We look for the inventory thresholds optimizing the average system performance with respect to all observations of random parameters entering the system description in each period of the planning horizon. These random parameters are the net supply of empty containers at ports, ship loading and unloading times and transport capacities. The optimal values of these thresholds are determined by an optimization algorithm, which belongs to the family of stochastic gradient methods.

■ TA-48

Tuesday, 8:30-10:00 - Building WE, 1st floor, Room 116

Financial Modelling 1

Stream: Decision Making Modeling and Risk Assessment

in the Financial Sector
Chair: *Sergio Ortobelli*

1 - Macroscopic look at the Equity Markets
Abdullah Alshelahi, Romesh Saigal

The aim of this research is to investigate the existence of sensors which may aid in the monitoring of Equity Markets. While the classical approach consists in studying the stock market following the evolution of individual stocks, we use a so-called macroscopic viewpoint by considering a global view of the equity markets. This method enables us to extract significant information about the overall dynamics. This way, we see the market within the context of the principles of mass and momentum conservation and the variables density, flux, pressure, average velocity, etc. We can then define ‘sensors’ that can monitor some of these variables in the market. In the era of high frequency trading, powerful tools are needed to monitor and control these activities in markets. We propose a method that predicts and provides alerts in the case of such abnormal activities. Our preliminarily analysis shows that our sensors capture valuable information during the flash crash day in which the volatility was extraordinarily high and which was created by high frequency trading.

2 - Timing and hedging portfolio strategies with derivatives
Sergio Ortobelli, Tomas Tichy, Filomena Petronio, Filomena Petronio

In this paper, we propose portfolio selection strategies with options. We generally assume that the returns follow Markov processes that are approximated with proper Markov Chains. Then we preliminary examine all the American options with underlying the components of the Dow Jones Industrial index and we discuss different portfolio strategies based either on hedging the risk of the underlying or on optimizing proper expected first passage times of the wealth at some benchmark levels. The main contribution of this paper is an empirical comparison among different hedging and timing portfolio selection strategies. In particular, we compare the ex post wealth obtained by optimizing new performance strategies based either hedging properly the portfolio risk or optimizing the average first passage time of the wealth at some benchmark levels.

3 - High-frequency price discovery and price efficiency on interest rate futures
Jing Nie

High-frequency traders in the futures market generate the adverse selection and increase the trading costs for hedgers. This paper examines the impact of price efficiency on the high-frequency traded Eurodollar futures market. In a high-frequency world, the price can be decomposed into the efficient price (long term) and the pricing error (short term). To capture price efficiency, I calculate the mid-price return autocorrelation following the intervals: tick-by-tick, 1 ms, 2 ms, 5 ms, 10 ms, 15 ms, 20 ms, 25 ms, 50 ms, 75 ms, 100 ms, 150 ms, 200 ms, 500 ms, 750 ms, 1 sec, 5 sec, 15 sec, 30 sec, 60 sec, 300 sec, 600 sec, 900 sec, 1,200 sec, 1,500 sec, and 1,800 sec. Then, I utilize a vector autoregression to estimate the pricing error as the deviation of transaction prices from the efficient price to illustrate the structure of these costs. I have constructed a unique dataset using the complete messaging history (quotes and transactions) for the Eurodollar futures limit order book from 2008 to 2014. The findings suggest that the mid-quoted return autocorrelations are positive and gradually increase from the shortest time interval to the longest time interval. The adjustment time of trade returns completes in a very short time interval of one second. Considering the maturity effect in the futures market, I find that the trade prices are less sensitive about incorporating any available information into the market, as the Eurodollar future approaches its maturity.

■ TA-52

Tuesday, 8:30-10:00 - Building PA, Room C

Multidisciplinary Applications of Global Optimization

Stream: Global Optimization
Chair: *Ahmet Sahiner*
Chair: *Hakan Altunay*

1 - FuzzyLogic Modeling for Estimating Daily Global Solar Radiation in Turkey Comparison with (DMI) Data
Idris Abdulhamed, Ahmet Sahiner, Murat Ozturk

The main objective of the present study is to develop a Fuzzy Logic Model to predict the daily average of the solar radiation over Turkey’s Region, which covers the 12 provinces (Tekirdag, Izmir, Denizli, Zonguldak, Bilecilk, Burdur, Samsun, Kayseri, Antakya, Artvin, Elazig and Van) the global solar radiation has been measured by the Turkish State Meteorological Service (DMI) over all the country, the results obtained by the Fuzzy Logic Model were compared with the actual data and error values were found within acceptable limits.

2 - Fuzzy Logic Modeling for Prediction of the Nuclear Tracks
Shehab Ibrahem, Ahmet Sahiner, Ahmed Ibrahim

In this paper, we have applied Fuzzy Logic Modeling (FLM) on nuclear track detector (CR-39) data. These data were obtained practically to find a number of effects tracks of alpha in nuclear track detector (CR-39) for different temperatures and different concentrations at different etchant times. We applied Fuzzy Logic Modeling on this physical data to make it continuous and that shows there is a match between original data and fuzzy and then we found optimal triple (temperature, concentration , etchant time) to get a clearer picture for the number of this tracks.

3 - A modified algorithm for solving derivative-free optimizations
Yongxia Liu, Lixin Tang

In this paper, we consider an algorithm for solving black-box optimization problems, whose derivatives are unavailable. This kind of problem is known as derivative free optimization (DFO). To solve this kind of problem, interpolation based trust region methods are often used. Namely, in the trust region, the objective function is approximately replaced by interpolation models. In this paper, based on the framework of sparse low degree interpolating polynomials for DFO, a new algorithm for solving DFO problem is proposed. In the proposed algorithm, alternating direction method of multipliers (ADMM) is used. The crucial feature ADMM algorithms is parallel computing which makes ADMM algorithms well suited for large-scale distributed modern problems. Thus, to determine the coefficient of the sparse low degree interpolation model at each iteration, considering the feature of ADMM algorithms, and the characteristic of the model built to obtain the interpolating polynomials coefficients at each iteration, ADMM method is adopted. At last, numerical experiment is carried out to validate the feasibility of the algorithm.

4 - Continuous Energy Values of 3-Amino-4-Nitraminofurazan Molecule by Modern Optimization Techniques
Sumeyya Koman, Fatih Ucun, Ahmet Sahiner

Conformational energy values of 3-amino-4-nitraminofurazan (C2N4O3H2) molecule changing with its two torsion angles were firstly modeled by using density functional theory (DFT) with Lee-Young-Parr correlation functional and 6-31 G(d) basis set on Gaussian Program. And then, these obtained discrete data were made continuous by using Fuzzy Logic Modelling (FLM) and Artificial Neural Network (ANN). This allows us to make predictions about untested data and to obtain optimized energy value of the molecule with reasonable computational cost, great efficiency and high accuracy. In addition, these two modern optimization techniques were compared with the DFT method by using regression analysis. This study offers an idea to the programmers to develop their studies.

■ TA-54

Tuesday, 8:30-10:00 - Building PA, Room B

Large scale structured optimization 2

Stream: Convex Optimization
Chair: *Silvia Villa*
Chair: *Saverio Salzo*

1 - Accelerated and preconditioned Douglas-Rachford algorithms for the solution of variational imaging problems
Kristian Bredies, Hongpeng Sun

We present and discuss accelerated and preconditioned versions of the Douglas-Rachford (DR) splitting method for the solution of convex-concave saddle-point problems which often arise in variational imaging. These algorithms solely depend on implicit steps such as proximal operator evaluation as well as solution of linear equations and do not require step-size constraints. While the basic DR iteration admits weak and ergodic convergence with rate O(1/k) for restricted primal-dual gaps, acceleration enables, under appropriate strong convexity assumptions, to obtain convergence rates of O(1/k2) and O(qk) for 0 < q < 1. Furthermore, all methods allow for the incorporation of preconditioners for the implicit linear step while preserving the convergence properties. Neither the error nor the step-sizes have to be controlled for the inexact linear inversion. The methods are applied to non-smooth and convex variational imaging problems. We discuss in particular variational models with total variation (TV) as well as total generalized variation (TGV) penalty. Preconditioners which are specific to these penalties are presented, the results of numerical experiments are shown and the benefits of the respective accelerated and preconditioned algorithms are discussed.

2 - Asymmetric forward-backward-adjoint splitting for solving monotone inclusions involving three operators
Puya Latafat, Panagiotis Patrinos

In this work we propose a new splitting technique, namely Asymmetric Forward-Backward-Adjoint Splitting (AFBA), for solving monotone inclusions involving three terms, a maximally monotone, a cocoercive and a bounded linear operator. Classical operator splitting methods, like Douglas-Rachford (DRS) and Forward-Backward splitting (FBS) are special cases of our new algorithm. Among other things, AFBA unifies, extends and sheds light on the connections between many seemingly unrelated primal-dual algorithms for solving structured convex optimization problems, proposed in the recent years. More importantly AFBA greatly extends the scope and the applicability of splitting techniques to a wider variety of problems. One important special case leads to a generalization of the classical ADMM for problems with three (instead of two) blocks of variables.

3 - A variable metric stochastic aggregated gradient algorithm for convex optimization
Andreas Themelis, Silvia Villa, Panagiotis Patrinos, Alberto Bemporad

In this talk we propose and study a novel variable metric stochastic gradient algorithm for minimizing the sum of a convex nonsmooth function and a large number of convex smooth functions. For problems of this kind, incremental gradient methods have proven very effective and have recently received much attention as they achieve the same theoretical convergence rates of full gradient methods, yet with computational costs per iteration independent of the number of components. Following this trend, we extend the theory behind SAGA [1], an incremental aggregated gradient method, by integrating the algorithm with a stochastic variable metric scheme. This opens the door to possibly account for the sensitivity to ill conditioning which characterizes first order methods, include curvature information, or exploit specific problem structures such as sparsity. We then propose a stochastic diagonal scaling in the fashion of AdaGrad [2] intended for sparse problems, and show the improvements of the chosen metric with numerical simulations.

■ TA-56

Tuesday, 8:30-10:00 - Building CW, 1st floor, Room 122

Academic-Practitioner Bazaar

Stream: Workshops and roundtable
Chair: *Galina Andreeva*

1 - Academic-Practitioner Bazaar
Galina Andreeva

Practitioners are constantly challenged to demonstrate that their results are based on solid evidence and robust analysis; academics are constantly under pressure to demonstrate results and evidence of impact. This 'bazaar' is a semi-structured session aimed at enabling academics and practitioners to meet and build interactions exploring potential areas of interest to both. The session is part poster-based, part discussion. Poster-presenters (both academic and practitioner) will kick off the session with 60-second presentations of their posters, explaining the key points. Other participants will then be able to give a 90-second presentation of their key areas of interest and what they would like to discuss. Once all presentations are completed, the audience will be free to visit the posters and presenters that most interest them, for further discussions.

Posters currently planned include inventory optimisation algorithms, decision support systems for district heating networks and energy production, improving MCDA methods, Dial-A-Ride network, wind power forecasting for operational dispatch, and a cloud-based platform for prganizing open challenges for solving optimization problems.

Participants without a poster, who wish to present, are advised to contact the session chair beforehand in order to reserve a slot.

All presenters' information will (if they wish) subsequently be made available across the European Practitioner Network and/or relevant EURO working groups, to widen the opportunities for making connections.

Tuesday, 10:30-12:00

■ TB-01

Tuesday, 10:30-12:00 - Building CW, AULA MAGNA

Keynote Gerrit Timmer

Stream: Plenary, Keynote and Tutorial Sessions
Chair: *Ruth Kaufman*

1 - Making an Impact with OR; Lessons Learned from 35 Years of Experience in Applying OR
Gerrit Timmer

Improving business processes using optimization techniques can lead to huge benefits. Yet it is far from trivial how to apply mathematical modelling and optimization to realize those benefits. Moreover, the incredible advances in computer power; the explosion of data being available and the impressive advances in algorithmic ingenuity, make that models that are suitable today will not capture what is possible in the future. In the past 35 years, I have been in the position to observe hundreds of projects in various industries and application areas, where subtle differences in circumstances and approach led to the impact varying from huge to none at all. I will summarize this experience in a number of lessons learned. Moreover, the lessons learned will be translated into directions for further research and may stimulate to see and grasp the endless opportunities for our field to have a huge impact in the future.

■ TB-02

Tuesday, 10:30-12:00 - Building CW, 1st floor, Room 7

Rough Sets in Decision I

Stream: Rough Sets in Decision
Chair: *Jerzy Grzymala-Busse*

1 - Toward interactive feature selection - rough set perspective
Dominik Ślęzak

Data exploration is a general term for a variety of methods aiming at data extraction and processing for the purposes of, e.g. business analytics and decision support. When speaking about data exploration, people often distinguish between the areas of data mining / machine learning and exploratory / investigative data analytics. The first area is perceived as the realm of "automatized" algorithms. The second area is devoted to more "manual" interactions between the users and the data processing / business intelligence systems. In the latter case, the users formulate queries and make decisions subject to their outcomes. In the former case, the situation is analogous - the only difference is that the humans are replaced by the data mining algorithms. In this paper, we discuss how to make those algorithms interactive, so the users can influence them and learn from them. We investigate the stage of feature selection, i.e. identification of attributes that are sufficient to build prediction and classification models. We focus on methods inspired by the theory of rough sets, which lead toward intuitive framework for interpreting feature selection results. We also study how to achieve interaction by letting the users compare the accuracy of various methods applied against various data sets, as well as accelerating the feature selection algorithms by utilizing some approximate computing techniques.

2 - Applying the principle of dominance to the multi-criteria search for a relevant web content
Ayrton Benedito Gaia do Couto, Luiz F. Autran M. Gomes

This study shows the use of the principle of Dominance to a particular case of web content search under multi-criteria approach: searching for "Rio de Janeiro" (City and/or State) followed by other attributes or criteria. It is known that depending on the content of research that is carried out through a search engine on the Internet, the result may fall short of the desirable, in terms of quantity and quality of the links returned. The principle of Dominance, post-treatment of collected information (unstructured data) on the Internet, aimed at revealing patterns (logical rules) on a set of information and showed how a web content search can become more effective. This effectiveness was achieved by the construction of a decision table from the data obtained in the search result on the Web, considering a "core" (when possible) of condition criteria and a decision criterion (ranking bands) under the principle of Dominance. The choice of the principle of Dominance is due to the possibility of inaccurate data (inconsistent) and the need for treatment of these inaccuracies when processing an information system (data table) under a mathematical perspective, and do not need a history of these data. Other techniques and tools have been applied to the mining web content, and exemplified in this study.

3 - Rough sets in social indicators research
Francisco Gutierrez Sanin

Social indicators are increasingly used for big scale decision making. They are, however, hounded by vagueness and definitional issues. The discussion of how to rehash social indicators has become a significant intellectual endeavor, involving Nobel Prize winners Stiglitz and Sen. Clear cut improvements, however, have not appeared. And standard solutions are riddled by difficulties. Social researchers, for example, lack clear-cut ways of tuning their parameters so as to apply reasonably fuzzification techniques. This is the type of problem that seems tailored for the use of rough sets (RS). I discuss some fundamental uses of rough sets in social indicator research, including the identification of concepts, the definition of concepts without clear cut-offs, and indicators-bases classification, both with classical RS and tolerance spaces. My basic claim is that the use of RS can lead to the building of indicators that are conceptually clearer, more believable, and actually easier to interpret. All the discussion is accompanied by examples of applications of RST to indicator building (programmed in Haskell and Mathematica).

■ TB-03

Tuesday, 10:30-12:00 - Building CW, 1st floor, Room 13

Preference Learning 2

Stream: Preference Learning
Chair: *Willem Waegeman*

1 - Paired comparisons and least squares on graphs: a statistical perspective
Ori Davidov

This talk will discuss some statistical aspects of ranking by paired comparisons with cardinal scores within the framework of combinatorial Hodge theory. In particular statistical aspects of least square estimators will be discussed when the number of items to rank is either fixed and finite or growing to infinity. Unbiasdness, consistency and asymptotic normality of the merits are discussed for linear rankings. A goodness of fit test is proposed. Exponential convergence for the ranking vector is demonstrated. Relations with the topology of the comparison graph are emphasized. The methodology is extended to rankings with cyclicality. Methods for improved rankings using order restrictions are developed. Consistency and improved efficiency will be demonstrated. Simulations and real data analysis will be presented.

2 - **Online learning of isotonic functions**
Wojciech Kotlowski

We consider the online version of the isotonic regression problem. At the start, the algorithm is given a set of T linearly ordered points (e.g., on the real line). Then, over the course of T trials, the nature picks a new (as of yet unlabeled) point and the algorithm predicts a label from [0,1] for that point. Then, the true label (also from [0,1]) is revealed, and the algorithm suffers the squared error loss. After T rounds, the algorithm is evaluated by the regret, which is its total squared loss compared against the best isotonic (non-decreasing) function in hindsight. We survey several standard online learning algorithms and show that none of them achieve the optimal regret exponent; in fact, most of them (including Online Gradient Descent, Follow the Leader and Exponential Weights) incur linear regret. We then prove that the Exponential Weights algorithm played over a covering net of isotonic functions has regret is bounded by O(T1/3) log2/3(T)) and present a matching Omega(T1/3) lower bound on regret. We also provide a computationally efficient version of this algorithm. We also analyze the noise-free case, in which the revealed labels are isotonic, and show that the bound can be improved to O(log T) or even to O(1) (when the labels are revealed in the isotonic order). Finally, we extend the analysis beyond squared loss and give bounds for log-loss and absolute loss.

3 - **Recipe construction with preference learning methods**
Willem Waegeman

Preference learning techniques have a lot of potential for constructive machine learning purposes. In this talk I will elaborate on this idea, with a particular focus on the construction of recipes. Completing recipes is a non-trivial task, as the success of ingredient combinations depends on a multitude of factors such as taste, smell and texture. We illustrate that preference learning methods can be applied for this purpose. Non-negative matrix factorization and two-step regularized least squares are presented as two alternative methods and their ability to build models to complete recipes is evaluated.

■ TB-04

Tuesday, 10:30-12:00 - Building CW, ground floor, Room 6

Some results on optimization, simulation and multicriteria decision making

Stream: Recent Developments on Optimization and Some Results on Game Theory
Chair: *Gülser Köksal*

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

Firm performance in the context of new product development(NPD)depends on the continuous creation of new products and processes and the implementation of new organizational forms and business models which both require dynamic capabilities supported by senior management involvement(Pavlou and EI Sawy,2011).In this context, senior management can sense the market using research,analysis and scanning to detect relevant information and opportunities.This helps them shape the future by unshackling the firm from its past practices and stay ahead by augmenting knowledge assets, protecting them with intellectual property rights, establishing new value-enhancing asset combinations, and transforming organizational and, if necessary, regulatory and institutional structures(Teece,2007).Our study aims to operationalize and develop the three main interrelated capacities of the dynamic capabilities model(Teece,2007),namely:sensing capacity, seizing capacity and reconfiguration capacity, with respect to the micro-foundations which include organizational and managerial process for the NPD process.Our framework can be used to help managers to make robust decisions in both volatile and stable business environments where market demand and technology are ever changing. Multiple criteria decision analysis(MCDA) was applied to develop the DC hierarchical decision framework to assess the dynamic capabilities (DC) of a firm in order to assess, predict and improve its performance in NPD context.

2 - **Multi-winner scoring election methods: Condorcet consistency and paradoxes**
Mostapha Diss

The goal of this paper is to propose a comparison of four multi-winner voting rules, k-Plurality, k-Negative Plurality, k-Borda, and Bloc, which can be considered as generalisations of well-known single-winner scoring rules. The first comparison is based on the Condorcet committee efficiency which is defined as the conditional probability that a given voting rule picks out the Condorcet committee, given that such a committee exists. The second comparison is based on the likelihood of two paradoxes of committee elections: The Prior Successor Paradox and the Leaving Member Paradox which occur when a member of an elected committee leaves. In doing so, using the well-known Impartial Anonymous Culture condition, we extend the paper of Kamwa and Merlin (2015, Journal of Mathematical Economics) in two directions. First, our paper is concerned with the probability of the paradoxes no matter the ranking of the leaving candidate. Second, we do not only focus on the paradoxes that can occur when one wishes to select a committee of size k=2 out of m=4 candidates since the technique that is considered in our paper allows us to consider more values of k and m.

3 - **Confidence interval estimation of Weibull parameters and percentiles in small samples via Bayesian inference**
Burak Birgoren, Meryem YalÇinkaya

Weibull distribution has been vastly used in component reliability modelling, and confidence interval estimation of Weibull parameters and percentiles in small samples has been a recent concern. Weibull modelling of advanced materials, namely ceramics and composites, can be given as a major application area. There has been an extensive literature on this topic in classical estimation theory, and there is some in Bayesian estimation theory. However, no study has been found on Bayesian confidence interval estimation of Weibull percentiles. In this study, confidence interval estimation algorithms have been developed for the Maximum Likelihood Method, which was shown to give the best confidence intervals for the Weibull percentiles in the classical estimation theory, and the Bayesian Weibull Method for which a non-informative prior distribution was used for the scale parameter and uniform and normal priors were used for the shape parameter. Monte Carlo simulations have been designed and run for the comparison of the two method. The results showed the Bayesian Weibull Method was better for the percentiles and scale parameters, that is, it provided narrower confidence intervals. However the results were inconclusive for the shape parameter.

4 - **A guideline for choosing parameters of multivariate loss functions**
Gülser Köksal, Gökçe Özkan

In this study, we consider the multivariate loss functions and suggest a method for the selection of the parameters. Although there are several studies on multivariate loss functions, only a few of them suggests a method for the parameter selection. For the determination of the cost matrix components we propose a method based on multi-objective decision making tools.

■ TB-05

Tuesday, 10:30-12:00 - Building CW, 1st floor, Room 8

Practical Applications of Multiobjective Optimization

Stream: Multiobjective Optimization
Chair: *Karthik Sindhya*
Chair: *Ana Belen Ruiz*

1 - High Performance Multi-objective Voyage Planning
Kateryna Mishchenko, Mats Molander

This work presents a new high performance multi-objective grid search method based on modification of Dijkstra's Dynamic Programming algorithm designed for optimal voyage planning of sea going vessels. The problem includes three conflicting objectives as total travel time, total fuel consumed and comfort factor and solved subject to constraints on speed, power and passing over land. For efficient Pareto front computations the direction method was used to limit the number of Pareto optimal solutions in a controlled way. Numerical results from the voyage planning using real weather data (waves and currents) of the route between Gothenburg, Sweden and New York, USA are presented. The 3-D search grid consists of 90 stages with 17 position nodes and around 800 time nodes on each stage. The total number of all tested node transitions are 1.8491e+09 .The results show that it is possible to solve the problem in less than 8 minutes on 10 cores using the efficient high performance techniques. The novelty of this approach is the combination of high performance computing, multiobjective optimization for solving voyage planning problems using grid search methods tested on real routes. Implementation of such powerful methods gives a significant benefit for ship yard owners allowing to simultaneously minimizing the trip time, discomfort, hazard, amount of fuel consumed and wear on the equipment on vessels.

2 - Multiobjective Optimization in Assessment of Transmission Network Compensation Strategy
Karthik Sindhya, Tuomas Rauhala, Tinkle Chugh, Yaochu Jin, Kaisa Miettinen, Jussi Hakanen

Real life optimization problems often involve multiple conflicting objectives and there usually exist several so-called Pareto optimal solutions for such problems. In this study, we assess an efficient electricity transmission network compensation strategy involving several objective functions pertaining to system performance, investment and robustness. For this study, we utilize a reduced equivalent network model provided by FINGRID Oyj, Finnish electricity transmission system operator as a simulator to evaluate the objective and constraint functions and use a recently proposed surrogate assisted reference vector based evolutionary multiobjective optimization algorithm capable of handling a large number of computationally expensive objectives to find a set of Pareto optimal solutions. We also discuss how a decision maker is supported finding his preferred Pareto optimal solution as well as advantages of the multiobjective optimization approach.

3 - Selection Beyond Fitness: Accounting for Differential Costs of Estimating Fitness
Richard Allmendinger, Julia Handl, Joshua Knowles

Motivated by a practical application of multiobjective optimization in the design of combinatory drug therapies, we consider how selection can be made sensitive to differential financial costs incurred during optimization. We formulate this problem as an "outer" multiobjective problem such that each point on the outer-Pareto front represents a whole Pareto front approximation on the original MO problem. We compare this formulation to simpler approaches where financial cost is just an added objective, where the cost is ignored, or where the cost is the primary consideration.

4 - A Multi-Objective Simulation-Based Optimization Algorithm to Determine Ordering Parameters in Divergent Supply Chains
Mualla Gonca Avci, Hasan Selim

In this study, a divergent supply chain consisting of a supplier and a number of manufacturers is dealt with. The manufacturers have separate inventory systems, and use periodic order-up-to policy to maintain their material inventory. As the supply chain is a just-in-time system, stock-out is not allowed. In case of a stock-out risk, a manufacturer has to request a premium freight from its supplier. However, premium freights incur very high cost to manufacturers in a short time-frame. Therefore, minimization of premium freights should be considered as an objective in addition to minimization of holding cost. Thus, a multi-objective simulation-based optimization algorithm is developed to determine supplier flexibility and safety stock levels yielding best premium freight and holding cost performance. The simulation phase of the algorithm consists of a simulation model of the divergent supply chain. For the optimization phase of the algorithm, non-dominated sorting genetic algorithm II (NSGA-II) is employed. The performance of the algorithm is evaluated on a real-world supply chain. The results reveal that the proposed algorithm yields favorable solutions for the supply chain.

■ TB-06

Tuesday, 10:30-12:00 - Building CW, ground floor, Room 2

Complex preference learning in MCDA 1

Stream: Multiple Criteria Decision Aiding
Chair: *José Rui Figueira*

1 - ELECTRE TRI-nB: A new multiple criteria ordinal classification method
José Rui Figueira, Eduardo Fernandez, Jorge Navarro, Bernard Roy

This paper presents a new method for multi-criteria ordinal classification problems. This type of problems requires that the different classes be pre-defined and ordered, from the best to the worst or from the worst to the best. A set of objects (not necessarily known a priori) is assigned to the different and ordered classes. Several ELECTRE type methods were designed to deal with such a kind of problems. However, no one proposes to characterize the classes through a set of limiting profiles. This is the novelty of the current method, which may be considered as a generalization of ELECTRE TRI-B. It fulfills a set of structural requirements: uniqueness of assignments, independence, monotonicity, homogeneity, conformity, and stability with respect to merging and splitting operations. All these features will be presented in the current paper.

2 - Multicriteria selection based on lexicographical filter
Yves De Smet, Jean-Philippe Hubinont, José Rui Figueira

We propose a new ordinal multicriteria method for the choice problematic. As input, the Decision Maker is assumed to provide a complete ranking of the criteria. Then a procedure based on a lexicographical filter is applied; at each step, a subset of the best alternatives is kept. First, mathematical properties such as monotonicity, solution existence, deletion of a non-discriminating criterion are investigated. Then a data-driven preference elicitation procedure is analyzed. This is formalized as a combinatorial optimization model and solved by means of a dedicated algorithm.

3 - Interactive Multiobjective Optimization guided by Dominance-based Rough Set Approach for portfolio facility location problems
Maria Barbati, Salvatore Greco

We consider the Multi-Objective Portfolio Facility Location (MOPFL) problem in which a set of facilities has to be located attaining acceptable levels for a set of criteria like travel distance, cost, equity, profit and coverage; several constraints can be added for modelling different applications. Many approaches can be used for handling MOPFL problems. The majority of the methodologies converts the multi-objective problem in a single objective problem; alternatively a set of the Pareto optimal solutions are proposed as solutions for the problem; moreover, when the problems are very complex, multiobjective evolutionary algorithms are implemented. We propose a new approach based on the interaction with the decision maker. We propose a non-dominated set of portfolio facilities to the decision maker and she is expected to indicate indirect preferences expressed in the form of 'if ..., then...'. We use these preferences in a Dominance-based Rough Set Approach in order to guide the search of the "best compromise" non-dominated set of facilities thanks to the definition of decision rules. This way we can focus on the part of the non-dominated set most preferred by the DM. The iteration terminates when the decision maker is completely satisfied with one portfolio of facilities.

■ TB-07

Tuesday, 10:30-12:00 - Building CW, 1st floor, Room 123

EURO Doctoral Dissertation Award

Stream: EURO Awards and Journals
Chair: *Ahti Salo*

1 - Planning and Operations in Fully Renewable Electric Energy Systems
Ruth Dominguez, Antonio Conejo

The integration of renewable energies in power systems represents a key point to achieve a sustainable development, since more than 30% of the total GHG emissions are due to electricity generation. However, the electricity production from wind and solar technologies depends on resources which are variable and, in general, difficult to predict. Hence, high penetration of stochastic resources in power systems introduces high levels of uncertainty in planning and operations. On the other hand, renewable technologies are still under maturing stage and their investment costs are subject to high uncertainty. Therefore, in this dissertation we focus on the operation and planning of renewable-dominated power systems. A scheduling model for energy and reserves in the day-ahead market considering a fully renewable electric energy system where most of the electricity is supplied by non-dispatchable technologies is proposed. Additionally, static and multi-stage investment models are proposed to efficiently integrate renewable energies in power systems. We use stochastic programming to model the uncertainty involved in such models. A linear-decision-rule approach is also applied to efficiently solve multi-stage investment models. Finally, numerous realistic case studies are analyzed.

2 - Theoretical and Practical Contributions on Scatter Search, Variable Neighbourhood Search and Matheuristics for 0-1 Mixed Integer Programs
Raca Todosijevic

This work consists in results obtained studying Scatter Search (SS), Variable Neighbourhood Search (VNS), and Matheuristics in both theoretical and practical contexts. The main theoretical contribution of this work is a convergent SS algorithm for 0-1 Mixed Integer Programs (MIP) along with the proof of its finite convergence. Additionally, we identify two variants of the implementation of a convergent SS algorithm. Stemming from this convergent SS algorithm several SS heuristics have been proposed and tested on some instances of 0-1 MIP. Our findings demonstrate the efficacy of these first stage methods, which makes them attractive for use in situations where very high quality solutions are sought with an efficient investment of computational effort. This work also includes new variants of VNS metaheuristic that have been successfully applied for solving NP-Hard problems arising in transportation, logistics, power generation, scheduling and clustering. On all tested problems, the proposed VNS heuristics turn out to be new state-of-the art heuristics. The last contribution of this work consists in proposing several matheuristics for solving the Fixed-Charge Multicommodity Network Design problem and finding a first feasible 0-1 MIP solution. The performances of these methods have been disclosed on the benchmark instances and the obtained results demonstrate the competitiveness of the proposed methods with other approaches in the literature.

3 - Reactive Robustness and Integrated Approaches for Railway Optimization Problems
Joergen Haahr

Planning railway operations is not a simple task as it entails solving multiple interdependent optimization problems. My thesis focuses on recovery methods and the integration of interdependent planning problem. During recovery fast solution methods are essential, and solving problems in isolation can be problematic as it can lead to an overall infeasibility. Several railway problems are studied in this thesis, and both theoretical and practical contributions have been made. The problems have been formulated as optimization problems and solution methods have been proposed to solve them using optimization theory and techniques. Real-life and realistic data has been used to benchmark and test the solution methods. The central actor of the thesis is the rolling stock running on the railway infrastructure. With a given public timetable a rolling stock schedule is sought that provides the best compromise between operational cost, robustness, contract requirements and passenger satisfaction. In between train services the rolling stock units must be parked in the available depots avoiding conflicting movements. Furthermore, rolling stock units are heavy and consume a considerable amount of energy in operation; with proper optimization tools a significant amount of the energy can be saved. A prompt optimization of individual train journeys helps the driver to drive efficiently and enhances robustness in a realistic (dynamic) environment.

■ TB-08

Tuesday, 10:30-12:00 - Building CW, 1st floor, Room 9

IBM Research Applications 1

Stream: IBM Research Applications
Chair: *Marco Laumanns*
Chair: *Susara van den Heever*
Chair: *Martin Mevissen*
Chair: *Xavier Nodet*

1 - IBM Optimization Mine to Ship
Fabio Tiozzo, Kameshwaran Sampath

Iron ore trading is the second-largest commodity market by value after crude oil. Unlike oil, iron is abundant and makes up 5% of the earth's crust. The difficulty is finding it in sufficient concentrations and then shifting millions of tons of materials to where it is needed. The iron ore supply chain starts from the mine where the ore is extracted and extends till delivery at the steel plants. The supply chain is generally global in nature, with most of the deliveries via sea. In this work, we are concerned with the logistics of moving materials from the mines to ships, which is usually controlled by the mining company. The mines to ship logistics is composed of series of optimization problems like berth allocation, ship scheduling, stockyard scheduling, and rail scheduling, which are individually NP-hard. In this work, we present a scheduling application, called as IBM Optimization Mine to Ship (MSS), for end-to-end integrated operations scheduling. The application is built on IBM Decision Optimization Center with advanced features like rescheduling under deviations and disturbances, and maintenance scheduling. The modeling and computational complexity of integrated scheduling optimization is tamed using hybrid optimization technique that leverages mathematical programming and constraint programming.

2 - Demand and Supply Analytics in a Crowdsourcing Platform of Software Development
Ta-Hsin Li

An emerging business model in application software development in large enterprises is to employ a flexible workforce, or a resource pool, which consists of vetted freelancers, to support the application development process, including software design, coding, and application testing. The success of this model depends crucially on having the right participants at the right time when their skills are needed. However, the need for each set of skills fluctuates over time, depending on the software development activities of the business; the number of participants also fluctuates because participation is entirely voluntary and performed via self-selection of work. Therefore, maintaining the appropriate capacity, or supply, of the resource pool is an important and challenging problem for the service provider who utilizes this type of delivery platform. Undersupply of talent can impact project deliveries and cause work to go unstaffed, and oversupply reduces the effectiveness and commitment of the participants, causing them to lose interest when the work is not plentiful enough. In this paper, we present some results of predictive analytics for the demand and supply in a real resource pool operation. The analysis enables a data-driven strategy for capacity planning and management.

3 - Mixed Integer Polynomial Optimisation in Power Systems
Martin Mevissen, Bissan Ghaddar, Jakub Marecek, Jonas Christoffer Villumsen

A number of challenging optimisation problems in power systems involve both, binary planning or operational decisions and accurate models of the underlying physics described by alternate current power flows. We propose approaches, that combines recent advances in hierarchies of semidefinite programming relaxations of polynomial optimisation problems for the optimal power flow problem with techniques for mixed integer nonlinear optimisation with binary variables. These approaches are demonstrated on examples arising from transmission network expansion planning.

4 - Integrating Passenger Assigment and Timetabling for Capacitated Public Transit Networks
Marco Laumanns, Jacint Szabo, Maya Voegeli

In this talk we present a bilevel optimization model for the integration of passenger assignment into the (periodic) timetabling problem for capacitated public transportation networks. For the lower level problem we present a mixed-integer problem formulation which is based on the assumption that passengers are daily commuters with perfect information and which takes into account selfish routing and prioritization of already on-board passengers over boarding passengers. The integration of this problem formulation into the timetabling problem results in a mixed-integer bilinear programming problem. In order to solve this problem we propose a heuristic solution approach for general instances. Additionally, we present a direct approach which is obtained by a mixed-integer linear program reformulation using unary or binary expansion and McCormick relaxation. To improve the performance of the direct approach we provide problem-specific cutting planes as well as a reduction of the number of binary variables motivated by analysis of the problem structure.

■ TB-09

Tuesday, 10:30-12:00 - Building CW, 1st floor, Room 12

MINLP Software

Stream: Mathematical Programming Software
Chair: *Timo Berthold*

1 - Advances in the Xpress MINLP solver
Zsolt Csizmadia

We will present the advances in the mixed integer nonlinear program (MINLP) solver in Xpress 8. The MINLP solver in Xpress is based on the sequential linear programming technique. The new version features a parallel branch and bound built on top of the new parallel scheduler framework in Xpress 8. Improved root and new in-tree heuristics have been added. The convergence control for the solved SLP problems has been simplified and made easier to tune. Following an overview of the parallel framework, the talk will discuss the computational effort balancing necessary to efficiently flip between working on the linearization versus fully solving nonlinear nodes. Furthermore, we will discuss synchronization challenges in the parallel code.

2 - Using Functional Programming to recognize Named Structure in an Optimization Problem: Application to Pooling
Ruth Misener, Francesco Ceccon

Branch-and-cut optimization solvers typically apply generic algorithms, e.g., cutting planes or primal heuristics, to expedite performance for many mathematical optimization problems. But solver software cannot use the specialized algorithms developed for named structures such as the Traveling Salesman Problem or Max-Cut; solver software receives an input optimization problem as vectors of equations and constraints containing no structural information. This presentation proposes automatically detecting named special structure using the pattern matching features of functional programming. Specifically, we deduce the industrially-relevant nonconvex nonlinear Pooling Problem within a mixed-integer nonlinear optimization problem and show that we can uncover pooling structure in optimization problems which are not pooling problems. The pooling structure inside of a generic process optimization problem is a subset of the entire problem, so specialized, pooling-specific, cutting planes will also be valid bounds for the entire process networks problem. Primal heuristic solutions to the standard pooling problem would are a good starting point for primal heuristics for the entire optimization problem.

3 - A Branch-and-Price Algorithm for the Recursive Circle Packing Problem
Benjamin Müller, Ambros Gleixner, Stephen Maher, Joao Pedro Pedroso

A large fraction of the total costs in tube industry arise from the delivery of tubes inside rectangular-shaped containers. The problem of minimizing the number of containers to transport a set of different tubes can be modeled as the recursive circle packing problem (RCPP), which is a non-convex MINLP. This class of packing problems is practically unsolvable for any state-of-the-art MINLP solver.

We present a reformulation of the RCPP based on an enumeration scheme for all possible packings of tubes inside other tubes on a 1-level recursion. The reformulation is solved by a branch-and-price algorithm implemented inside the MINLP-solver SCIP. Our computational results show that this approach solves small-sized instances to optimality and produces better solutions than the best known heuristic for RCPP.

■ TB-10

Tuesday, 10:30-12:00 - Building CW, ground floor, Room 1

AHP Applications 2

Stream: Analytic Hierarchy Process / Analytic Network Process
Chair: *Alessio Ishizaka*

1 - Evaluation of ecodestinations using Analytic Hierarchy Process
Erdem Aksakal

Due to the changes in tourism trends, there is a rising attention to ecotourism. According to The International Ecotourism Society (TIES), ecotourism defined as "responsible travel to natural areas that conserves the environment, sustains the well-being of the local people, and involves interpretation and education". On the other hand as being a form of nature-based tourism, ecotourism provides conservation of ecological, cultural and natural resources. In recent years, as considering the dimensions of the ecotourism, multi criteria decision making methods have been applied in ecological evaluation studies. The purpose of this study is to propose an approach for the selection of an ecodestination with using Analytic Hierarchy Process. Criteria were taken as "needs of the tourist" which is specified on the Ecotourism Handbook (A Simple User's Guide to Certification for Sustainable Tourism and Ecotour) of TIES. The weights of the evaluation criteria were determined by pair-wise comparison and Analytic Hierarchy Process is used to make a prioritization among seven different destinations all over the world.

2 - AHP analysis of the repurchase influence priority on six motive factors in seven steps of an e-customer behavior process
Xiangping Ji, Si Yuan Mao, Yuxin Xie, Hong Seung Ko

In the online business environment , a company must retain the customer who frequently and continuously repurchase for increasing the profitable sales. We can judge that a customer repurchase by the repurchase process which involves four key factors such as satisfaction, reliability, brand relationship, and repurchase intention after first buy. Therefore, we think that these four key factors must be involved in the suitable repurchase process. However, we cannot find out the suitable repurchase process which involved four key factors in existing repurchase process models reviewed. That is why we focus on e-customer 7 steps behavior process proposed by Ko et al in 2010, and we can judge that this process model clearly involves four key factors by the result of analysis. That is, we can judge that four key repurchase factors are existed with being influenced by six motive factors in this process model. Simply we can say, it is clear that repurchase process which involves four key factors is built on influences of six motive factors in this model. Finally, we consider the seven steps of an e-customer behavior process as a proper repurchase model for retaining a customer in online business environment. Consequently ,we analyze the influence priority affecting repurchase behavior on six motive factors by AHP technique.

3 - Sorting municipalities in Umbria according to the risk of wolf attacks with AHPSort II
Alessio Ishizaka, Francesco Miccoli

In Italy, the recent wolf expansion process is the result of a series of historical, natural, ecological and conservation factors that have characterized the Italian environmental context in the last few decades. The difficulties in broaching the environmental management of wolf species have increased economic conflicts mainly with livestock farmers. To facilitate and pacify the debate, we carried out an assessment of the risk of wolf attacks on livestock farms in Umbria's municipalities. To address this problem, which has a large number of alternatives, we developed a new multi-criteria sorting method: AHPSort II. This is used for sorting the alternatives into predefined, ordered risk categories. It requires far fewer comparisons than its predecessor, AHPSort. This sorting method can be applied to different environmental problems which have a large number of alternatives. In our case study, AHPSort II requires only 1.4% of the comparisons that would have been required by AHPSort. Combined with clustering, only 0.54% of the comparisons are required. The resulting map shows a high number of municipalities at risk, especially those near protected areas.

■ TB-11

Tuesday, 10:30-12:00 - Building CW, 1st floor, Room 127

Discrete and Global Optimization 4

Stream: Discrete and Global Optimization
Chair: *Meral Azizoglu*
Chair: *Derya Dinler*

1 - An Integer L-shaped Benders decomposition for a two-stage Stochastic Facility Location Problem
Emine Gundogdu

In this study, a humanitarian facility location problem is considered with uncertain demand, transportation time and the capacity of the facilities. In the literature, the problem was formulated by using two-stage stochastic program. Since the model size will increase with the number of scenarios from which random parameters are generated, it was solved by a Lagrange based heuristic. However, in this talk, I will propose an Integer L-shaped algorithm for the problem with complete recourse. Therefore, there is no feasibility cuts that must be generated from the sub problem. The performance of the decomposition algorithm will be discussed.

2 - A Blood Distribution System: An Application to Turkish Red Crescent
Atil Kurt, Meral Azizoglu, Ferda Can Cetinkaya

Blood supply chain is very considerable due to the vital importance of blood for human beings. It is also more difficult and interesting problem than the supply chain problem of ordinary goods. Recognizing these facts, we have considered blood distribution system in the blood supply chain. We have focused on Orta Anadolu regional blood center (RBC) for thorough understanding of the problem. The problem consists different characteristics than ordinary distribution problems such as irradiation centers, urgent demands, vehicle availability and traveling time restrictions. We have developed a multi objective mathematical model that has two objectives: maximizing weighted amount of satisfied demand, and minimizing total traveled distance. We have developed a mathematical model and created some valid inequalities to improve the performance of mathematical model. We also developed two decomposition based heuristic algorithms and a heuristic algorithm based on mathematical model to solve this problem. We solved some problem instances to discuss the performance of solution methodologies. Finally, we have validated our solution methodologies by solving a real life problem.

3 - Robust Semi-supervised Clustering with Polyhedral and Circular Uncertainty
Derya Dinler, Mustafa Kemal Tural

We consider a semi-supervised clustering problem where the locations of the data objects are subject to uncertainty. Each uncertainty set is assumed to be either a closed convex bounded polygon or a closed disk. The final clustering is expected to be in accordance with a given number of instance level constraints. The objective function considered minimizes the total of the sum of the violation costs of the unsatisfied instance level constraints and a weighted sum of squared maximum Euclidean distances between the locations of the data objects and the centroids of the clusters they are assigned to. We propose a mixed-integer second order cone programming formulation for the considered clustering problem which is only able to solve small-size instances to optimality. For larger instances, approaches from the semi-supervised clustering literature are modified and compared in terms of computational time and quality.

4 - A New Scheduling Problem for Hybrid Cellular Manufacturing Systems in Dual Resource Constrained Environments
Omer Faruk Yilmaz, M. Bülent Durmusoglu

The aim of this study is to solve hybrid manufacturing system (HMS) scheduling problem by using meta-heuristic approaches. HMSs are known to be highly similar to real manufacturing environments. Since the problem evaluated within the scope of this study reflected real manufacturing environments, it also reflects an expensive structure. In order to clearly express this problem, we developed a mathematical model based on the job-shop scheduling (JSP) model. Since this model evaluates HMSs and is based on the JSP model, it also has a strong NP-Hard structure. Two different meta-heuristic algorithms are used to solve the model, and comparisons are made between these algorithms. Computational results showed that Particle Swarm Algorithm (PSA) outperforms and provides better results than Genetic Algorithm (GA).

■ TB-12

Tuesday, 10:30-12:00 - Building CW, ground floor, Room 029

VeRoLog: Routing In Practice 2

Stream: Vehicle Routing and Logistics Optimization
Chair: *Philip Kilby*

1 - Linear Complexity Algorithms for Compact Routes in the VRP
Philip Kilby, Dan Popescu

In the Vehicle Routing Problem (VRP) we develop efficient routes to serve customers using a fleet of trucks. “Visually appealing” routes are often preferred as they allow more flexibility for reordering visits in reaction to unexpected events. Compact routes can be achieved using a penalty on the area of the convex hulls enclosing the customers on each route.

We present two efficient, alternative methods to directly penalising the convex hull. Our methods are based on the computation of features similar to the convex hull area, but have low computational complexity, O(n) instead of O(n log n). Experiments conducted on both randomly generated Euclidean problems, and problems derived from real-world road network data, show that our proposed features are strongly correlated with the convex hull area; in particular, for realistic networks the Pearson correlation coefficient is typically greater than 0.98.

We also show that these penalties achieve good guidance: insertion-based route construction methods can be guided towards compact route shapes. Embedded in an Adaptive Large Neighbourhood Search procedure, the penalties were able to achieve similar performance in terms of route compactness to a full convex hull calculation, but had significantly reduced computation time.

2 - Crowdshipping in PDPTW - Effects of Different Compensation Schemes

Lars Dahle, Marielle Christiansen, Henrik Andersson

The concept of crowdshipping, where ordinary people handle some transportation requests for a company, is at its early stages. This gives rise to an interesting new variant of the Pickup and Delivery Problem with Time Windows (PDPTW), where companies not only use their own vehicles to service transportation requests, but also take advantage of ordinary people already on the road to handle some of their requests. As transportation can be a significant cost for last-mile and same-day pickup and delivery, studying the potential savings of using crowdshipping is an important task.

The literature is scarce regarding crowdshipping in routing problems. In this article, we introduce the PDPTW with Occasional Drivers, and study the effect of different compensation schemes for how to compensate occasional drivers. We allow an occasional vehicle to handle multiple requests and model the preferences of a driver using threshold values.

3 - Is Electric Commercial Vehicle a Cost-effective Alternative to Diesel Truck in Urban Delivery?

Jane Lin, Wei Zhou

This study investigates the cost-effectiveness of electric vehicle (EV) as a green alternative to diesel truck (DT) in vehicle routing operations through a series of comparisons among an all-DT fleet, an all-EV fleet, and mixed EV-DT fleets with various EV penetration ratios. At the core of the cost estimation is a green EVRP (G-EVRP) model. G-EVRP minimizes the total daily operating cost of EV that consists of travel time cost, energy cost and en-route battery recharging time cost. The energy cost is a nonlinear function of travel speed and vehicle load. The mathematical formulation of G-EVRP with flexible (full or partial) recharging is detailed in the paper. A construction-reinsertion heuristic algorithm is designed for solving large scale G-EVRP. Demonstrated with both a small and a big numerical example it is found that while EV is a greener alternative to DT, it incurs much greater total cost due to the long en-route recharging time, which could make up as much as 30% of the total daily operating cost. Furthermore, the EV fleet size and the network size have a nonlinearly increasing impact on the en-route recharging time and cost. More innovative solutions to reducing en-route recharging time are needed to make EVs a competitive alternative to DTs in reality.

4 - The Vehicle Routing Problem with inconsistency constraints

Maaike Hoogeboom, Wout Dullaert, David Lai

Cash in Transit (CIT) companies transfer valuable goods to banks, ATMs and stores. Legal regulations and security considerations force these companies to take various measures to protect their transported goods against attacks. Driving varying routes to serve their customers is one key strategy to lower the risk of an attack. In this research we want to generate sufficiently unpredictable routes while minimizing the transportation cost. We will discuss existing and new developed methods to achieve inconsistent routes in which we will focus on two characteristics of routes: customer arrival times and the order in which customers are served. Furthermore, waiting at a customer location is not allowed, since the CIT companies indicate that the armored truck is most vulnerable when standing still. The inconsistent VRP is a relatively new topic, only recently a couple of papers are published about this problem. We present a variable neighborhood tabu search to solve the inconsistent VRPTW and we will show the impact of the different inconsistency constraints on the transportation cost and unpredictability level of the routes.

■ TB-13

Tuesday, 10:30-12:00 - Building CW, ground floor, Room 3

VeRoLog: Exact methods for VRP variants

Stream: Vehicle Routing and Logistics Optimization
Chair: *Paolo Gianessi*

1 - Column Generation Based Algorithms for a VRP with Time Windows and Variable Departure Times

Stefano Michelini, Yasemin Arda, Hande Kucukaydin

We investigate a solution methodology for a variant of the VRP with time windows. In the examined variant, the departure time of each vehicle from the depot can be determined by the decision-maker, who aims at minimizing the overall duration of the routes, including waiting times, while respecting the maximum allowed working duration of each vehicle. In order to solve this problem with a branch-and-price methodology, we address the associated pricing problem as an elementary shortest path problem with resource constraints (ESPPRC). We propose an adapted bidirectional dynamic programming algorithm for the studied ESPPRC. The decremental state space relaxation (DSSR) technique is also implemented as an acceleration technique both to obtain ng-routes and elementary routes. Several implementation and integration strategies are considered for the DSSR and ng-route relaxation techniques. The ng-route pricing and the elementary route pricing algorithms are compared inside a column generation procedure. For both column generation procedures, the algorithmic choices are made and the values of the numerical parameters are determined using an automatic algorithm configuration tool, the irace package. Finally, we discuss how these column generation procedures can be included as a component in the development of a matheuristic.

2 - An Exact Solution Approach for the Multi-Commodity Two-Echelon Vehicle Routing Problem with Time Windows

Fardin Dashty Saridarq, Nico Dellaert, Tom Van Woensel, Teodor Gabriel Crainic

This paper studies the multi-commodity two-echelon capacitated vehicle routing problem with time windows. This problem is an extension of the two-echelon capacitated vehicle routing problem in which each commodity is delivered from its origin (depot) to its destination (customer) within the time window of the customer. Urban vehicles and city freighters are used in the first and the second echelon, respectively. We propose mathematical formulations and a branch- and-price based exact solution approach. A feasible solution for the problem consists of urban vehicle tours and city freighter tours such that each commodity is handled using an urban vehicle and a city freighter tour. The problem is modeled as a set partitioning problem in which variables are defined on the vehicle tours. Two different path-based formulations are proposed. The first one defines interconnected first and second echelon tours as variables while the second one exploits the structure of the problem to decompose it and defines the first and second echelon tours as variables while the connectivity of the tours is guaranteed using explicit constraints. The proposed branch-and-price algorithm is based on the second path-based formulation. Urban vehicle tours and city freighter tours are generated using two coupled column generation methods. We test the performance of the proposed algorithm through a computational study on instances with up to 100 customers.

3 - New findings regarding the most used formulations of vehicle routing problems
Pedro Munari

We present a theoretical and computational study regarding the two most used types of formulations of vehicle routing problems: vehicle flow formulations and set partitioning formulations. It is well known in the literature that they differ from each other in many aspects, such as strength of linear relaxations, symmetry, requirements for computational implementation, performance on different types of problem instances, among others. In this research, we study some relationships between them that have not been observed before. Theoretical and computational results help us to understand the main advantages and disadvantages of each formulation and reveal an interesting outcome: they are special cases of a novel, generalized formulation of vehicle routing problems.

4 - A Branch & Cut algorithm for the Multi-trip Vehicle Routing Problem with Time Windows
Paolo Gianessi, Diego Cattaruzza

The Multi-trip Vehicle Routing Problem with Time Windows (MTVRPTW) generalizes the well-known Capacitated Vehicle Routing Problem (CVRP) in that vehicles can recharge at the depot and perform more than one trip within a maximum shift length but must comply customer time windows. In its most frequent form, which we address, the MTVRPTW features service-dependent loading times, i.e. the time to recharge depends on the total service time of the subsequent trip. Other variants exist that consider e.g. profits or trips with limited duration. As far as we are aware of, the literature of exact methods for the MTVRPTW is still scarce. We propose a three-index MILP formulation for the MTVRPTW that makes use of base and replenishment arcs. The former model the direct connection between two nodes, while the latter imply a recharge in between two clients. Base and replenishment arc variables are vehicle-indexed. Replenishment arcs allow to represent a journey as an elementary path and thus to ensure connectivity by separating SECs on a transformation of the graph. Further sets of two-indexed variables allow to impose time windows, shift length, and service-dependent loading time constraints. The use of classical capacity constraints to enforce the load limit on vehicles leads to a Branch&Cut algorithm. Capacity constraints are then strengthened after branching decisions to exploit some properties of the vehicle index. Preliminary tests have been conducted, with promising results.

■ TB-14

Tuesday, 10:30-12:00 - Building CW, 1st floor, Room 125

MILP Applications 2

Stream: Mixed-Integer Linear and Nonlinear Programming
Chair: *Jörg Ries*
Chair: *Daniel Guimarans*

1 - Scheduling ground operations for improved aircraft turnaround performance: A Turkish low-cost airline case study
Yagmur Simge Gok, Ammar Al-Bazi, Cemalettin Ozturk, Daniel Guimarans

In recent years, with the phenomenal growth of many low-cost airlines, competitiveness has increased significantly. The main focus became to reduce delays and minimise the time that aircraft spend on the ground. A reliable schedule of turnaround operations plays a crucial role to achieve this target. In this study, we develop a mixed integer programming model to formulate and solve the problem as a Project Scheduling Problem with additional precedence and space constraints. While the precedence constraints ensure safety regulations (e.g. fuelling cannot start until all passengers have left the aircraft), the space constraints impose that operations to be performed in the same limited space are not scheduled simultaneously (e.g. loading catering and boarding passengers with reduced mobility). We tested our model using a set of real data gathered from a Turkish low cost airline considering different connection types and (de-)boarding methods. Our results are used by the airline to find the best schedule of turnaround operations for each connection type, along with finding the best (de-)boarding strategy. Our findings are also used for highlighting the key operations and improving the efficiency of ground operations.

2 - Urban-Planning MIP Model With Connectivity Constraints
Alena Melnikava, Philippe Michelon, Cyrille Genre-Grandpierre, Serigne Gueye

We are interested in an urban planning problem, where we model accessibility to different activities as a MIP with connectivity constraints for these activities. Connectivity of spatial units is an important element in the urban design. E.g. connectivity of green corridors for environmental reasons, but also the connectivity for habitats or industrial zones is often needed to be considered in view of sharing the same infrastructure, area viability, etc. We also examine the priority in the connectivity: e.g. green corridors should dominate any other connectivity or habitat connectivity should be preferred over the industrial zones connectivity. There are several approaches to address the connectivity problem. Here we are going to present the problem as an undirected graph, where the vertices represent the spatial allocation units (green areas, habitats or industrial units). We say that graph is connected if any two of its vertices are linked by a path in the graph. We are going to use a technique based on the notion of node-cut sets (Carvajal et al (2013)). Due to the large instance (1500 vertices) no exact solution is possible. Thus, we are going to present a heuristic allowing us to obtain near-optimal solutions for our urban planning problem and demonstrate the respective results.

3 - Mat-heuristic procedure based on Lagrangean relaxation for the Link Constrained Steiner Tree Problem
Luigi Di Puglia Pugliese, Manlio Gaudioso, Francesca Guerriero, Giovanna Miglionico

We address a variant of the classical Steiner tree problem defined over an undirected graph (USTP). The objective is to find a minimum cost Steiner tree, with a number of edges less than or equal to a given upper bound K. The link constrained USTP (LCSTP) is NP-hard. We developed a mat-heuristic based on the optimal solution of a sequence of restricted LCSTP, defined on sub-graphs of the original one, containing at least one Steiner tree. Each sub-graph is built starting from a Steiner tree, not necessarily feasible (number of edges greater than K), and adding edges belonging to the original graph. To define proper sub-graphs, a Lagrangean relaxation of the LCSTP is defined and the associated dual problem is solved. Indeed, the Steiner tree available at each iteration of the Lagrangean heuristic is used to define new sub-graphs. The solution strategy is tested on a set of benchmark instances drawn by the literature.

4 - Environmental impact of integrated model for warehouse and inventory planning
Jörg Ries, Konstantin Biel

The consideration of environmental impacts, especially GHG emissions caused by product storage and transportation activities, has become an increasingly important concern for companies of various industries. Although there has been considerable research on environmental sustainability in the area of supply chain management, most of this research has concentrated on the transport elements while neglecting the impact of required storage facilities so far. A major proportion of total warehouse emissions emanates from heating, cooling, air conditioning, and lighting which is largely related to the required warehouse size. This, in turn, is greatly influenced by both inventory management, affecting stockholding levels, and warehouse design, affecting the footprint required for holding a given amount of stock. Emissions emitted by other sources, such as material handling equipment, are closely related to warehouse throughput and equipment choice. Currently, there is a substantial gap in the literature regarding this interaction between inventory and warehouse management and its environmental impact. To examine this interaction, we develop a mixed integer non-linear programming model. The results highlight the key effects of inventory management on warehouse-related greenhouse gas emissions.

■ TB-15

Tuesday, 10:30-12:00 - Building CW, 1st floor, Room 126

Mixed-Integer-Nonlinear Programming for Gas Networks

Stream: Optimization of Gas Networks
Chair: *Lars Schewe*

1 - A Penalty Alternating Direction Method for Nonconvex MINLPs in Gas Transport
Martin Schmidt, Bjoern Geissler, Antonio Morsi, Lars Schewe

We present a novel penalty algorithm that is based on an alternating direction method for the penalty subproblems. This work is motivated by a preceding paper ("Solving power-constrained gas transportation problems using an MIP-based alternating direction method", Comput. Chem. Eng. 2015(82)), in which a variant of the method is used to solve large-scale non-convex mixed-integer nonlinear feasibility problems from steady-state gas transport. In this talk, the extensions of the method are discussed and we give a sketch of the convergence theory for the new algorithm. The practical strength of the proposed method is demonstrated by a computational study, in which we apply the method to large-scale real-world problems from steady-state gas transport including both pooling effects and a highly detailed compressor station model.

2 - Using a Longest Edge Bisection to Solve Mixed-Integer Nonlinear Programs by Mixed-Integer Linear Program Relaxations
Robert Burlacu, Lars Schewe

We present a new variant of a known method for solving Mixed-Integer Nonlinear Programs (MINLPs) by Discretization Techniques. The main idea of the method is based on using Piecewise Linear Functions to construct Mixed-Integer Linear Program (MILP) relaxations of the underlying MINLP. In order to find a global optimum of the given MINLP an iterative algorithm is developed which solves MIP relaxations that are adaptively refined. The new variant uses a Longest Edge Bisection to refine occurring MIP relaxations. Both the theoretical background and numerical results for the new variant are presented.

3 - Tight Convex Relaxations for Gas Expansion Planning
Ralf Lenz, Felipe Serrano, Robert Schwarz

Gas transmission companies often need to extend their networks, in order to enable feasible operations. This is known as Expansion Planning and can be modeled as a nonconvex MINLP, where discrete decisions correspond to the operation of active network elements and nonlinearities are due to the flow-pressure relationship in pipes. An appreciated extension method in practice is to build new pipes in parallel to existing ones, called looping. Compared to the original pipe, a loop provides the possibility of transporting more gas and leads to a reduction of the pressure loss.

The decisions to be taken comprise the selection of the pipes to be looped, the continuous loop lengths as well as the appropriate choice of loop diameters out of a discrete set. Since we are able to determine the best looping diameters a priori, we can efficiently reduce the problem size of the resulting MINLP. This model is still nonconvex but we solve it to global optimality using outer approximation and spatial branching.

In this presentation, we focus on theoretical and practical aspects of loop extensions. We show how to strengthen our model formulation by analytically deriving the convex envelope of the constraint function that describes the pressure loss in a looped pipe over the amount of transported flow and the impact of variable diameters and loop lengths. Finally we present computational results and show how a solution can be transformed into a concrete loop extension in practice.

4 - Approximate Convex Decomposition in Gas Network Optimization
Benjamin Hiller, Tom Walther

In some optimization problems, the feasible region of the constraint set can be described as the union of convex polytopes and thus forms itself a nonconvex polytope. Known approaches to treat such feasible regions involve Disjunctive Programming or the use of binary indicator variables for each of the original convex polytopes. We apply a decomposition method known as Approximate Convex Decomposition to such sets in order to obtain relaxations that can be hierarchically refined when required. Thereby, each hierarchy level yields a decomposition that reduces some measure of concavity until a specified tolerance threshold is attained. We will illustrate our approach with the example of optimizing the operational details of gas compressor stations.

■ TB-16

Tuesday, 10:30-12:00 - Building CW, 1st floor, Room 128

Kidney exchange programs

Stream: Healthcare Logistics
Chair: *Joao Pedro Pedroso*
Chair: *Ana Viana*

1 - Position-Indexed Formulations for Kidney Exchange
James Trimble, John Dickerson, David Manlove, Benjamin Plaut, Tuomas Sandholm

A kidney exchange is an organized barter market where patients in need of a kidney swap willing but incompatible donors. Determining an optimal set of exchanges is theoretically and empirically hard. Traditionally, exchanges took place in cycles, with each participating patient-donor pair both giving and receiving a kidney. The recent introduction of chains, where a donor without a paired patient triggers a sequence of donations without requiring a kidney in return, increased the efficacy of fielded kidney exchanges—while also dramatically raising the empirical computational hardness of clearing the market in practice.

In this paper, we address the tractable clearing of kidney exchanges with short cycles and chains that are long but bounded. This corresponds to the practice at most modern fielded kidney exchanges. We introduce three new integer programming formulations, two of which are compact. Furthermore, one of these models has a linear programming relaxation that is exactly as tight as the previous tightest formulation (which was not compact) for instances in which each donor has a paired patient. On real data from the UNOS nationwide exchange in the United States and the NLDKSS nationwide exchange in the United Kingdom, as well as on generated realistic large-scale data, we show that our new models are competitive with all existing solvers—in many cases outperforming all other solvers by orders of magnitude.

2 - Small Representations of Big Kidney Exchange Graphs
John Dickerson, Aleksandr Kazachkov, Ariel Procaccia, Tuomas Sandholm

Kidney exchanges are organized markets where patients swap willing but incompatible donors. In the last decade, kidney exchanges grew from small and regional to large and national—and soon, international. This growth results in more lives saved, but exacerbates the empirical hardness of the NP-complete problem of optimally matching patients to donors. State-of-the-art matching engines use integer programming techniques to clear fielded kidney exchanges, but these methods must be tailored to specific models and objective functions, and may fail to scale to larger exchanges. In this work, we observe that if the kidney exchange compatibility graph can be encoded by a constant number of patient and donor attributes, the clearing problem is solvable in polynomial time. We give necessary and sufficient conditions for losslessly shrinking the representation of an arbitrary compatibility graph. Then, using real compatibility graphs from the UNOS nationwide kidney exchange, we show how many attributes are needed to encode real compatibility graphs. The experiments show that, indeed, small numbers of attributes suffice.

3 - Long Term Management of Multi-Country Kidney Exchange Programs
Ana Viana, Joao Pedro Pedroso

Kidney exchange programs (KEPs) are conducted in many countries to provide an alternative of transplant for patients suffering from kidney failure who, although having a living donor willing to donate one kidney to them, the patient-donor pair is not physiologically compatible.

KEPs are successfully running in e.g. UK, USA, Portugal and the Netherlands, on national or regional basis. However, there is evolving impetus in Europe to consider the possibility of creating international pools in which different countries can participate in a multi-country KEP (mKEP), some countries having already established a collaboration program. This joint collaboration would lead to programs with many more incompatible pairs in a common pool, a crucial factor to increase the number of total possible transplants

We propose an Integer Programming (IP) model for the mKEP that considers the possible existence of multiple optimal solutions in each matching period of a KEP and that, in consecutive matching periods, selects the optimal solution among the set of alternative ones in such a way that in the long-term the benefit each country gets from participating in the mKEP is balanced.

4 - Nash equilibria in the kidney exchange game
Margarida Carvalho, Andrea Lodi, Joao Pedro Pedroso, Ana Viana

Kidney exchange programs have been set in several countries within national, regional or hospital frameworks, to increase the possibility of renal patients being transplanted. Previously, a patient would receive a kidney transplant from a deceased donor, or from a compatible living donor that is a patient's relative or friend. These two possibilities only satisfy a tiny fraction of the demand. Kidney exchange programs allow exchanges between a patient in an incompatible pair and a compatible donor in another incompatible pair.

In some countries the exchange programs take place at regional or hospital level. It has been claimed that these entities would benefit if they collaborated with each other, sharing their internal pools and allowing transplants involving patients of different entities. Nevertheless, for the case of hospital's programs, it has been observed that each hospital is a self-interested agent whose aim is to maximize the number of its patients receiving a kidney. This claim led to the study of multi-player exchange markets. We propose a novel direction in this setting by modeling the exchange market as a game. The analysis of the 2 player case with pairwise exchanges allowed us to prove that the most rational game outcome, Nash equilibrium, maximizes the social welfare, it is Pareto efficient, minimizes the number of external exchanges, and that it can be computed in polynomial time.

■ TB-17

Tuesday, 10:30-12:00 - Building CW, ground floor, Room 0210

Retail Inventory Management 1

Stream: Demand and Supply Management in Retail and Consumer Goods
Chair: *Richa Jain*
Chair: *Pedro Amorim*

1 - Optimal continuous review policy for online retailing considering customer order time windows
Gonçalo Figueira, Pedro Amorim

Online retailing is growing globally at an annual rate of approximately 15%. However, profit margins in this channel, particularly in the grocery sector, are thin or even negative. Therefore, retailers must optimize their operations in order to stay competitive, gain market share and become profitable. A distinctive feature of online demand is the customer order time window, which results from the fact that the customer places an order at a given time and receives at another (selected) time. This provides more flexibility in the way inventories are managed, since the retailer may receive in-transit quantities or even replenish before delivering to the customer. In this research we assess the potential advantages of using a customized inventory policy that takes into account this additional flexibility. We consider that both the demand quantity and the time window are stochastic, and the supplier's lead time is deterministic. We adapt the (s, Q) policy, by dividing demand in different classes, according to the relation between supplier's lead time and customer order window. With these demand classes, we derive the expression for the expected total cost (due to inventory holding, order setups, and shortages), and hence obtain the optimal policy. The devised policy is validated against simulation experiments, and compared to the traditional (s, Q) policy, providing savings between 7% and 26%, depending on the portion of demand that can use in-transit inventory.

2 - Customer impatience and optimal service level
Agust Thorbjornsson, Pall Jensson, Thorlakur Karlsson, Armann Ingolfsson, Eyjolfur Asgeirsson

The retail sector is one of the biggest employer worldwide. Ad hoc approaches for staffing level decisions in the retail business are common with limited use of optimization systems. Furthermore, customer impatience is rarely considered in staffing decisions despite of its impact on cost and customer satisfaction and loyalty. In this research we are developing optimization model incorporating impatience. We are studying the impact of retail and call centre customer impatience on the service level threshold and its implications for labour planning. By comparing stated preferences (through surveys) to revealed preferences (through tracked behaviour) for call centre data, and by taken into account the impact of customer waiting time and impatience on the loyalty we hope to be able to extrapolate from data on retail customers collected through surveys to predict an optimal service level in retail settings. We work in close cooperation with two call centres and three retail chains, where we are conducting customer surveys and video recording.

3 - Buyer-backed purchase-order financing for supplier facing yield uncertainty
Richa Jain, Matthew Reindorp, Arun Chockalingam

We consider a retailer whose supplier is prone to a risk of severe yield shortfall. The risk is present due to a shock that the supplier might experience during his production process, affecting his final yield. This shock is modeled as a compound distribution, comprising a probability of disruption and a yield distribution. The risk of shortfall entails that the supplier cannot independently finance production, or is offered a very high rate of interest by the bank. The retailer can influence the supplier's operational decision and the bank's financing offer by means of a (partial) loan guarantee for the supplier. We present analysis and insights for the retailer's optimal purchase order commitment and loan guarantee level as well as the optimal rate of interest offered by the bank. In a single period setting, we find that (i) the probability of disruption beyond which retailer is compelled to offer a guarantee to ensure supplier participation, increases with supplier's expected yield, (ii) rate of interest offered by the bank is influenced by the shock distribution and the retailer's loan guarantee, (iii) for a given yield distribution, increasing probability of disruption decreases the feasibility of the transaction, and (iv) retailer can increase profit for himself and the supplier by offering a purchase order commitment that incorporates a (partial) loan guarantee.

■ TB-18

Tuesday, 10:30-12:00 - Building CW, ground floor, Room 023

Flexibility

Stream: Production and Operations Management
Chair: *Ton de Kok*

1 - Customer Order Management in Group Companies under Smart Cloud Manufacturing
Ting Zhang

This paper considers the customer order management problem in a group company which consists of one headquarters and several geographically dispersed and operationally semi-autonomous manufacturing subsidiaries. The headquarters configures the manufacturing resources and manages the production planning and scheduling on a smart cloud manufacturing (S-CM) platform. An order management model is formulated. The model is applied to study two situations respectively. One situation is that the customer demands exceed the production capacity of each individual subsidiary so that the headquarters has to combine the manufacturing resources together to complete the task. The other situation is that the several customer orders are within the production capacity of a single subsidiary so that orders should be merged into one batch before allocating to one subsidiary. Different heuristics are proposed and a series of simulation experiments is conducted. The results show that the group company performs a good robustness against the demand variability by the application of the S-CM platform. This achievement is largely due to the effects of pooling of different customer orders and sharing of manufacturing resources among subsidiaries.

2 - Setting optimal planned leadtimes in a configure to order manufacturing system
Sjors Jansen, Zumbul Atan, Ton de Kok

We study the production planning in Configure To Order (CTO) manufacturing systems. Products are specifically configured for each customer and are characterized as low volume, high value. The system consists of multiple stages that converge to one final assembly stage. Leadtimes per stage are stochastic due to extensive testing at the end of each stage. Our goal is to determine optimal planned leadtimes for each stage such that the total expected production costs are minimized. Included in the cost function are holding costs per stage and penalty costs for late completion of the final product. Besides the classical Newsvendor equation for the complete system, we also derive Newsvendor equations for each individual stage. This set of equations is solved and the exact optimal planned leadtimes for each stage are obtained. These equations also give an important insight in the dynamics of the system, since they indicate to what extend a specific stage can be blamed for the lateness of the final product. To relate this subjective idea of blaming to the Newsvendor equations a 'blame policy' is introduced.

3 - Empirical Bayes Approach to Designing Screening Procedures with Inspection Error
Young H. Chun

A batch of expensive items, such as IC chips, is often inspected multiple times in a sequential manner to further discover more conforming items. In such a situation, an important managerial decision is how to estimate the number of non-defective chips still remaining in the batch after a given number of screening cycles. Conversely, we also want to determine the number of screening cycles that produce the maximum profit or the minimum cost. We propose in this paper a Bayesian estimation method and compare its performance with that of the traditional maximum likelihood method. One of the difficulties in Bayesian analysis is how to determine the "prior distribution" of the total number of conforming items in a batch and estimate its parameter values. In the paper, we use the so-called "empirical Bayes" estimation, where the parameter of a binomial prior distribution is estimated from the inspection data. . In a modest simulation study, we evaluated the accuracy of the empirical Bayes method and showed its outstanding performance over the traditional maximum likelihood method. In the repetitive screening procedure, another important decision problem is when to stop the screening process and salvage the remaining items. We propose various types of stopping rules and illustrate their procedures with a simulated inspection data. Finally, we explore various extensions to our empirical Bayes estimation method in multiple inspection plans.

4 - Design of Optimal Volume Flexible Systems with Implementation Latency
Abhijit Deshmukh, KiHyung Kim

This research studies the effects of time to build a volume flexible system on the optimal strategic level decisions and the optimal operational level decisions. Strategic level decisions include when to build the volume flexible system and how much maximum capacity to be installed in the system. Once the system is built, the system operator adjusts the system's yield rates within the maximum capacity limit to cope with underlying demand uncertainty. This research focuses on 'build latency' among the various factors that affect to the optimal decisions. The operational level problem is modeled as a stochastic optimal control problem. Given the optimal operational decisions, we formulate the strategic level problem as a delayed optimal stopping time problem. Postulating that a geometric Brownian motion appropriately describes the underlying demand uncertainty of the volume flexible system, we derived closed form solutions for the optimal decisions. Moreover, we highlight the effect of build latency on strategic level decisions of a volume flexible system by comparing it to an inflexible system. As an application, we analyze the optimal decisions in two different types of power generation systems, a gas turbine power plant and a small hydropower plant.

■ TB-19

Tuesday, 10:30-12:00 - Building CW, ground floor, Room 021

Location and tree problems

Stream: Telecommunications and Network Optimization
Chair: *Dimitri Papadimitriou*

1 - An Exact Algorithm for the Optimal Mapping of Cloud Virtual Machines
Guanglei Wang, Walid Ben-Ameur, Adam Ouorou

One of the challenges of cloud computing is to assign virtual machines to physical machines optimally and efficiently. The aim of telecommunication operators is to minimize the mapping cost while respecting constraints regarding location, assignment and capacity. First, we propose an exact formulation, which leads to a 0-1 quadratically constrained problem. Second, we introduce a variety of cuts by exploiting the problem structure. Third, we present a problem-specific branch-and-cut procedure, where cuts are only added upon violations. Further, a Lagrangian-based decomposition is proposed reducingthe problem into a number of subproblems, which are then solved by a cutting plane algorithm. A set of experiments is carried out by implementing the branch-and-cut procedure and the cutting plane algorithm with CPLEX 12.5 routines. The numerical results show that several global optimums and lower bounds of good quality can be obtained in a reasonable time by the proposed approaches.

2 - Leveraging Web Analytics for Automatically Generating Mobile Navigation Design Models
Fabrizio Rossi, Andrea Salini, Ivano Malavolta

Today activity on smartphones and tablets accounts for an incredible 60% of the time spent on digital media in the United States. People will rely more and more on mobile devices for performing very different activities like purchasing products, messaging, ordering food, booking holidays, etc. Nowadays, a common technological trait is that browsing even a responsive website on a device can be "uncomfortable" and always more often a dedicated mobile app is introduced from an existing website (e.g., Facebook, Amazon, Ebay, Youtube, Wikipedia, to name a few). However, the structure and the information architecture of a mobile app can be totally different from the one of a website due to many factors such as display size, different physical and modal contexts, etc. Therefore, developers cannot simply replicate the structure and the information architecture of a website into the corresponding mobile app, but a complete redesign is needed. In this talk we present an approach for leveraging web analytics for generating mobile navigation design models. The approach collects usage data of a website, builds a model of the web usage patterns coming from mobile-specific usage sessions, analyses it, and generates a mobile-oriented navigation model of the app. Such a generation amounts to solve a variant of the Steiner Tree problem with revenues, budget and hop constraints. Finally, we discuss a set of experiments on existing websites that prove approach feasibility.

3 - A dual-ascent-based branch-and-bound framework for the prize-collecting Steiner tree and related problems
Martin Luipersbeck, Markus Leitner, Ivana Ljubic, Markus Sinnl

A branch-and-bound framework based on a dual ascent algorithm for the directed (asymmetric) prize-collecting Steiner tree problem (APC-STP) is presented. The framework is computationally explored in combination with various other algorithmic ingredients, including reduction tests, branching strategies and primal heuristics.

Given a directed graph with non-negative edge costs, node revenues and a (potentially empty) set of terminal nodes, the goal of the APC-STP is to find an arborescence that spans all terminals and such that the sum of arc costs plus the sum of node revenues of not connected nodes is minimized.

This problem generalizes many network design problems, including the prize-collecting Steiner tree problem on an undirected graph (PC-STP), the maximum-weight connected subgraph problem, and the Steiner tree/arborescence problem. These problems are well-known and cover a broad range of relevant applications.

The presented dual ascent algorithm describes a fast procedure for obtaining a valid lower bound by computing a heuristic solution to the dual of a cut-based ILP formulation. Our algorithm shares similarities to the Goemans-Williamson primal-dual algorithm for the PCSTP and generalizes the dual ascent algorithm for the Steiner arborescence problem proposed by Wong.

Extensive computational results show the effectiveness of the proposed methods and previously unsolved benchmark instances from the PC-STP literature are solved to optimality.

4 - Combined routing - multi-level facility location problem
Dimitri Papadimitriou

The canonical formulation of the facility location problem (FLP) models the cost of allocating the demand originated at a given customer point independently of the demands issued by other customer points. However, the combination of this problem with routing decisions removes the allocation independence, leading in turn to strongly interrelated location and routing decisions. Facility location aggregates demands whereas routing decisions may or not be governed by the aggregation of the corresponding traffic flows depending on the adopted routing strategy (following various spatio-temporal criteria). An additional problem arises in multi-level hub/facility location problems as the routing strategy adopted may be different in between levels. This setting characterizes environments where the routing between customer demand points and first level follows different objectives than the routing in between levels. In this talk, we propose a modeling approach for the combined traffic flow routing - multi-level facility location problem. We then analyze and compare different mixed-integer formulations of this problem for different facility location and routing models. We then evaluate and compare their computational performance by means of case studies involving the two and three-level variant of this problem. The latter finds applicability in multi-layer network modeling such as information distribution systems and (virtual) data centers.

■ TB-20
Tuesday, 10:30-12:00 - Building CW, ground floor, Room 022

How OR found its way into universities 1

Stream: How OR found its way into Universities
Chair: *Jakob Krarup*

1 - From control rooms to common rooms: how OR found its way into UK Universities
Graham Rand

This talk will trace aspects of the history of OR from the control rooms of WWII to common rooms of UK Universities, with a particular emphasis on the setting up of the first Department of OR at Lancaster. Contrasts with the developments in the States, both as to timing and the nature of the curricula will be noted. It is expected that the talk will be illustrated with audio-visual material, including extracts from prime-time BBC TV in the early 1960s.

2 - OR in Poland - historical remarks
Jan Weglarz

Some remarks on how OR became an academic discipline in Poland are presented. Basic research directions as well as activities in EURO and IFORS are characterized.

3 - Development of OR at South African Universities
Theodor Stewart

The emergence of OR as a recognizable discipline in South Africa during the 1960s was primarily driven by practice, particularly but not exclusively from the mining sector. Nevertheless, a number of universities quickly instituted academic programmes in response to the training needs which emerged, the earliest perhaps being at the universities of Stellenbosch, South Africa, Cape Town and Potchefstroom (now known as North West University). A distinguishing feature of the development of OR at South African universities is that each found a particular niche in different areas of theory and/or practice. We shall trace the trends that emerged at these universities from the 1960s up to the present time, and discuss how they came to serve different OR activities in the country.

■ TB-21
Tuesday, 10:30-12:00 - Building CW, ground floor, Room 025

Vehicle (re)scheduling

Stream: Public Transportation
Chair: *Leo Kroon*

1 - A Multi-Depot Vehicle Routing Problem with Travel Costs and Customer Costs for Tamping Scheduling
Franziska Heinicke

An important part of railway infrastructure maintenance is tamping. If the track is well tamped, track irregularities are reduced that increases travel safety and comfort, and protects against other failure on the track. If the ballast is in a bad condition, the train speed must be restricted which leads to delays and penalty costs for the track operator. So, the tracks have to be tamped regularly depended on traffic volume and track geometry. By scheduling the tamping activities of the near future two aspects have to be considered. On the one hand, the maintenance operator is interested in reducing the travel costs. On the other hand, penalty costs have to be reduced. Penalty costs depends on the track condition and the traffic volume. They have to be paid for every day until the task is resolved. With it, the later the execution time, the higher are the penalty costs. By minimising the sum of penalty costs and travel costs, a solution with small overall costs can be found. Sections with high penalty costs will be maintained preferred but with minimal detour to reduce costs. The resulting scheduling problem is a multi-depot vehicle routing problem with travel costs and customer costs. In contrast to common vehicle routing problems, the costs not only depend on the distance to the precede job, but also on the position in the whole route. With it, the problem is more complex. In this talk, the problem will be presented in detail and some solution methods will be shown.

2 - Computational Method to Assess the Service Process Capacity of a Shunting Yard
Bob Huisman

Usually the capacity of a shunting yard for trains is expressed by the total track length. However, often these yards are not only used to park trains, but as well for providing services like inspection, repair and cleaning. Then the total track length does not provide an appropriate measure to check whether the required shunting and service processes are logistically feasible. To assess the process capacity of a shunting yard more advanced methods are required.

We propose to express the service process capacity of a shunting yard by a Pareto front of a set of distribution parameters that describe the shunting and service activities that have to be executed during a day, such that for a given threshold percentage of the instances a feasible plan can be found within a given time limit.

To be able to cope with different planning and scheduling methods, we developed a modular system that performs Pareto analysis, instance generation, problem and solution storage, planning module interaction, and feasibility checking.

The presentation will give an overview of the problem, the approach to assess the shunting and service capacity of a yard, the different planning methods used, the results so far, and the research questions left. Furthermore, it addresses the fruitful cooperation between industry and universities.

3 - The Simultaneous Vehicle Scheduling and Passenger Service Problem with Flexible Dwell Times
Joao Fonseca, Evelien van der Hurk, Allan Larsen, Roberto Roberti, Stefan Ropke

In this talk, we deal with a generalization of the well-known Vehicle Scheduling Problem (VSP) that we call Simultaneous Vehicle Scheduling and Passenger Service Problem with Flexible Dwell Times (SVSPSP-FDT). The SVSPSP-FDT generalizes the VSP because the original timetables of the trips can be changed (i.e., shifted and stretched) in order to minimize a new objective function that aims at minimizing the operational costs plus the waiting times of the passengers at transfer points. Contrary to most generalizations of the VSP, the SVSPSP-FDT establishes the possibility of changing trips' dwell times at important transfer points based on expected passenger flows. We introduce a compact mixed integer linear formulation of the SVSPSP-FDT able to address small instances. We also present a meta-heuristic approach to solve medium/large instances of the problem. The effectiveness of the proposed solution methods is shown on a set of real-life instances provided by the main bus operator on the greater Copenhagen area. The effects of considering flexible dwell times on the objective function and on the provided solutions are also analysed.

4 - Disruption management and maintenance routing
Leo Kroon, Marie Schmidt, Joris Wagenaar

In real-time passenger railway operations, several rolling stock units may have a planned maintenance appointment during the day. In the case of a disruption, the rolling stock duties usually have to be rescheduled to fit with the rescheduled timetable again. Also in such a case, the maintenance appointments must be taken into account as much as possible. Therefore, in this presentation we describe three optimization models to integrate this maintenance routing process in the disruption management process. These models are extensions of the well-known composition model of Fioole et al. (2006). The composition model has been used by Netherlands Railways since 2004 for scheduling its rolling stock duties. In the first model, the set of rolling stock types is extended for each rolling stock unit with a maintenance appointment. In the second model, a shadow account is maintained for the rolling stock units with a maintenance appointment. The third model creates rolling stock duties for all rolling stock units, in particular those with a maintenance appointment. We also present computational results, showing that the models effectively combine the maintenance routing process with the disruption management process.

■ TB-22

Tuesday, 10:30-12:00 - Building CW, ground floor, Room 027

Applications in Combinatorial Optimization 2

Stream: Combinatorial Optimization
Chair: *José Fernando Oliveira*

1 - A strategic capacity planning MILP model with multiple-generation products' renewal including demand and price cannibalization
Gorkem Yilmaz, Amaia Lusa, Ernest Benedito

One of the crucial activities in companies is Strategic Capacity Planning (SCP) and Product Portfolio Management (PPM). SCP is composed of decisions for purchasing new technologies, renewal of existing manufacturing technologies either with an upgraded version or a completely new technology, sales of the obsolete technology, level determination and configuration of the capacity. PPM is comprised of selecting ideal product or products, marketing and decisions for optimum manufacturing timing. In the cases of actual life, a new product to be introduced to the market has an impact on prices of and demands for the existing and new products. Demand and price interactions of products (cannibalization) affect the timing of product launching time, and then manufacturing technology configuration. In a pricing competitive environment, optimal sustainable real-life long term capacity plans should take into account of price and demand cannibalizations. To the best of our knowledge, product cannibalization effects are ignored or neglected by modelers and the proposed solutions for SCP and PPM does not include price and demand cannibalization. A MILP model is developed for solving SCP and PPM problems in an integrated manner considering supply chain requirements and benefiting from existing scientific and technological opportunities. According to the results of a wide computational experiment, the suggested model can be considered as an appropriate tool to deal with this kind of problem.

2 - Optimization of sustainable logistic chains: saleable products reached from wastes
Ana Amaro, Rémy António, Ana Barbosa-Povoa

This contribution presents a novel optimization model to manage an industrial logistic chain responsible for wastes recovery. This is based on the study of an innovative continuous manufacturing process, consisting of several operational stages that go from the reception and separations of various wastes (inbounds), till the treatment, mixing and extrusion stages (depending on the type of wastes). Different value-added products (e.g. pallets, and cutting) are then obtained from also different combinations of waste materials. Besides that, the integrated optimal planning approach explicitly models the logistic chain responsible for the waste collection and supplying process to the manufacturing process. Also, the network responsible for the final product distribution is modelled and sustainable indicators are evaluated. The proposed decision-making oriented approach, is supported on the integration of production metrics and its impact on the management of logistic flows. A MILP formulation is obtained and solved using CPLEX. The validation of the proposed model is illustrated through its implementation to an industrial case.

3 - Optimization of waste collection systems: Development and application of a decision model

Chiara Magrini, Daniele Vigo

Planning the urban waste collection system in a Municipality is a strategic long-term decision, which involves many factors and large consumption of economic resources. The optimization model described in this presentation aims at supporting such decisions by determining the most convenient collection method for each waste fraction, taking into account some characteristics of the town and target levels of separated collection. The model is tested on realistic scenarios from an Italian region.

4 - Optimal Scheduling of Evaporation Lines with Time-varying Capacities and Decaying Performance

Carlos Gómez Palacín, José Luis Pitarch Pérez, Mendez Carlos, Cesar de Prada

This work addresses the optimal allocation and scheduling of several continuous evaporation lines. The performance of each evaporator is affected by load, weather and fouling in the pipes. The main characteristics of the problem are: -There exist 2 kinds of cleaning tasks with different features. -Only one evaporator can be cleaned at the same time. -Evaporators can be connected to different feed lines, and own different capacities. -Evaporators only can run above a minimum load level.

Decisions for the scheduler are: assigning feeds and loads; and deciding the right instant and type of cleaning tasks. The solution will be implemented as a real-time MILP routine. The nonlinear behavior of the plant is approximated by interpolations of linear models.

We choose 3 months as prediction horizon, discretised in days. A work flow for an evaporator is based in normal run stages, that can be initial or critical. We assume that the evaporator won't need to be cleaned in the initial stages. Therefore, an evaporator is in an initial stage if, and only if, it will be in the next stage in the next time instant. In the critical stages, we can choose if the next stage will be either: normal subsequent stage, cleaning or stand-by. A cleaning stage must be performed before starting a new operation cycle. Every constraint has to be fulfilled in each sampling time.

Finally, the objetive is to minimise a weighted sum between the scheduled stages, divided by the prediction horizon.

■ TB-23

Tuesday, 10:30-12:00 - Building CW, ground floor, Room 028

Graph Algorithms and Graph Modelling

Stream: Graphs and Networks
Chair: *Raphael Delhome*
Chair: *Amad Mourad*

1 - Efficient approach for the maximum clique problem based on machine learning

Alexey Nikolaev

In this talk a new approach for solving the maximum clique problem will be presented. For a given graph the suggested approach uses machine learning technique to predict the fastest algorithm from several algorithms for the maximum clique problem. Then the chosen algorithm is applied for solving the maximum clique problem in this graph. The computational results show the efficiency of the proposed approach.

2 - Finding a Feasible Solution to Restricted, Large-Scale Transportation Problems

Jörn Schrieber, Dominic Schuhmacher, Anita Schöbel

Recent efforts to tackle large-scale transportation problems via linear programming include the restriction of the allowed transports to a small subset. Optimal transports for these restricted (or sparse) instances are then often assumed to be provided by standard LP-solvers, see for example Oberman and Ruan (2015) or Schmitzer (2015). However, in our tests for the unrestricted (dense) transportation problem a revised version of the simplex algorithm, similar to the Network-Simplex, turned out to be more efficient than generic solvers due to its more specialized nature.

There is one main issue that arises when adapting the algorithm to the restricted problem. While there are a lot of efficient methods to obtain a basic feasible solution to the full problem, such as the Northwest Corner Rule or Row Minimum Rule, they frequently fail in the restricted case.

This talk will give an insight into the current state of transportation problem solving and details on how the standard procedure of the construction of a basic feasible solution for Network-Simplex can be tailored to the special structure of the restricted transportation problem, as well as some computational results.

3 - Calibration of Time-Dependent Contraction Hierarchies based on Sensitivity Analysis

Raphael Delhome, Romain Billot, Nour-Eddin El Faouzi

As a speed-up technique for shortest path calculations in road networks, Contraction Hierarchies (CH) are extremely powerful in comparison with classic Dijkstra-like algorithms. The best experiments show that it can solve queries in less than 0.1 millisecond at the cost of less than 10 minutes of preprocessing for continental graphs. CH are considered as one of the best acceleration algorithms and are used by many routing engines nowadays. This contribution aims at studying the performance of Time-Dependent CH in terms of computation time. A focus is done on preprocessing phases which are composed of two main operations: a node hierarchy construction and the graph contraction. CH and its time-dependent variant are strongly sensitive to calibration: the produced hierarchy may be completely different regarding the preprocessing parameter values. A variance-based sensitivity analysis has been implemented to evaluate the sensitivity of preprocessing time with regards to four state-of-the-art parameters: the edge creation ratio, the node depth, the original edge ratio and the travel time function complexity ratio. Coupled with Monte-Carlo methods, this technique allows exploring the parameter set space. As a result, a detailed evaluation of the parameter influence can be drawn. Some well-performing parameter sets are identified and confirmed during a subsequent local search procedure, so that calibration recommendations are possible.

4 - Skip Graph for Improving Lookup in P2P Architectures

Amad Mourad, Abdelmalek Boudries, Djamil Aïssani, Zineb Maouche, Farida Guenounou

Lookup in P2P architecture is an important service and frequently used. It is done at the application layer, and then its optimization is a critical issue, particularly for specific environment such as real time applications.

In this paper, we propose a scalable P2P architecture that uses Skip graph as underlying overlay network, and a specific routing algorithm that optimizes the hop numbers from any source node to any requested node in the network.

The performance evaluations of the proposed solution show that results are globally satisfactory.

■ TB-24

Tuesday, 10:30-12:00 - Building BM, 1st floor, Room 119

Scheduling and Applications

Stream: Project Management and Scheduling

Chair: *Florian Jaehn*

1 - New exact and approximation algorithms for the twin robots scheduling problem
Andreas Wiehl

We present a detailed look on the NP-hard 'twin robot scheduling problem' (TRSP) in which two moving robots (or cranes) positioned at the opposite ends of a rail are required to deliver items to positions along the rail with a non-crossing constraint. The objective is to minimize the makespan. We present exact and approximation algorithms for the TRSP. Further, we compare the results with other existing algorithms in a numerical study and adjust the TRSP for the practical situation on transshipment yards.

2 - A Fair Placement of Distribution Tours Among Subcontractors
Christian Billing, Thomas Wensing

In fields like transport or materials sourcing it is common industrial practice nowadays to contract several partners for the fulfilment of similar sets of tasks. A typical template is to include quotes to the contracts on orders to specify which portion of the total volume should be given to the contracted partner. In this study we examine the question of operationally distributing jobs to a set of partners as to meet the contracted quotes in different dimensions such as kilometers, number of stops, etc. as closely as possible. We propose the term Fair Task Allocation Problem (FTAP) and analyse its complexity. While the problem is NP-hard in the general case, we show that it is pseudopolynomially fixed parameter tractable for a given number of partners and dimensions. Furthermore, we will formulate a special case of the problem with equal quotes for the partners as a scheduling problem. In addition, we present two solution strategies, a Tabu Search procedure and an exact algorithm, which will be tested on real-world instances.

3 - Scheduling Parallel Injection Machines with Setups
Marcin Kulus, Marek Goslawski, Joanna Józefowska

We consider a set of parallel injection molding machines. The main task for the production plant is to complete a set of production orders following from a given master production schedule. Each production order is considered as a separate task executed on any machine with the same processing time. Injection molding process is a manufacturing method for producing articles by injecting plastics into the mold. The change of task produced on particular machine requires change of mold and/or plastics, which is known as setup. There are three possible scenarios of setup: change of plastics, change of mold or change of both: plastics and mold. The goal is to find a schedule, i.e. assignment of orders to machines and a sequence of orders on each machine such that the due dates are met and the total setup time is minimized. A MIP model has been designed and implemented using CPLEX library. Moreover, a greedy heuristic has been developed to solve the formulated problem. Computational experiments on randomly generated data have been executed using both the CPLEX and dedicated heuristic approach. The CPLEX was stopped after finding an optimal solution or exceeding the permitted computational time (set at 2 hours). The solutions obtained by the heuristic within seconds differ only by 11% from those produced by CPLEX.

4 - Scheduling Crossover Cranes at a Container Block During Seaside Peak Times
Anne Ehleiter, Florian Jaehn

This presentation deals with crane scheduling in a block of a container terminal equipped with two crossover cranes. We concentrate on the situation when all requests in this block refer to the seaside, that is when a container ship is berthed and has to be served as quickly as possible. In this case, the two cranes highly interfere. We formulate this problem as a MIP. Further, we provide several heuristic solution procedures based on priority rules. A comparison of all procedures concludes this presentation.

■ TB-25

Tuesday, 10:30-12:00 - Building BM, ground floor, Room 19

Emotions and strategic thinking

Stream: Behavioural Operational Research
Chair: *Raimo P. Hämäläinen*

1 - Modelling a Strategic Thinking Capability
Leon Young

The versatility of the word strategy has created significant headaches for those looking to develop the area. The unfortunate position of the word strategy is that it has "acquired a universality which has robbed it of meaning". Not only is strategy poorly understood and poorly used, the subservient capabilities that allow for the development of strategy, specifically strategic thinking, are equally mired in confusion and debate. Yet, despite this historical confusion, strategy and strategic thinking are often cited as the reason for organisational success or failure. Like the term strategy, strategic thinking is equally mired in confusion. There is no agreement in the literature on what strategic thinking is and this is perhaps because it has almost become accepted as an axiom within the strategy field. Given the diverse and abstract use of the term strategic thinking, one can be forgiven for believing that attempting to quantify strategic thinking would be akin to unraveling a Gordian knot. This paper seeks to not only outline the contemporary understanding of strategic thinking, through an understanding of strategy, but also proposes a theory of a strategic thinking capability. The paper outlines a model of developing a strategic thinking capability, described by four simple behavioural measures, and demonstrates the utility of modelling human behaviour in decision making.

2 - Inquiry and Advocacy in Human Interactions - A Psychophysiological Study
Ilkka Leppänen, Raimo P. Hämäläinen, Esa Saarinen, Mikko Viinikainen

Emotions are important in group decision making and negotiations. We present the first psychophysiological study of emotions related to group interaction. Two interaction modes are explored that are frequently used in decision making and negotiations, inquiry and advocacy. Inquiry refers to an interested and explorative interaction mode, and advocacy to an assertive and narrow mode. These modes can be used to generate cognitive conflict which has been shown to improve group decision making and negotiation outcomes. We studied the related emotional responses by facial electromyography and skin conductance. Subjects were asked to adopt the different modes in hypothetical encounters with another person who was represented by a facial picture with an opinion statement. We found that Duchenne smiles were specific to the inquiry mode and furrowed brows were specific to the advocacy mode. Subjects with a higher empathy score expressed more Duchenne smiles. The results highlight that positive emotional expressions are related to inquiry and negative emotional expressions to advocacy. This reflects the emotional basis of the cognitive conflict that is related to the introduction of the modes in negotiation situations.

3 - Context Matters: Effects of Emotional Attachment and Information Overload
Pekka Malo, Pekka Korhonen, Tommi Pajala, Outi Somervuori, Niklas Ravaja, Jyrki Wallenius

In this paper, we show that the product type matters for choice accuracy, i.e. context matters. When subjects make choices with hedonic products, some of them make fewer dominated choices than with utilitarian products. Secondly, we show that information overload is a relevant phenomenon in Multiple Criteria Decision Making experiments. However, what matters is the quality of information, not just the quantity. When we add information that does not change the dominance relations between products, choice accuracy is not degraded. All of our considerations are based on a simple experiment, where the participants were asked to make several multiple criteria choices from 3, 4, and 6 alternatives which were evaluated on 2 or 3 criteria. We utilize a new method for generating many similar choice problems, which enables the objective measurement of choice quality.

4 - PoSITeams 2.0 - Positive Systems Intelligent Teams, an Agent-Based Simulator for Studying Group Behavior
Raimo P. Hämäläinen, Teemu Tiinanen, Juha Törmänen, Esa Saarinen

Systems intelligence is the ability to act intelligently within complex systems involving interaction and feedback. Organizations and social groups are typical examples of everyday systems. PoSITeams is a web-based multi- agent simulator to study the dynamics of emotions. We present a novel agent- based emotional contagion model based on psychological research to study the dynamics of positive and negative emotions in organizations. The purpose of the simulator is to let the user explore the effects of different behavioral and structural changes in organizations. This facilitates perceiving the organization as a system and lets the user recognize the potential of changing the system from within, thus promoting systems intelligent behavior in the organization. The presented emotional contagion model is also considered as an optimization problem to let the simulator suggest systems intelligent actions.

■ TB-26

Tuesday, 10:30-12:00 - Building BM, 1st floor, Room 109D

Stochastic data modelling

Stream: Business Analytics and Intelligent Optimization
Chair: *Vadim Strijov*
Chair: *Arsentii Kuzmin*

1 - Thematic Classification for EURO/IFORS Conference Using Expert Model
Arsentii Kuzmin, Alexander Aduenko, Vadim Strijov

Every year the program committee of a major conference constructs its scientific program. Some participants take part in invited sessions, but for the majority of participants the PC along with experts have to choose sessions according to their contributed abstracts. To fit an abstract into the current conference programme one has to construct an expert system. It should respect previous conferences structure and use thematic modeling techniques.

The conference structure represents a tree. It has abstracts as leaves and areas, streams, sessions as nodes. Abstracts from the previous conferences already have their positions in this structure. To classify a new abstract one can use divisive hierarchical classification methods, based on SVM, NB or kNN. However, these methods are greedy. Insufficient number of abstracts in each lowest level cluster makes classification unstable. In addition, expert and algorithmic classifications differs. So a group of the most relevant clusters is preferable than the best one to meet expert needs.

We propose a relevance operator that returns all clusters sorted by their relevance. We consider three ways of constructing such operator using hierarchical multiclass SVM, PLSA with Adaptive Regularization, and proposed weighted hierarchical similarity function. We construct a model of EURO 2010 using expert models of EURO 2012 and 2013 to demonstrate performance of proposed methods.

2 - Large-scale time series forecasting
Vadim Strijov, Anastasia Motrenko, Mikhail Kuznetsov

The talk is devoted to investigation of behavior of a device, a member of the internet of things. A device is monitored by a set of sensors, which produces large amount of multiscale time series during its lifespan. These time series have various time scales, due to measurements could perform over each millisecond, day, week, etc. The main goal is to forecast the next state of a device. The investigation assumes the following conditions for a single device unit time series: there are large set of multiscale time series; the sampling rate of a time series is fixed; each time series has its own forecast horizon. To make an adequate forecasting model hold the following hypothesis: the time history is sufficient long; the time series have auto- and cross-correlation dependencies. The model is static, so there exists a history of optimal size. Each time series could be interpolated by some local model, a that there exist a local approximation model, which could be applied in the case of local data absence. The vector-autoregression approach conducts problem statement. To find a model of optimal complexity a consequent model generation-selection procedure was constructed. The test-bench compares random forest, boosting and mixture of experts.

3 - A transportation distance based stability results for linear Markov decision processes
Adriana Kiszka, David Wozabal

The approximation of stochastic processes is an important topic in multistage stochastic optimization. In this paper we focus on the approximation of Markov process by lattices. We measure the quality of the approximation by a distance between Markov processes.

To this end, we introduce a distance between Markov processes, which is transportation distance arising from a generalization of the Wasserstein distance. We take into account the effect of the information, which, in contrast to similar approaches for general stochastic processes, includes only the last state and not the whole history of the process. We apply the obtained results for lattices and compare with approach presented in "A distance for multistage stochastic optimization models" by G.Ch. Pflug, A. Pichler, where the distance between trees was considered. Our main result states that the difference of the optimal values of linear multistage stochastic problems, which differ only in the underlying Markov processes, can be bounded by the distance between these processes. We show several properties of the distance such as a dual representation and apply our results to realistic problem instances of stochastic optimization problem in the field of energy planning.

■ TB-27

Tuesday, 10:30-12:00 - Building BM, ground floor, Room 20

Data Science in Optimisation

Stream: Data Science in Optimisation
Chair: *Andrew J. Parkes*

1 - An ensemble scheduling optimization model and solution algorithm for molten iron transport system considering uncertainty and real-time response
Yang Yang, Lixin Tang

To improve the precision of energy consumption forecasting, an ensemble model is introduced based on statistical correlation analysis, multiple regression model, KNN model and least squares boosting model while solving scheduling optimization. There are various factors affecting the hot metal temperature (factors are divided into measurable variables, labels and unmeasurable data), and intermediate process (Conduction, Convection, Radiation) is difficult to measure. In the modelling process, seven main factor variables, that is, the initial temperature and the weight of molten iron, the iron content, the empty travel time and the mission time(receiving time, transport time, pouring time) of the torpedo tank, are selected out. Additionally, the labels of weather, different torpedo tanks and iron works are joint used with the factor variables. Then, the density of data points is uneven and distribution presents a certain regularity in the high dimensional space coordinates. It causes the different feasibility and accuracy of the three models in the different areas. Thus, a piecewise ensemble model is designed with discriminant functions to judge which model should be chosen. Furthermore, it is not desirable to establish the regression model to predict the chemical and physical phenomena. Thus a relaxation direction is introduced by the statistical correlation analysis to get the upper and lower bounds model.

2 - Machine Learning of Local Search Heuristics in SAT
Andrew J. Parkes, Andrew Burnett
Optimisation problems, in a desire to improve efficiency, typically employ heuristics as a technique to drive an algorithm towards good candidate solutions. One long standing desire within research has been to automate the generation of heuristics that perform well upon a specialised problem domain. Genetic programming is the dominant methodology that has been used to build bespoke heuristics. We present a contrasting approach based upon systematic search, and show an application in a local-search algorithm for the specialised case of 0-1 Integer Programming, Boolean Satisfiability. We consider several extensions to the system which improve performance, and discuss how it can be compared to current genetic programming methods.

3 - Supply-function equilibrium for transmission-constrained electricity markets
Keith Ruddell
Supply-function equilibria are used to model electricity spot markets where generators submit offer curves against an uncertain demand. If there are only a few generators, then they will have the power to influence prices through the shape of their offer curves. The presence of transmission constraints and hedging instruments complicates the exercise of this market power.

We construct an SFE model with several generators located at each end of a transmission line. The set of first-order conditions on offer curves that simultaneously maximise expected profit for all generators gives a system of ordinary differential equations, which we solve to find the supply-function equilibrium. Demand shocks at each node are distributed such that the flow on the line tends to be in one direction. We find that when the probability of congestion is very low, the market behaves like a pool market. When the line is almost certainly congested, the market behaves as two independent markets with agents taking the transfer of energy as given. Between these two cases we find equilibria where generators at the importing end of the line will withhold energy from the market so as to congest the line and reap greater profits. Further to this, we examine the incentives that arise in the wholesale market for generators that sell electricit in the forward market through options, futures, and fixed-price-variable-volume contracts, or hold financial transmission rights.

4 - Dimensionality Reduction on Mixed-Type Datasets Including Non-Numeric Attributes
Chung-Chian Hsu, Yu-Ting Lu, Jhen-Wei Wu
Distribution of high-dimensional data are not visible, leading to some difficulty in data analysis. For instance, the popular k-means clustering algorithm which requires the analyst to pre-determine k, the number of clusters. Without some information about how the data distribute, it is difficult to determine k. Dimensionality reduction techniques which can transform a high-dimensional dataset to a visible, low-dimensional, say 2D, space are useful in exploring the distribution of the high-dimensional data. Conventional dimensionality reduction techniques were proposed and studied in the context of numeric datasets. However, data with mixed-type attributes including numeric and categorical ones are commonly seen in real-life data repositories. In this study, we propose a framework for dimensionality reduction on mixed-type datasets including non-numeric attributes. Methods which measure dissimilarity between categorical values as well as distance between two mixed-type data points are investigated. Metrics for evaluating the quality of dimensionality reduction are also discussed. Experiments were conducted and the results verified the feasibility of the proposed framework.

■ TB-29

Tuesday, 10:30-12:00 - Building BM, ground floor, Room 7

Soft OR and Problem Structuring Methods 1

Stream: Soft OR and Problem Structuring Methods
Chair: *Doris Behrens*
Chair: *Jennifer Morgan*

1 - Behavioural implications of goal setting in standardised back-office tasks: An experimental investigation
Ann-Kathrin Hirzel, Michael Leyer

Service provider foster the standardisation of their processes and use goal setting in teams to increase efficiency of employees within these processes. This seems promising as goal setting theory postulates positive effects of goal achievement feedback on performance of employees. However, little is known regarding the impact of such a workplace design on employee satisfaction, emotions and team feeling. We investigate this impact in the domain of financial services being characterised by many standardised back-office tasks. Managers with a profound working experience are confronted with a standardised process of completing loan applications in an experimental setting. The treatment group (N=97) receives team feedback regarding the goals set while the control group works on the same task without goals (N=63). The results show that efficiency in decision making regarding loan applications made is 40 per cent significantly higher in the treatment group. However, while satisfaction (plus 12.5 per cent) and positive emotions (plus 37.8 per cent) are significantly enhanced, negative emotions and team feeling are not significantly different. The results indicate that goal setting fosters satisfaction which is expected to be important in maintaining efficiency benefits over time. Also, positive emotions can be associated with a standardised task that is otherwise typically associated with being boring.

2 - Strategic Options for Financial Sustainability in Brazilian metrological laboratories
Mischel Carmen N. Belderrain, Rafael Ichihara, Alberto Paucar-Caceres

The demand for metrological services has been growing in Brazil because of pressures to improve the competitiveness of manufactured goods in a global market. That improvement is to be achieved by using modern and complex industrial processes, introducing innovation, and complying with quality standards set by regulatory agencies. However, most Brazilian metrological laboratories have financial difficulties due to a number of factors such as the high cost of obtaining and maintaining the accreditation from the regulatory agencies and the high cost for training of technicians, among others. Thus, this work aims to apply the problem structuring method SODA (Strategic Options Development and Analysis) in a case study involving the metrological laboratories of SENAI CTGAS-ER, in order to identify the key issues to be explored and the strategic options for improving the financial performance of the services, considering the underlying oaganization dynamics.

3 - Regional development strategy: use of the DEMATEL method.
Magdalena Wagner

The aim of the paper is to discuss possible applications of operational research in spatial planning in general, and in regional planning in particular. Spatial planning is a multidisciplinary field which comprises various aspects of several disciplines, such as: law, statistics, environmental science, sociology, or mathematical analysis. It seems fair to say that operational research and multi-criteria decision aiding are remarkable, yet not thoroughly investigated, solutions to the spatial decision making. This paper offers a simple example of how to use and incorporate operational research into decision making at regional level. In the presented case study, DEMATEL method, which is used to capture the causal relationships between strategic goals or criteria, is examined as a solution for assessing interdependencies and linkages between regional strategy objectives. The research presents an analysis of relationships between goals adopted in the Development Strategy of the Lower Silesian Voivodeship 2020; the evaluation is based on an interview with an expert and decision maker co-responsible for the Strategy preparation. The conclusions drawn from this paper illustrate how operational research and MCDA methodology could be incorporated into spatial planners' workshop in order to make the strategy making process at regional level more transparent, rational, and efficient.

4 - Which Drivers Should Transport Your Cargo? Empirical Evidence from Long-haul Transport
Jelle de Vries, Debjit Roy, René de Koster

Every day thousands of people die in fatal traffic accidents on highways worldwide. Truck drivers are involved in a large share of these accidents, and face continuous pressure to combine driving safely with meeting productivity targets. Not all drivers respond equally well to these demands. Using a combination of GPS data gathered during 403 long-haul trips on 124 distinct routes in India, survey data of 50 drivers, and data obtained from the enterprise resource planning system, this study examines the role of individual driver characteristics (safety consciousness and personality in particular) in predicting risky driving behavior and driving productivity. The results show that, after controlling for trip-specific factors, more safety conscious drivers were generally more productive, and that more conscientious drivers displayed more risky driving behavior. Additional analyses suggest that a certain level of safety consciousness might be a necessary condition to achieve top levels of productivity. Transport companies and operations managers can use these results in the training and selection of drivers to meet their operational objectives in terms of safety and productivity.

■ TB-30

Tuesday, 10:30-12:00 - Building BM, 1st floor, Room 110

Recent Advances in Dynamics of Variational Inequalities and Equilibrum Problems 2

Stream: Recent Advances in Dynamics of Variational Inequalities and Equilibrum Problems
Chair: *Patrizia Daniele*

1 - Equilibria for semi-infinite programming
Giancarlo Bigi, Simone Sagratella

Bilevel optimization, noncooperative games and semi-infinite programming share some similarities, which may lead to meaningful connections. Indeed, theoretical developments and algorithms developed for one of these models could be exploited to cope with the others. In this talk we focus on the relationships between generalized Nash games and semi-infinite programming. In particular, we show how generalized Nash games can be exploited to solve semi-infinite programs with convex-concave constraints, relying on penalization techniques and a sequence of suitable saddlepoint problems.

2 - On minimax theorems for lower semicontinuous functions in Hilbert spaces
Monika Syga, Ewa Bednarczuk

We present minimax theorems for lower semicontinuous functions defined on a Hilbert space. The main tool is the theory of abstract convex functions and sufficient and necessary conditions for the minimax equality to hold for abstract convex functions. These conditions are expressed in terms of abstract subgradients. The talk is based on the joint work with Ewa Bednarczuk.

3 - Freight Service Provision for Disaster Relief: A Competitive Network Model with Computations
Anna Nagurney

We develop a competitive freight service provision network model for disaster relief. A humanitarian relief organization is interested in determining its most cost-effective deliveries of needed supplies in a crisis setting. Multiple freight service providers are engaged in competition to acquire the business of carrying the supplies in the amounts desired to the destinations. We describe the objective functions faced by the various decisionmakers and their underlying constraints, and present the optimality conditions. We then define the freight service provision network equilibrium for disaster relief and formulate it as a variational inequality problem. We provide qualitative results for the equilibrium product shipment pattern in terms of existence and uniqueness. For completeness, we also construct a new cooperative system-optimization model and discuss the price of anarchy relating the two models, along with additional theoretical results. In addition, we propose algorithmic schemes that take advantage of the underlying network structure of the problem. We present a case study on the shipment of personal protection equipment (PPE) supplies in the context of the Ebola humanitarian healthcare crisis in west Africa. The computational results in this paper yield insights on the equilibrium shipment and price patterns in the freight service provision sector for humanitarian operations in terms of enhanced or reduced competition, as well as increases in demand.

■ TB-31

Tuesday, 10:30-12:00 - Building BM, 1st floor, Room 111

Multiple Criteria in Humanitarian Logistics and Development

Stream: Humanitarian Operations
Chair: *Begoña Vitoriano*

1 - A multicriteria optimization approach to integrally deploy humanitarian logistic operations during floods
Christopher Mejía-Argueta, Juan Gaytán, Rafael Caballero, Julian Molina, Begoña Vitoriano

Natural disasters are phenomena which strike countries and lead to terrible consequences for the community. The highest growth has been observed in the hydrometeorological phenomena, possibly due to the increasing volume of precipitations. On the other hand, all disasters need quick and effective relief operations to diminish negative impacts and to maximize the fairness for those in need. However, these operations will depend on the disaster stage in order to be prepared for, respond to or recover from any kind of disaster. This work deals with frequent floods in the preparedness phase using a multicriteria optimization model. The proposed model considers integrally four operations: evacuation, distribution of humanitarian aid, location of emergency facilities (i.e. distribution centers, shelters and meeting points) and prepositioning of humanitarian aid. The three criteria modeled in the formulation are: Minimize the maximum evacuation flow-time, the maximum distribution flow-time and the total cost. The authors will show that using these criteria gives rise to equity in evacuation and distribution The efficient frontier is built using the weighting and the epsilon-constraint methods via a commercial software. The usefulness and the robustness of the model are verified utilizing data from the second worst Mexican flood and by means of different scenarios. The model provides more efficient solutions compared to those implemented by the Mexican authorities during the flood

2 - Multicriteria decision-making models for last mile distribution of humanitarian aid
Begoña Vitoriano, M. Teresa Ortuno, Gregorio Tirado, José María Ferrer, F. Javier Martin-Campo

The response phase in disaster management include activities developed after the impact of a disaster. Sometimes, they are carried out under very high time pressure and uncertainty, decreasing over time. Distribution of humanitarian aid in the last steps, from depots to the distribution points, is known as last mile distribution. These activities are developed under very different conditions of time pressure, lack of resources, state of infrastructure, security. . . being some criteria more important than others depending on the situation and the time from the impact, as well as the available time to obtain a solution. Several models for last mile distribution will be shown, including different assumptions and criteria related to cost, distribution time, equity, reliability and security. As an additional performance criterion, the runtime to solve them will be shown for three case studies: Niger famine (2005), Haiti earthquake (2010) and Pakistan floods (2010).

3 - Sizing and cost estimation of long-term maintenance systems to provide sustainable energy for rural development
M. Teresa Ortuno, Begoña Vitoriano, F. Javier Martin-Campo, Javier León, Luis Miguel Carrasco, Luis Navarte

Providing sustainable energy for rural development is one of the sustainable development goals proposed in 2015. Several initiatives have been launched in developing countries with governmental and international institutions support, being the photovoltaic rural electrification programs an alternative to grid and fossil fuels for remote areas. In order to ensure the access and provision along time, private-public partnerships with fee-for-service schemes have been implemented in several countries, as Morocco. These services include installation and maintenance for a given period. The sizing and cost of these maintenance systems must be estimated in advance to determine the fees when designing the scheme. The objective of this research is to obtain a model to approximate the cost and the required resources for such a system. An integer programming model has been developed with this aim, validated with real data of a company working in an area of Morocco. Nevertheless, usually companies and institutions will not be able to run a mathematical programming model which also requires an extensive information of the system. Therefore this research also includes the development of a simpler model, using basic information and based on rules and statistics.

4 - Improving the accessibility after a disaster: A double ant colony system
Antonio Jiménez-Martín, Víctor Sacristán, Alfonso Mateos

We propose a novel double ant colony system to deal with accessibility issues after a natural or man-made disaster. The aim is to maximize the number of survivors that reach the nearest regional center (center of economic and social activity in the region) in a minimum time by planning which rural roads damaged by the disaster should be repaired given the available financial and human resources. The double ant colony system considers pairs formed by an explorer and a worker ant. The aim of the explorer ant is to build paths from cities to their nearest regional centers, whereas the goal of the worker ant is to identify the optimal repair plan to maximize net accessibility. The two ants always work concurrently in pairs to build the paths and repair roads simultaneously. Candidate roads for repair have to be previously selected by the explorer ant in a transition rule, whereas the possibility of repairing a damaged road has to be taken into account when deciding which node to visit next. The proposed algorithm is illustrated by means of a large instance based on the Haiti natural disasters in August-September 2008, and its performance is compared with the combination of two metaheuristics: GRASP and VNS.

■ TB-33

Tuesday, 10:30-12:00 - Building BM, 1st floor, Room 113

Emerging Applications of Data Mining and Computational Statistics 6

Stream: Computational Statistics
Chair: *Pakize Taylan*
Chair: *Gerhard-Wilhelm Weber*
Chair: *Donghwan Kim*

1 - Identifying Quasi Equally Informative Subsets in Multi-objective Feature Selection Problems for Classification
Gulsah Karakaya, Stefano Galelli, Selin Damla Ahipasaoglu, Riccardo Taormina

We introduce a novel multi-objective feature selection approach for classification problems conceived to identify 1) a subset that maximizes the performance of a given classifier and 2) a set of subsets that are quasi equally informative, i.e., have almost the same classification performance, to the performance maximizing subset. The availability of quasi equally informative subsets enables us to 1) study the tradeoff between multiple measures of classsification performance and 2) understand the relative importance of each feature. We test our approach on several binary and multi-class classification problems benchmarking against traditional feature selection methods and demonstrate that our approach works well.

2 - Machine Learning Approaches towards Knowledge Extraction and Exploitation of Fleet Data
Subanatarajan Subbiah, Alexis-Sarda Espinosa, Sascha Rosbach, Simone Turrin

Machine learning algorithms aid to extract the knowledge hidden in the data and exploit it in a way that is beneficial to the user. The applications of machine learning are manifold, but classification is one of the most common ones. In this work, we implement and compare some of the recent machine learning techniques for classification. We look at several strategies for cross-validation and confidence interval generation and apply them to various datasets in order to assess performance. Finally, we utilize these results to extract knowledge from real data collected from a condition monitoring system from ABB, which pertains a fleet of electrical motors. We use this to explore the data, to gain insights into the workflow of the analysis, and interpret the outcome in the context of motor health monitoring. In addition we also present another learning approach for effective maintenance using self-organizing maps (SOM). Using the quantization error of the test data as a metric to diagnose the system with healthy and faulty training data is not reliable in all cases as the training data might contain noise thus resulting in an unreliable result of the SOM. In this work we introduce a method to use SOM and U-matrix to build an undirected graph and using shortest path algorithms to define a proximity measure that represents the closeness of the test data to that of the training data thereby improving the results of the SOM more reliable for maintenance and diagnostic purposes.

3 - Kernel LDA-based Rotation Forest for Improvement of Classification performance
Donghwan Kim, Seung Hwan Park, Jun-Geol Baek

Classification is one of the main issues in the field of machine learning. In general, an ensemble classifier has a more accurate performance compared to a single classifier. Empirically, ensemble methods tend to yield better results when there is a significant diversity among the each classification models. Many ensemble methods, therefore, seek to promote diversity among the models that they combine with. Rotation Forest is a tree-based ensemble method by applying principal component analysis to Random Forest that enhance the high accuracy and diversity. However, existing rotation method have a disadvantage, because rotation using principal component analysis do not reflect the information of the data labels. In addition, there is also meaningless when applied to the principal component analysis for rotation, because of the nature of the data itself. In this study, to overcome these problems, we suggest a Kernel Fisher's Discriminant Analysis-based rotation Forest that reflect data labels and can be used in the non-linear data structure. Applying to real dataset and verifying the performance of the proposed method by comparison with the existing method.

4 - Performance of Big Data Business Analytics
Marijana Zekic-Susac, Adela Has

Big Data business analytics is emphasized as crucial for managing business performance today. The enormous quantity of data generated every day by companies, social networks, web sites is also characterized by a variety of multimedia formats of data, documents, social media content, etc. However, besides a number of advantages of using Big Data analytics over analytical procedures within a standard transactional database system or a data warehouse, there are still some limitations that should be addressed. For example, available business analytics tools included in Big Data platforms still do not provide the same variety of methods for modeling purposes as in traditional analytics. This paper compares several popular business analytics tools within Big Data platforms in relation to the methods supported, result explanation and visualization. Also, a comparison of modelling accuracy by using a dataset in a Big Data analytics and in a local analytical system is conducted. Predictive power and input space flexibility is analyzed. Finally, some suggestions for improving the modeling precision of Big Data analytics tools, and for extending the diversity of methodological basis are given. It is concluded that business analytics today needs adjustments to address user needs in order to provide the accuracy as well as flexibility to deal with structured and unstructured data.

■ TB-34

Tuesday, 10:30-12:00 - Building BM, 1st floor, Room 116

Rail Operations and Operations of Container Terminals

Stream: Supply Chain Scheduling and Logistics
Chair: *Alena Otto*
Chair: *Jenny Nossack*

1 - Scheduling Planned Maintenance Activities: A Metaheuristic Approach
Sundaravalli Narayanaswami

Railway transportation operations are planned and operated under four levels of hierarchies: strategic, tactical, operational and real-time. Strategic level plans are typically developed for a couple of years and tactical level planning is done for a year's time typically. At the operational level, humans assign tracks to trains for specic times. The objective is to typically maximize the overall system efciency while abiding by a number of safety and desirability constraints. Some decisions that are made at this level are (i) which train takes the siding when two trains travelling in opposite directions meet each other, or (ii) when a faster train overtakes the leading slower train. Dispatchers also decide on the exit and hold times at all arc segments of the territory. Maintenance of track while adhering to the movement planning problem is a major activity undertaken at the operational level. The territory consists typically of few miles of single track and double track segments with sidings on each. To enable smooth and regular maintenance, maintenance of Way (MOW) window is well-dened on these segments, at specic mileposts at specic times and durations, during which train movements are forbidden. Trains are of different physical and operational features which further impose some strict and preferred planning restrictions. The objective of our model is to develop a deadlock-free, feasible movement plan.

2 - Static Timetable Re-Scheduling for Work Maintenance Operations
Samuel Deleplanque

Today, several railway companies need a tool applied on the train timetables which have to be rescheduled when the company must make some maintenance operations on the network. Indeed, this rescheduling process is often made by hand and it is not usually well optimized if the network is relatively large. In this work, we consider a specific railway optimisation problem which will modify the timetables in order to leave some tracks empty at a specific moment and in order to realize some work maintenance. The difficulties are the number of constraints, the size of the network, the quantity of trains and many other features related to the specific railway system considered. These difficulties imply that some choices have to be made. However, the maintenance works considered are planned three weeks in advance. Then, we solve the problem by an exact method. We propose a model with a Mixed Integer Program taking into account several maintenance operations (but a maximum of one by track) for a given time window and for a given area. The model integrates some transfer constraints (one train can not arrive after the departure of one another) and minimizes the total arrival delay.

3 - Shunting Operations at Flat Yards: Retrieving Freight Railcars from Storage Tracks
Kilian Seifried, Florian Jaehn, Alena Otto

In this paper, we study the railcar retrieval problem (RRT) where a specified number of certain types of railcars has to be withdrawn from the storage tracks of a flat yard. This task arises in the daily operations of yards belonging to a workshop for railcar maintenance. The objective is to minimize the total costs of shunting, i.e. minimizing the usage of shunting engines.

We describe the RRT formally as a mixed-integer program and prove it to be NP-hard in the general case. In addition, we analyze several heuristics for solving the problem and provide their worst case performance guarantee. Furthermore, computational experiments are conducted that show the average performance of the introduced heuristics and compare them to the optimal solution provided by the mixed-integer program. The results show that both, the heuristics and the exact formulation come to solutions for realistically-sized instances in running times acceptable to practitioners, leading to the advice that optimization should be implemented in practice in order to save valuable resources.

4 - Container Dispatching and Conflict-Free Yard Crane Routing in an Automated Container Terminal
Jenny Nossack, Dirk Briskorn, Erwin Pesch

We focus on a container dispatching and conflict-free yard crane routing problem that arises at a storage yard in an automated, maritime container terminal. A storage yard serves as an intermediate buffer for import/export containers and exchanges containers between water- and landside of a maritime terminal. The considered storage yard is perpendicular to the waterside and employs two rail mounted gantry cranes that have different sizes and have thus the possibility to cross each other. The problem at hand evaluates in which order and by which crane the import/export containers are transported in order to minimize the makespan and prevent crane interferences. We solve this problem to optimality by a branch-and-cut approach that decomposes the problem into two problem classes and connects them via logic-based Benders constraints. We assess the quality of our solution method in a computational study.

■ TB-35

Tuesday, 10:30-12:00 - Building BM, ground floor, Room 17

3D Structure Prediction and Evaluation

Stream: Computational Biology, Bioinformatics and Medicine
Chair: *Piotr Lukasiak*

1 - Predicting microRNA Structure, Dynamics, and Function
Francois Major

Structure. We use sets of nucleotide cyclic motifs to define RNA structures. This model allows us to unify all base pairing energetic contributions in an effective scoring function to tackle the problem of RNA folding. We used this model to define rules of precursor microRNA (miRNA) folding in double helices, despite the presence of a number of presumed mismatches and bulges.

Dynamics and maturation. MiRNAs are crucial gene expression regulators. We studied a single nucleotide polymorphism (SNP) in miR-125a, a miRNA located within a minor allele expressed by breast cancer patients. Building upon a model of RNA dynamics derived from nuclear magnetic resonance studies, we developed a quantitative model enabling the visualization and comparison of networks of transient structures. We observed a high correlation between the distances between networks of variants with that of their respective wild types and their relative degrees of maturation to the latter, suggesting an important role of transient structures in miRNA homeostasis.

Function. We introduced a new algorithm to predict genome-wide expression data from initial transcriptome abundance. The algorithm simulates the miRNA and mRNA hybridization competition that occurs in given cellular conditions, and derives the whole set of miRNA::mRNA interactions at equilibrium (microtargetome). Interestingly, solving the competition improves the accuracy of miRNA target predictions.

2 - RNAComposer and 3D Structure Prediction with Module Substitutions
Marta Szachniuk, Maciej Antczak, Mariusz Popenda, Tomasz Żok, Joanna Sarzynska

RNAComposer is an original knowledge-based method for RNA 3D structure prediction. It has been implemented as fully automated webserver tool available at http://rnacomposer.cs.put.poznan.pl and http://rnacomposer.ibch.poznan.pl. Since its release in 2012, it has gathered many users - from scientific and educational side - needing a quick and easy access to the 3D models predicted from RNA sequence or secondary structure. However, it has been observed that full automation of the modelling process and the limited repository of experimentally solved RNA structures (serving as knowledge base for the prediction algorithm), in some cases hinders high-quality prediction. Here, we present an upgraded version of the RNAComposer system, that allows the user to adjust preliminary prediction. It is achieved by a selection of new functions, in particular module substitution, specified structure exclusion and control over de novo generated fragments.

3 - Computational Strategy for Consensus-based Ranking of 3D Models of Biomolecules
Piotr Lukasiak, Tomasz Ratajczak, Maciej Antczak, Thomas Villmann

Progress in computational methods devoted to predict 3D structure of biomolecules (proteins, RNAs) create the decision to select the best near-native structure among all available ones, as a crucial step in such process. One can find many different approaches that were applied to solve that problem over the years including mathematically and biologically based measures and strategies. Unfortunately, despite the available, sophisticated approaches, the quality of obtained solution is still far from satisfactory level. Trying to cure that problem new consensus-based method devoted to rank structures has been proposed. Our approach combines clustering strategy with consensus approach. Each model is divided into the same number of substructures, and for corresponding substructures consensus score is calculated. Based on such local score, preranking for all models is created, and then, similar structures with the highest, and lowest score are grouped into clusters. Final ranking is obtained based on distances between clusters. Extensive benchmark sets of various collections of predicted models in comparison with real cases shows high quality of proposed strategy.

■ TB-36

Tuesday, 10:30-12:00 - Building BM, ground floor, Room 18

Information and Intelligent Systems 1

Stream: Information and Intelligent Systems
Chair: *Roman Senkerik*
Chair: *Gerhard-Wilhelm Weber*

1 - EIV Regression with Bounded Error Distributions and Generalized Linear-Fractional Programming
Michal Cerny, Milan Hladik

We consider a linear regression model where the design matrix is stochastic and is observable only in a contaminated form ("structural errors-in-variables model"). We impose the following assumptions on the random variables involved: (i) we need a form of an asymptotic regularity of regressors, (ii) we assume that all errors (both in the explanatory variable and in the regressors) share a uniform bound, which is unknown and is to be estimated, (iii) that asymptotically, the error bounds are approached arbitrarily close with probability tending to one. These are, in a sense, non-traditional assumptions. They are quite general and it is interesting that we need neither independence, nor zero means, nor identical distributions. Under assumptions (i)-(iii), we derive a consistent estimator for the regression parameters. The estimate of the regression parameters can be understood as a solution to the Total Least Squares problem where the usual Frobenius matrix norm is replaced by Chebyshev matrix norm. Finally, we design an algorithm for computation of the estimator. Using interval-theoretic techniques, we reduce the problem to solving a family of generalized linear-fractional programming problems. A practically important consequence of our methodology is: when the signs of regression parameters are known a priori (e.g., they are known to be nonnegative), then a single GLFP suffices.

2 - Developing an Air Traffic Control Difficulty Index Using Aircraft Trajectory Information
Sakae Nagaoka, Mark Brown

Future air traffic management will be based on aircraft trajectory information. Indices derivable from aircraft trajectory information will be needed to assess airspace complexity and safety. To identify complex airspace "hot spots", we are developing a new index associated with the difficulty of air traffic control using the proximity situations of aircraft pairs. This is a directly observable time-dependent metric. First, we developed an aircraft pairwise proximity-based metric derived from trajectory information which reflects changes of three-dimensional proximity in a projected time horizon, treating horizontal and vertical distances independently and assuming linear motions of aircraft. Its objective function is the product of three exponential functions which represents the relative horizontal and vertical separations and decays with increasing projected time. Next, we transformed this pairwise index to an airspace-wise metric to evaluate the difficulty of control of volumes of airspace containing multiple aircraft. Then, to avoid the erroneous prediction of proximity situations due to linear extrapolation, we considered how to modify the method to use trajectory change point information. We briefly describes the development of the index, including our method of transforming from pairwise to an airspace-wise metrics and the use of trajectory change point information. Simple calculated examples are shown for illustration.

3 - Green Virtual Network Functions Placement Under Uncertainty Constraints
Antonio Marotta, Andreas Kassler

Reducing the CAPEX and OPEX is a major concern for Telecom Operators (TOs). Network Function Virtualization (NFV) has been considered a key aspect to virtualize network functions. Virtual Network Functions (VNFs) can be deployed as a set of Virtual Machines (VMs) on commodity hardware. It becomes crucial for network operators to minimize the power consumption of their VNF infrastructure, by using the minimum set of physical servers and networking equipment subject to the constraints that VNFs impose in terms of resource requirements. In this work, we present a joint resource and flow routing assignment problem for VNFs, with the objective of minimizing both the power consumption of the servers and switches needed to deploy the VNF service graphs. In contrast to existing works, which assume perfect knowledge on input parameters, such as traffic demands among the VNFs, we propose a novel model based on Robust Optimization (RO) to cope with uncertainty on input parameters. As use-case we apply our model to the virtualized Evolved Packet Core (vEPC), namely the cornerstone for next-generation mobile networks. The model allows to trade-off between two important aspects: the power consumption minimization on one side and the protection from severe deviations of the input parameters, such as traffic demands and compute resources needed by individual components, which may result into SLA violations. Part of this work has been funded by KK-Stiftelsen through the HITS project.

4 - Symmetry Breaking in Mixed Integer Programming Formulations for Blocking Two-level Orthogonal Experimental Designs
Nha Vo-Thanh, Peter Goos, Raf Jans, Eric Schoen

Two-level orthogonal designs play an important role in industrial screening experiments, in which the main goal is to identify the most important factors impacting the output of a process or the performance of a product. Often, the tests suggested by the orthogonal designs cannot be performed on a single day or using a single batch of raw material. This causes day-to-day or batch-to-batch variation in the experimental results, and necessitates the use of orthogonal blocking patterns. These blocking patterns ensure that the factors' main effects can be estimated independently from the day-to-day or batch-to-batch variation. Finding an optimal orthogonal blocking pattern for an orthogonal design is a major challenge. Recently, mixed integer programming has been used for that purpose. While this approach is promising, computational experiments have indicated it is quite slow. We show how to speed up the mixed integer programming approach by adding symmetry breaking constraints, and study the usefulness of an asymmetric representatives formulation. In other words, we introduce state-of-the-art symmetry breaking approaches in optimal experimental design. We perform extensive computational experiments to test which combinations of symmetry breaking constraints work best. Throughout, we consider two kinds of symmetry: symmetry due to the fact that the blocks can be relabeled without affecting the quality of the blocking pattern, and symmetry due to replicated test combinations.

■ TB-38

Tuesday, 10:30-12:00 - Building BM, 1st floor, Room 109M

Health Care Management 2

Stream: Health Care Management
Chair: *Mohamed Cissé*

1 - Finding Good Solution Subspaces in Nurse Scheduling

Atsuko Ikegami, Masaya Hasebe, Koji Nonobe

Nurse scheduling is a hard combinatorial problem, with tight constraints involving factors such as the skill levels of teams, balancing of workload among nurses, and consideration of nurses' preferences. In nurse scheduling, it is also difficult to evaluate the goodness of solutions. This is because it is impossible for a human to explicitly describe all considerations in advance. If, however, the solution space can be understood, particularly the subspace of optimal/good solutions for a given objective function, then this subspace can be helpful in scheduling nurses efficiently. In previous work, we showed one way to represent all feasible schedules for a specific nurse by using a network, whose nodes represent feasible 7-day schedules for each week along with the feasible numbers of total shifts each nurse works until the week. We also showed a method for choosing good schedules from the network after fixing the schedules of other nurses. Here, that type of network is reduced in size by taking the minor that results from relaxation of the lower and upper bounds for the number of allowed shifts. Then, using the modified networks and choosing optimal schedules that satisfy the relaxed constraints in the networks, we enumerate the optimal solutions, as a seed, using the optimal solution obtained by a solver. We are able to find many optimal solutions, even for problem instances that were given as algorithmically intractable in some papers and on a benchmark site.

2 - Exploring Bed Management Behaviour Through Unsupervised Neural Networks

Michele Sonnessa, Marina Resta, Elena Tanfani, Angela Testi

Hospital bed management is considered a critical function in managing capacity and patient flows across emergency departments and hospital wards. Literature stresses its importance in avoiding system bottlenecks by considering both the elective and emergent patient flow admissions. In fact, the success of bed management should be assessed in its ability to effectively support the flows across integrated healthcare systems in a concise way. Nevertheless, there are no clear definitions of the rules and best practices adopted by bed managers in smoothing the competing flows and allocating them the available bed capacity. They are often based on fuzzy approaches, mostly relying on individual experience. Previous works tested alternative algorithms, which mimic the behavior of bed managers Discrete Event, System Dynamics and Hybrid simulation models. They are aimed at supporting the performance assessment of bed management performance and testing alternative rules effectiveness. This work presents the attempt to catch bed manager real-world rules by means of a neural network. In particular, we use an unsupervised neural model to explore input data and to extract significant patterns. This should help bed managers to both test the effectiveness of the rules actually in use and to explore the feasibility of alternative approaches based on the intrinsic features of incoming data.

3 - Resource Allocation and Interday Appointment Scheduling in Primary Care

Matthias Schacht, Brigitte Werners, Lara Wiesche

During the week, varying demand for treatment in primary care is observable. This is because the number of those patients who join the clinic without an appointment (walk-ins) strongly depends on the specific weekday. Without anticipating these variations, there are days with high patient's occurrences causing long waiting times for patients and overtime for the primary care practitioner (PCP). Thus, matching capacity with demand is an important task in order to satisfy PCPs as well as patients preferences. The resources offered - in terms of capacity of treatment time for each working day - can be adjusted to a limited extend in order to provide more treatment time on days with high demand. In addition to walk-ins, there are patients who book their appointments in advance (preschedules). For those preschedules, appointment slots are provided by the PCP. By offering appointment slots on days with a small amount of walk-ins, a more balanced utilization can be obtained. We present an innovative MILP capturing the characteristics of walk-ins and preschedules as well as PCPs objective of a steady utilization and constant working times during the week. The model gives back a configuration of a weekly profile for PCPs with working time and the number of appointment slots to be provided on each working day. Results are evaluated using stochastic simulation.

4 - A Hybrid Genetic Algorithm for Home Health Care Routing Problem

Mohamed Cissé

Home health care routing problem (HHCRP) is an extension of vehicle routing problem (VRP) augmented by many un-sual constraints. HHCRP consists of designing a set of routes used by care workers to provide care to patients who live in a geographic area and who must be treated at home. Hence, care activities (i.e., patient visits) must be planned over a planning horizon to minimize criteria, such as travel cost, overtime or to maximize the quality of service while respecting several side-constraints: time windows, synchronization, break, qualification, continuity of care. To solve the problem, we propose a genetic algorithm hybridized with a local search procedure, namely a memetic algorithm or hybrid genetic algorithm.

A chromosome encoding a solution consists of a giant tour of services without trip delimiters. A new Split procedure is introduced to decode the solution. From an inital population generated both simple heuristics, the genetic algorithm evolves this population to find better solutions. Parents are selected thanks to a binary tournament, OX is used as crossover operator and local search replaces mutation. Distance measures are implemented to guarantee and maintain the diversity of population. This framework was already proposed to solve VRP. However, to the best of our knowledge, it is the first time that this framework is implemented to solve HHCRP.

Finally, experiments are conducted on instances from the literature to evaluate our approach.

■ TB-39

Tuesday, 10:30-12:00 - Building WE, 1st floor, Room 107

Applications in Decision Making & Decision Analysis

Stream: Decision Support Systems
Chair: *Boris Delibasic*
Chair: *Isabelle Linden*

1 - Incorporating value judgements in measuring the regional competitiveness of Peru
Charles Vincent

Competitiveness measures how a nation administers its competencies and resources to bring more prosperity to its people. The concept of competitiveness of regions within a country is similar to the concept of competitiveness of countries. Undoubtedly, competitiveness has a positive effect on long-term economic growth. This paper provides an envelopment-based methodology without explicit inputs to develop a regional competitiveness index for the 26 regions of Peru, and further discusses possible ways to incorporate value judgements of the decision-makers into the model. In this way, the model advances a more realistic way to derive a regional competitiveness index, considering not only the five pillars of competitiveness (economy, firms, government, infrastructure, persons), but also the knowledge of the decision-makers.

2 - Design of an Information System for Analyzing the Performance of Continuous Production Systems
Volkan Sönmez, Murat Caner Testik

Companies that want to improve their processes should analyze performances of processes or equipment. To analyze performance effectively and on time, intelligent systems like decision support systems or expert systems are suggested in the literature. However, systems developed within a company can be more beneficial compared to purchasing general solutions. In this research, an information system is designed for manufacturing companies having continuous production lines. The components of proposed framework are described by using some tools of general modeling languages, specifically UML and SysML. A database is normalized by applying normalization technique, and relationships within the database are described via entity-relationship diagrams. Users and their primary operations are described by use-case diagrams. Basic calculations and unit conversions are presented with parametric diagrams. Flow charts are used to design and document the working principles of the components of the system. With the proposed design, it is aimed to put forth a guideline for companies to develop an effective information system easily, quickly and with a low cost.

3 - Decision Tables in the Qualitative Multi-Criteria Method DEX: Assessment of Completeness, Consistency, Monotonicity, Linearity and Symmetricity
Marko Bohanec

DEX (Decision EXpert) is a hierarchical, qualitative, rule-based, multi-criteria decision modelling method. It has been used in the development of numerous knowledge-based decision-support models and systems in various areas, including economy, finance, agriculture and tourism. We have compiled a research database of DEX models, containing 582 models developed in 140 decision-making projects conducted in the period 1979-2015. All these models are "real" in the sense that they were developed by real people with specific decision problems in mind, and as such provide a useful research resource. In this paper, we analyze decision tables and decision rules that occur in the dataset. In total, there are 6362 decision tables of very different sizes, aggregating from one to eight decision criteria. In average, they aggregate 2.5 criteria and map to 3.7 qualitative classes. There are 3062 unique decision tables in the sense that they differ from all other unique tables in at least one decision rule. In addition to statistical analyses, we assess various properties of decision tables and underlying aggregation functions: completeness, consistency, monotonicity, linearity, and symmetricity. For instance, 92.57 % of functions in the dataset are complete and 93.25 % of functions are monotone. The obtained results are useful particularly for improving the design of decision-rule acquisition methods used in the construction of DEX models for knowledge-based decision support systems.

■ TB-40

Tuesday, 10:30-12:00 - Building WE, 1st floor, Room 108

Mathematical Models in Macro- and Microeconomics 2

Stream: Mathematical Models in Macro- and Microeconomics
Chair: *Gerhard-Wilhelm Weber*
Chair: *Ying-Chin Ho*
Chair: *Duan Li*

1 - A Supportive Pricing Model for Small Suppliers with Purchase Order Financing
Andy Wu

Traditionally, a business buyer should try his best to reduce the cost by cutting the purchase price. However, if this buyer's unreliable supplier has limited resources to process this order, the situation may become different. We propose a scheme named pricing support purchase order financing, under which it may be the buyer's best interest to raise the purchase price such that the value increment of the order (as the loan mortgage) can reduce the supplier's obstacles in financing. In this study, a Stackelberg model is used to illustrate the interaction between the buyer and the supplier. For a rational supplier, his optimal input quantity shall depend on the order price set by the powerful buyer. It is verified that when the price is lower than the supplier's break-even value, it is optimal for him to give up the deal. When the price is between the break-even value and the supplier's sweet spot, it is optimal that the supplier takes his input equal to the buyer's order size. Otherwise, the supplier is better off enlarging his input to ensure fulfilling the entire order. The buyer can foresee supplier's response and design the purchasing contract accordingly. First, we verify that the buyer's optimal order size is a step function of the order price. Second, we prove that there are only four types of design in the collection of the optimal purchasing contracts. Sometimes, waiving the supplier is preferred.

2 - Short Selling and Liquidity
Bo Liu

I establish a theoretical model to examine the interaction between short selling and market liquidity and document that short selling has two channels to affect the market liquidity: first, it would directly change sellers' pricing strategy by involving in the competition of sales orders offering; second, it would indirectly change buyers' strategy from the perspective of liquidity consumption. Full short selling will expand the uninformed traders' sales orders, and mitigate the adverse selection contained in the pooling order flows that the liquidity providers may face thus increase the market liquidity. However, restricted short selling will highlight the relative strength of informed traders in the pooling order flows and increase the potential adverse selection risk hence discourage the liquidity providing.

3 - A Study on the Operational Problems at the Inbound Side of a Distributor Cross Docking Workplace
Ying-Chin Ho, Chih-Feng Chou

The environment of this study is a distributor cross docking workplace. In this environment, inbound trucks deliver different types of items to the cross docking workplace. Each type of items is placed in a temporary storage block. Human pickers collect items from temporary storage blocks according to customer orders and place them on palettes. Palettes with completed orders are then placed on outbound trucks and shipped to customers. Studies have shown cross docking has several advantages, e.g. less storage and handling cost, faster delivery of goods to customers and less storage space requirement. Despite of these advantages, it is possible none of these advantages can be achieved, if cross docking is executed incorrectly and/or inefficiently. In this study, we study three operational problems at the inbound side of a distributor cross docking workplace. These problems include the problem of assigning receiving doors to inbound trucks, the problem of clearing the temporary storage blocks for inbound items and the problem of assigning temporary storage blocks to inbound items. We proposed different solutions for each problem and conducted simulation experiments to compare their performance in three different performance measures - total system time, total receiving distance and total picking distance. It is hoped the knowledge learned from this study can assist distribution centers with similar crossing docking environments in improving their crossing docking performance.

■ TB-41

Tuesday, 10:30-12:00 - Building WE, 2nd floor, Room 209

Finance and OR 3

Stream: Financial Mathematics and OR
Chair: *Nuray Celebi*
Chair: *Gerhard-Wilhelm Weber*
Chair: *Ali Hamidoglu*

1 - Financial Condition Index: Could it be a Better Policy Instrument for Identifying Financial Risks for an Economy?
Sayan Banerjee

The impact of financial sector shocks seems to have a real impact on the overall economy and therefore,need has aroused for an alternative economic model, developing a single indicator that could be constructed taking into account multiple financial variable. Financial Condition Index (FCI) is one such attempt. A series of such financial models have been developed in last decade using a variety of methodologies. Most of the methodologies could be divided into two broad categories: a Weighted Sum Approach and a Principal Component Approach (PCA). In the first case, the weights on each financial variable are generally assigned on the basis of estimates of the relative impacts of changes in the variable on real GDP. The principal component methodology extracts a common factor from a group of several financial variables. This component factor captures the greatest common variation in the variables and used as the FCI. The FCIs are used for two main purposes, they can be useful in forecasting the impact of financial condition on growth (GDP) or they could be useful tools to measure whether financial condition have tightened or loosened. However, construction and interpretation of this new instrument is not standardized neither it is based on any strong theoretical framework. It is therefore, important, that we look at various existing FCIs, identify their characteristics and limitations, which then could be helpful in in constructing one for an economy.

2 - Forth Order Stochastic Dominance Efficiency Test and an Empirical Evaluation
Nasim Dehghan Hardoroudi, Markku Kallio

Stochastic dominance is an important tool in aiding decisions under uncertainty when the decision maker's utility function is unknown. Forth order stochastic dominance (FOSD) is of interest in practice, since it accounts not only for risk-averseness and non-satiability of a decision maker, but also for prudence or down-side risk aversion (non-negative third derivative of the utility function), as well as temperance (non-positive fourth derivative) preferences. In this study, we propose a novel FOSD efficiency test. We derive the necessary and sufficient conditions for such test, which is based on nonlinear convex optimization problem. For comparison, we provide numerical illustrations for second and third order stochastic dominance (SSD, TSD) as well as decreasing absolute risk aversion stochastic dominance (DSD) besides the FOSD test, using stock market data of the US. The market index as benchmark is found inefficient and dominated under the all types of stochastic dominance.

3 - Some Tests for Stochastic Dominance Efficiency
Markku Kallio, Nasim Dehghan Hardoroudi

We consider third order stochastic dominance (TSD), decreasing absolute risk aversion stochastic dominance (DSD) as well as stochastic dominance (ESD) based on the family negative exponential utility functions. These concepts are of interest because the respective classes of utility functions convey observed properties of individual preferences. Using the efficiency concept introduced by Post, we derive necessary and sufficient tests for efficiency under the three types of stochastic dominance. For the well-known TSD efficiency test, we provide a simple and novel argument. Our DSD efficiency test is new, it relies on our argument for the TSD test, and it circumvents shortcomings in recent literature. Formally the ESD efficiency test is a minor modification of the DSD test. Using stock market data of the US, a companion paper (Dehghan Hardoroudi and Kallio) provides demonstrations, among others, for the three tests.

■ TB-42

Tuesday, 10:30-12:00 - Building WE, 1st floor, Room 120

Energy in the context of the Post Paris Climate policy

Stream: Long Term Planning in Energy, Environment and Climate
Chair: *Sandrine Selosse*

1 - Biofuel Potential in Mexico: Land Use, Economic and Environmental Effects
Hector Nunez

This paper aims to develop a framework to forecast biofuel policies impacts about a decade ahead in Mexico, where there have been several attempts to introduce biofuels into the market but so far no success. Technically, we develop an endogenous-price mathematical programming model emphasizing the Mexican agricultural and fuel sectors, which are embedded in a multi-region, multi-product, spatial partial equilibrium model of the world economy. There is a module for the U.S. and another for Rest of the World. Mexico is disaggregated into 193 districts. Production functions are specified for 14 major crops as well as livestock. Biofuel can be produced both from dedicated crops and from agroindustrial residues. Oil, diesel and gasoline production are also modeled in detail. We consider three policy alternatives as well as a base case in which, as now, liquid fuels are all derived from fossil sources. The first alternative consists of subsidies to biofuel producers, the second of blending mandates and the third of both combined. In all three cases, we consider several values for the policy variables. Biofuel imports are allowed in all cases. Preliminary results show that some compensating redistribution may be needed if these policies are to be seen as politically sustainable. The reduction of GHG emissions results in a small social welfare gain for Mexico.

2 - Towards a 1.5 degree compatible energy system for France
Ariane Millot, Edi Assoumou, François Briens, Rémy Doudard, Thomas Le Gallic, Nadia Maïzi

Over the last 20 years, successive COPs have highlighted the need for urgent action in reducing greenhouse gas emissions to avoid the global mean temperature exceeding a 2'C increase. To deal with climate urgency, that already weaken several regions of the globe, the target of 1.5'C has been mentioned in the Paris agreement in December 2015. This paper intends to explore the conditions under which such a stringent constraint must be fulfill at a country level, France. The study will focus on energy issues, relying on the TIMES-FR approach performing the optimization of the energy system in the long-term with descriptions of the technologies. The analysis horizon spans to 2072. New planning paths must be accepted that combine changing demographic structure,technologies and societal choices.

3 - The Post-Paris climate policy and the decarbonisation of the energy system
Sandrine Selosse

After a large awareness and decades of negotiations, a historic climate agreement was adopted by consensus by all 195 parties at the UNFCCC, the December 12, 2015, in order to provide an answer to this climate issue. This agreement marks a turning point towards a new world, a decarbonized world. At least, that is its ambition. Using a long-term prospective approach, and more precisely the bottom-up optimization model TIAM-FR, we investigate different GHG mitigation trajectories in line with 1) commitments occurring according to the Paris Climate Agreement, 2) an ambitious ultimate and global target by 2050 in line with the 2'C objective and the IPCC recommendations (AR4 and AR5), and 3) regional assumptions by 2050 according to the optimistic/pessimistic revisions of long-term commitments, including a carbon price. The latter is considered in the light of Paragraph 137 of the Paris agreement that recognizes the importance of providing incentives to emission reduction activities, in particular with regard to tools such as national policies and carbon pricing. We analyze a combination of these scenarios to discuss decarbonized pathway and the technological solutions to climate issues. Our analysis of the scenario results then focuses on the effects on the level of GHG emissions and the carbon abatement costs associated with the different GHG reduction targets for regions (developed, fast developing or developing countries) with national focus.

■ TB-43

Tuesday, 10:30-12:00 - Building WE, ground floor, Room 18

Optimization in Renewable Energy Systems 2

Stream: Optimization in Renewable Energy Systems
Chair: *Andres Ramos*

1 - Analysis of Operation Reserves in a Hydrothermal Electric System with High Wind Power Share under Demand and Wind Power Uncertainties
Andres Ramos, Germán Morales-Espana, Michel Rivier, Javier García-González, Jesus M. Latorre

The paper analyses the amount of operation reserves procured in a hydrothermal system to deal with wind power and demand uncertainty. The operation planning of the system is formulated as a detailed hourly unit commitment (UC) solved as an MIP optimization problem. This model takes into account the startup and shutdown power trajectories of thermal units, up and down secondary reserves, up and down power ramps, minimum up and down times. Besides, hydro power plants are represented in the model in an aggregated mode but still capturing their capability to provide operation reserves. The operation cost determined by the UC is re-evaluated through 5-min economic dispatch (ED) simulation under hundreds of wind generation and demand scenarios. This combination of optimization and simulation models allows to analyze:

• On the one hand, the effect in the operation reserve usage of the hourly energy-block operation planning versus the 5-min economic dispatch and • On the other hand, the impact of the wind power and demand uncertainty in the use of the operation reserves procured Additionally, alternative time periods for market clearance different from one hour are analyzed and their impact on the operation reserves usage, e.g., a half an hour or a quarter of an hour. The previous analysis is done for the Spanish electric system to see the effects of the current operation reserve procurement.

2 - Robust Unit Commitment with Dispatchable Wind: An LP Reformulation of the Second Stage
Germán Morales-Espana, Álvaro Lorca, Laura Ramirez-Elizondo, Mathijs de Weerdt

The increasing penetration of uncertain generation such as wind and solar in power systems imposes new challenges to the Unit Commitment (UC) problem, one of the most critical tasks in power systems operations. The two most common approaches to address these challenges — stochastic and robust optimization — have drawbacks that prevent or restrict their application to real-world systems. This paper demonstrates that an adaptive robust UC in which, by considering wind dispatch flexibility, the second-stage problem, usually being non-convex, can be represented with an equivalent linear program (LP). Consequently, the full two-stage robust UC formulation, which is typically a bi-level problem, can be translated into an equivalent single-level mixed-integer program. Experiments on the IEEE 118-bus test system show that the computation time, and the number of scenarios and violations can be significantly reduced in the unified stochastic and robust approach compared to a pure stochastic approach. In addition, the proposed formulation presents similar results compared to the adaptive robust approach which includes budget of uncertainty. The formulation is evaluated considering dispatchable wind (i.e., allowing wind curtailment), but it can be applied to any uncertain source with the possibility of being curtailed

3 - A binary-real coded electromagnetism-like algorithm for wind farm layout optimization
Alkin Yurtkuran

In this paper, a binary-real coded electromagnetism-like algorithm (EMA) is presented to solve wind turbine placement problem. The main objective of the problem is to find the optimum layout of wind turbines in order to maximize the wind farm power output and efficiency. Electromagnetism-like algorithm is one of the recently introduced physics-inspired meta-heuristic algorithms, which simulates the behavior of charged particles in an electromagnetic field. A special solution representation is proposed, where real and binary coding schemes are combined. In proposed solution representation, real part corresponds to turbine position in a two-dimensional space, whereas binary part represents turbine condition i.e. whether it is installed or not. Further, instead of fixed grid-based positioning as in past studies, real-coded based positioning is employed. Three well-known benchmarks cases are considered; (i) unidirectional uniform wind, (ii) uniform wind with variable direction, and (iii) non-uniform wind with variable direction. Experiments are conducted and proposed EMA is compared to other efficient meta-heuristic algorithms. Results reveal that binary-real coded EMA is an efficient approach for wind farm layout optimization.

■ TB-47

Tuesday, 10:30-12:00 - Building WE, 1st floor, Room 115

Numerical and Simulation Methods in Finance

Stream: Numerical and Simulation Methods in Finance
Chair: *Paulo Rotela Junior*
Chair: *Begoña Gutiérrez-Nieto*
Chair: *Mustafa Pinar*

1 - A Non-Linear Programming Approach to Extract the Physical Distribution of Asset Price from Intraday Option Prices
Yang Zhang, Julian Williams, Fabio Massacci

The Recovery Theorem proposed in Ross (2015) offers the prospect of extracting the physical probability distribution of future asset prices from option prices. Using the Recovery Theorem with actual market prices presents some significant challenges. First, risk neutral state prices over a range of tenors need to be carefully computed and this calculation in-of-itself can present some significant difficulties. However, arguably an even more difficult problem is presented in the second step where the risk neutral state transition matrix is imputed from the preceding sequence of estimated risk neutral states. As the first step results in a matrix estimated with error (usually with a significant degree of error), exact identification of the risk neutral state transition matrix often results in a matrix that violates the basic properties of the Markov chain presumed to be driving the evolution of asset prices. Basic theory provides some intuition on the properties of this matrix and we provide identifying restrictions for a fast non-linear programming approach to the Recovery Theorem. We demonstrate the methodology on S&P 500 index options and then extend this to individual stocks by appealing to the theoretical results in Carr and Yu (2012).

2 - Application of Mathematical Programming Methods for Public Debt Management
Leszek Klukowski

The paper presents examples of application of mathematical programming approach for optimization of public debt management in Poland. The results comprise: formulation and solving of appropriate mathematical programming problems on the basis of actual data. Basic tools applied for this purpose were: linear, convex and stochastic programming methods. The criterion functions (minimized) express servicing costs of a set of debt instruments; the cost of individual instrument is a product of its capital and profitability. The constraints of the problems comprise: budgetary requirements, measures of risk and other features of debt. The result of optimization determine a structure of debt, which minimizes servicing costs and satisfies constraints. The problems of debt management are of significant importance in Poland, because of high level of debt and its costs. Moreover, an administrative management generates excessive costs and gets worse budget situation.

3 - A Comparison of Algorithms for Profit Scoring: an Application to P2P Lending
Begoña Gutiérrez-Nieto, Carlos Serrano

The most profitable borrowers are not always the most solvent ones, but sometimes they are the ones that are paying high interest rates, also paying overdrafts and high fees. A lender wanting to maximize profits should use profit scoring systems for loan selection rather than credit scoring systems. The paper compares the performance of 8 data mining techniques: multivariate linear regression, support vector regression, partial least squares regression, multilayer perceptron, CHAID decision tree, radial basis function, regression tree and k-nearest neighbours. Error measures, such as root mean square error has been used as performance measures, but also the profitability obtained by a lender applying each technique. The empirical study uses Lending Club data, a P2P lending platform. In P2P lending, borrowers apply for loans through an electronic platform, and there, lenders choose which loans they fund. Factors explaining loan profitability are analyzed, finding that these factors are different from factors explaining the probability of default. Results show that P2P lending is not currently a fully efficient market. This means that data mining techniques, such as decision trees, are able to identify the most profitable loans, or in financial jargon, to beat the market. Results show that the 8 data mining techniques obtain positive abnormal returns, outperforming the average return of these loans. Support vector regression obtains the best performance.

■ TB-48
Tuesday, 10:30-12:00 - Building WE, 1st floor, Room 116

Financial Modelling 2

Stream: Decision Making Modeling and Risk Assessment in the Financial Sector
Chair: *Bertrand Tavin*

1 - Asset liability management with capital injections and withdrawals
Claudio Fontana

In this talk, we consider the asset liability management of a company that is required to meet an exogenous level of financial obligations. The company is allowed to invest in the financial market and, in order to guarantee that the value of the portfolio under management suffices to finance the liabilities, the company has the possibility of injecting additional capital. Since injecting additional capital is costly, we consider the problem of determining the strategy minimizing the net cost of capital injections, also allowing for the possibility of withdrawing capital if the value of the portfolio exceeds an endogenously determined "safety level". The optimization problem is solved via mixed regular-singular stochastic control techniques and, in the case of a linear performance functional, can be explicitly solved.

2 - Preparing for Basel IV in credit risk: Incorporating Probation Period within a survival model for Loss Given Default
Richard Wood

Recent consultations from the European Banking Authority (EBA) are paving the way for a new regulatory framework in which substantial changes would be required for credit risk Internal Ratings Based (IRB) models. Proposals for a probationary period, in which return to non-default status is delayed until at least 3 months of ability to make repayments is evidenced, represents a major adjustment to the definition of default integrated within the IRB component models, PD, LGD, and EAD. For retail mortgage Loss Given Default this means re-assessment of the probability model for the post-default outcomes Cure (no loss) and Possession (some loss). Whilst logistic regression is typically used to this end, it does not provide an adequate reflection of the problem and lacks the flexibility required to take account of the upcoming regulation. Furthermore, it is unable to make use of the large amounts of incomplete (censored) data on default behaviour. A recent study has investigated survival analysis to model post-default outcome probability, but has failed to adequately define outcome within the model applied. Here, we present a more sophisticated competing risks survival model that remedies this, and also provides a modelling framework that meets the requirements of the EBA proposals on probationary period.

3 - Measuring exposure to dependence risk with random Bernstein copula scenarios.
Bertrand Tavin

This paper considers the problem of measuring the exposure to dependence risk of a portfolio composed of an arbitrary number of two-asset derivative contracts. We use an algorithm to generate random doubly stochastic matrices in order to build a set of Bernstein copulas, each copula corresponding to a dependence scenario. We first study the properties of quantile and worst-case risk measures based on the set of generated dependence scenarios. We then devise a method to compute hedging positions when a limited number of hedging instruments are available for trading. In an empirical study we show that the proposed method can be used to reveal an exposure to dependence risk where usual sensitivity based methods fail to reveal it. We also illustrate the ability of the proposed method to generate parsimonious hedging strategies to reduce the exposure to dependence risk of two asset derivative portfolios.

■ TB-52
Tuesday, 10:30-12:00 - Building PA, Room C

Vector and Set-Valued Optimization I

Stream: Vector and Set-Valued Optimization
Chair: *Lidia Huerga*

1 - On the existence of directional derivatives of cone-convex mappings
Ewa Bednarczuk, Krzysztof Leśniewski

Cone-convex mappings appear in variational analysis in topological vector spaces as well as in constructions of efficient iterative schemes for solving multicriteria optimization problems. In these contexts the existence of directional derivatives of cone-convex mappings is a crucial issue. In the present talk we consider cone-convex mappings F acting on a linear vector space X and taking values in a Banach space Y with ordering relations induced by closed convex cones K. We show that if directional derivatives of any such F exist for any direction h, the space Y is weakly sequentially complete. The talk is based on the joint work with Krzysztof Lesniewski.

2 - Generalized Asymptotic Functions and Applications in Multiobjective Optimization
Felipe Lara

We use generalized asymptotic functions and second order asymptotic functions to deal with the nonconvex multiobjective optimization problem. A general existence result for the nonemptiness of the proper efficient solution set and a sufficient condition for the domination property are given in those terms. A new necessary condition for a point to be efficient or weakly efficient solution without any convexity assumption and a finer outer estimate for the asymptotic cone of the weakly efficient solution set are also provide in the nonconvex case. Finally, we apply our results for the linear fractional programming problem.

3 - Some Useful Set-Valued Maps in Set Optimization
Ruben Lopez, Elvira Hernández

In this talk we introduce some classes of set-valued maps which can be useful in set optimization due to their applications. We study their continuity and convexity properties. We compute their asymptotic maps which can be employed to establish coercivity and existence results in the framework of set optimization problems.

4 - Limit Behaviour and Nonlinear Scalarization of Approximate Efficient Solutions in Vector Optimization
Lidia Huerga, César Gutiérrez, Bienvenido Jiménez, Vicente Novo

We study the well-known notion of approximate efficient solution of a vector optimization problem due to Kutateladze, and we prove that the Painlevé-Kuratowski limit of the set of this type of solutions when the error tends to zero is the set of weak efficient solutions. Moreover, we characterize these approximate efficient solutions through non-linear scalarization and finally, as an application, we derive a Kuhn-Tucker multiplier rule for them when considering a convex Pareto multiobjective problem with inequality constraints.

■ TB-53

Tuesday, 10:30-12:00 - Building PA, Room A

Methodological Advancements in Metaheuristics

Stream: Metaheuristics
Chair: *Alberto Santini*

1 - Design of Metaheuristics for Matheuristics: The Special Case of Column Generation
Marc Sevaux, Fabián Castaño

Designing a metaheuristic is always difficult to make it really efficient, but designing a metaheuristic for a matheuristic is much more challenging. The goal of this presentation is to intend to give keys and hints to make such a design. As a support, the design of metaheuristics that have been used inside a column generation framework will be used. These matheuristics have been successfully used to solve several variants of the lifetime maximization problem in wireless sensor networks

2 - Impact of Solution Methodology Parameters on a Flexible Integrated Supply Chain Model
Elham Behmanesh, Jürgen Pannek

Nowadays, the design of the supply chain network must allow to operate the latter at the lowest cost while providing the best customer service as well as environmental protection. We observe that due to environmental issues and economic reasons, industrial players are under a pressure to take back products after their use. Most existing logistics networks, however, are unable to handle returned products and to incorporate flexible delivery paths. In this paper, we present an integrated forward/reverse logistics network with full delivery graph as a NP hard mixed integer linear programming model. To find a near optimal solution even for large problems, we propose a memetic algorithm with a novel population generation. Here, we particularly focus on the impact of different parameters on convergence and solution properties of the proposed algorithm. Analyzing the respective sensitivities, we will identify guidelines to obtain the best parameters for these kind of logistics networks.

3 - Assisting the Developer: Characterization of Neighborhood Behaviors
Patrick De Causmaecker, Nguyen Thi Thanh Dang

Metaheuristic algorithm development builds on intuition of the developers. Given the metaheuristic schema, there still remain important decisions to be taken. These decisions can be seen as a part of the modeling process and takes observed properties of the problem into account. We investigate how the developer can be assisted in this task through an example.

We consider a situation with a large number of possible neighborhoods. The probabilities of specific neighborhoods being selected are fixed parameters of the algorithm. Off-line tuning of the algorithm's parameters can be done by automated algorithm configuration tools. We proposed a systematic method to characterize each neighborhood's behaviors. A novelty of our characterization method is the ability of reflecting changes of behaviours according to hardness of different solution quality regions. Using neighborhood clusters instead of individual neighborhoods helped to reduce the parameter configuration space without misleading the search of the tuning procedure. This method is problem-independent and potentially can be applied in similar contexts.

We argue that this example method provides further insight to the developer. We have examples where at first sight different neighborhoods show similar behaviors. Developers intuitively classified neighborhoods as similar. The method provides ways to test their hypothesis.

4 - A Comparison of Acceptance Criteria for the Adaptive Large Neighbourhood Search Metaheuristic
Alberto Santini, Stefan Ropke, Lars Magnus Hvattum

The adaptive large neighbourhood search (ALNS) metaheuristic has become a popular template for implementing heuristic solution methods. The metaheuristic allows the use of problem specific knowledge when specifying operators for partially destroying and then repairing a solution to an optimisation problem. Problem independent components of the ALNS dictate how different destroy and repair operators should be used and control the search trajectory. One presumably important component that influences the search trajectory is the move acceptance criterion. In the original ALNS, this criterion was based on simulated annealing, whereas earlier work on large neighbourhood search by Shaw had accepted only improved solutions. Recently, some implementations have used the record-to-record acceptance criterion instead. Currently, however, there are no guidelines available to recommend one acceptance criterion over another. This paper intends to fill this gap by investigating a large number of different move acceptance criteria by subjecting them to extensive computational testing. Through empirical experiments we will attempt to 1) suggest which move acceptance criterion is better suited for an implementation of ALNS, 2) quantify the effect on performance from using different acceptance criteria, 3) attempt to measure in which way the move acceptance criteria influence the search behaviour.

■ TB-54

Tuesday, 10:30-12:00 - Building PA, Room B

Recent advances in first order methods

Stream: Convex Optimization
Chair: *Yura Malitsky*

1 - Massive Douglas-Rachford splitting
Dirk Lorenz

The aim of splitting techniques for convex optimization is to split the objective additively into parts that allow for simpler operations. In this talk we propose a method to massively split objectives into small parts until each part can be dealt with by an implicit step. The splitting in inspired by a recent interpretation of the Douglas-Rachford splitting method as a preconditioned proximal point step. We illustrate the efficiency of this massive splitting with examples where we split the objective in as many (or even more) terms as the number of free variables.

This is joint work with Kristian Bredies.

2 - Adaptive Smoothing Algorithms for Nonsmooth Composite Convex Minimization
Quoc Tran-Dinh

We propose an adaptive smoothing algorithm based on Nesterov's smoothing technique in [Nesterov, Math. Program. (2005)] for solving nonsmooth composite convex optimization problems. Our method combines both Nesterov's accelerated proximal gradient scheme and a new homotopy strategy for smoothness parameter. By an appropriate choice of smoothing functions, we develop a new algorithm that has up to the $O(1/varepsilon)$-worst-case iteration-complexity while allows one to automatically update the smoothness parameter at each iteration. Then, we further exploit the structure of problems to select smoothing functions and develop suitable algorithmic variants that reduce the complexity-per-iteration. We also specify our algorithm to solve constrained convex problems and show its convergence guarantee on a primal sequence of iterates. We demonstrate our algorithm through three numerical examples and compare it with other algorithms.

3 - Computational regularization in learning and inverse problems
Silvia Villa

Modern high dimensional estimation problems from random noisy data require the development of ever more efficient algorithms. A key observation towards this goal is that the numerical precision in the computations should be taylored to the estimation accuracy allowed by the data, rather than only their raw amount. Indeed, this suggests that efficient methods can be derived investigating the interplay and trade-offs between estimation and computational requirements. With this goal in mind in this talk we focus on iterative regularization methods where regularization is achieved by early stopping an iteration of a first order method depending on the data. Recent results in the context machine learning and inverse problems will be discussed.

Tuesday, 12:30-14:00

■ TC-01

Tuesday, 12:30-14:00 - Building CW, AULA MAGNA

Keynote Emma Hart

Stream: Plenary, Keynote and Tutorial Sessions
Chair: *David Pisinger*

1 - Lifelong Learning for Optimisation
Emma Hart

The previous two decades have seen significant advances in optimisation techniques that are able to quickly find optimal or near-optimal solutions to problem instances in many combinatorial optimisation domains. Despite many successful applications of both these approaches, some common weaknesses exist in that if the nature of the problems to be solved changes over time, then algorithms needs to be periodically re-tuned. Furthermore, many approaches are inefficient, starting from a clean slate every time a problem is solved, therefore failing to exploit previously learned knowledge.

In contrast, in the field of machine-learning, a number of recent proposals suggest that learning algorithms should exhibit life-long learning, retaining knowledge and using it to improve learning in the future. I propose that optimisation algorithms should follow the same approach - looking to nature, we observe that the natural immune system exhibits many properties of a life-long learning system that could be exploited computationally in an optimisation framework. I will give a brief overview of the immune system, focusing on highlighting its relevant computational properties and then show how it can be used to construct a lifelong learning optimisation system. The system is shown to adapt to new problems, exhibit memory, and produce efficient and effective solutions when tested in both the bin-packing and scheduling domains.

The proposed system is an example of an ensemble method, in which multiple heuristics collaborate.The final part of the talk will focus on why ensemble approaches to optimisation represent a promising way forward for optimisation in the future.

■ TC-02

Tuesday, 12:30-14:00 - Building CW, 1st floor, Room 7

Rough Sets in Decision II

Stream: Rough Sets in Decision
Chair: *Dominik Ślęzak*
Chair: *Jerzy Blaszczynski*

1 - Mining incomplete data - A rough set approach
Jerzy Grzymala-Busse

Main trends of research on a rough set approach to mining incomplete data are presented. Three types of lower and upper approximations, based on a characteristic relation, are defined. Three interpretations of missing attribute values are discussed. An idea of a probabilistic approximation, an extension of the lower and upper approximations, is presented. Some special topics, such as consistency of incomplete data are also discussed.

2 - Controlling decisions in incomplete information systems
Piero Pagliani

Controlling a decision amounts to contrasting its conditions with the decisions. Thus, let BS = (U,R) be a set of points U equipped with a relation R depending on an information structure I, and let FS = (U,R') be the same set U structured by a relation R', which depends on a different information structure I'. In such a framework, decisions can be made and/or checked by contrasting the state of affairs described by BS with that described by FS. For instance, if U is a set of regions evaluated by a set of economic parameters I, and I' a set of parameters concerning investments in U, then by contrasting BS with FS one can understand whether, why, and to what extent the information from I "justifies" those investments. If U is a set of products, I a set of features, and R' is a preference relation resulting from a marketing research using parameters from I', then one can, similarly, understand whether, why, and to what extent preference depends on the given set of features. Problems arise when I and/or I' have information gaps. We shall see that basically one can adopt an optimistic approach (only definitively inconsistent decisions are discharged) or a pessimistic approach (only definitively consistent decisions are assumed). Both approaches are expressed by rather complex first order formulas. However, they can be easily described and computed if one uses a particular propositional logic with operators.

3 - VC-DRSArank - rough-set-based learning method for multicriteria ranking
Marcin Szelag, Roman Slowinski, Salvatore Greco

We present a rule-based decision aiding methodology for the multicriteria ranking problem. In this problem, due to a typical incomparability of objects induced by dominance relation, one needs to create a preference model of a decision maker (DM). Traditional models (value function, outranking relation) are hard to comprehend and do not justify clearly their recommendation. Therefore, we employ a preference model in the form of a set of if-then decision rules, induced from exemplary pairwise comparisons of the DM using the Variable Consistency Dominance-based Rough Set Approach (VC-DRSA). Induced rules are applied on a set of objects to be ranked. We analyze different ways of constructing the preference structure obtained in this step. Then, we analyze desirable properties of several ranking methods that exploit this preference structure and yield final ranking of objects; based on this analysis we indicate a ranking method with best properties. Finally, we show the results of a computational experiment in which the proposed method, VC-DRSArank, was compared with state-of-the-art SVMrank method. Obtained results prove suitability of the proposed approach to the multicriteria ranking problem.

■ TC-03
Tuesday, 12:30-14:00 - Building CW, 1st floor, Room 13

Preference Learning 3

Stream: Preference Learning
Chair: *Antti Airola*

1 - Preference-Based Learning in Games
Johannes Fürnkranz

Game Playing has been a popular and successful application domain for machine learning. Typically, an evaluation function that assigns numerical utilities to different game states is learned from game traces or from self play. In this talk, we show how to use preference learning techniques for such tasks. For example, in games like Chess, expert feedback is amply available in the form of annotated games. This feedback usually comes in the form of qualitative information because human annotators find it hard to determine precise utility values for game states. We show the results of a case study, in which we used game annotations for learning a utility function that respects a set of preference constraints that have been obtained from the annotations. We will also briefly discuss current work in which we try to adapt Monte Carlo tree search techniques to a preference-based setting.

2 - On performing ROC Analysis with Leave-Pair-Out Cross-Validation
Tapio Pahikkala, Antti Airola

Leave-pair-out cross-validation (LPOCV) is an almost unbiased estimator for estimating the area under ROC curve (AUC) of a machine learning method with small data sets. However, in addition to AUC, LPOCV does not as such provide any other tools provided by standard ROC analysis. In order to bridge this cap, we use the well-known ordering-by-the-number-of-wins method to assign the so-called Kendall scores for the data and perform ROC analysis on these scores. We investigate the reliability of this approach by comparing the AUC values obtained directly from the LPOCV results with the ones obtained from the Kendall scores with practical problems.

3 - Leave-pair-out cross-validation for learning to rank
Antti Airola, Tapio Pahikkala

Pairwise ranking accuracy is a common performance measure for evaluating the ranking performance of predictive models. For the special case of bipartite ranking, the measure becomes equivalent to the area under ROC curve. When working with small data sets, cross-validation provides the standard approach for estimating the generalization performance of a predictor. However, for estimating the pairwise ranking accuracy the standard cross-validation approaches such as leave-one-out can be shown to be unreliable. Rather, leave-pair-out cross-validation is recommended, as it produces almost unbiased estimates with low deviation variance.

■ TC-04
Tuesday, 12:30-14:00 - Building CW, ground floor, Room 6

Recent results on optimization and simulation

Stream: Recent Developments on Optimization and Some Results on Game Theory
Chair: *Takashi Tsubota*

1 - Computing CIS Partitions for Additive Hedonic Coalition Formation Games
Shao-Chin Sung

Hedonic games are coalition formation games in which each player's preference over coalitions depends only on composition of members of her or his coalition, and an outcome of the game is a partition of the grand coalition. In additive case, player's preference is characterized by a function which assigns a real value to each of all other players. Here, we are concerned with the problem of finding a contractually individual stable partition for additive hedonic games. A partition is contractually individual stable (CIS) if each player is either has no incentive to leave her or his coalition, or has no permission to leave her or his coalition, or has no permission to join the coalition which she or he intended to join. It is known that a CIS partition exists for all instances of hedonic games. A polynomial time algorithm is proposed by Aziz, Brandt, and Seedig (2013), which is supposed to solve the problem. Here, we show the algorithm does not work for some instances, and propose a revised version of the algorithm which completely solves the problem whose running time remains polynomial. Moreover, this result is extended for more general cases.

2 - Multi-attribute auctions on interval data
Kurt Nielsen

We consider a procurement auction where the Principal announces the attributes that enter the auction and state a scoring function a priori that weights price and other attributes. The participants submit crisp bids that are extended to interval data by the auctioneer to describe the inherent uncertainty. The two suggested mechanisms apply a combination of scoring the crips submitted bids and evaluating the extended interval bids by an adjusted version of the so-called Fuzzy Weighted Overlap Dominance (FWOD) used to produce equivalence classes by complete pairwise comparison of bids. The two suggested auction mechanisms are briefly described below.

Mechanism 1: The auction assigns prices to all submitted crisp bids using a generalised version of the second score auction similar the generalised second price auction used in position auctions. Given these prices, the winner is selected by the Principal based on the extended interval bids using FWOD.

Mechanism 2: The auction uses FWOD to rank all of the extended interval bids into equivalent classes. The crisp bids in the top ranking equivalent class enters a standard second score auction that ends the auction.

We show how the inclusion of interval data influences the incentives in the two suggested auction mechanisms.

Throughout the paper we will use the example of mobile Internet where the Principal actual consumption and location patterns determine the quality of the service.

3 - Group Activity Selection from More General Preferences
Takashi Tsubota, Shao-Chin Sung

Group activity selection (GAS) game is a model of coalition formation games introduced by Darmann et al. (2013). An outcome of such a game is an assignment which associate one of given activities including the activity of "doing nothing" to each player. It is assumed that each player cares only about which activity she or he is assigned to and how many participants attending in the same activity. That is, preference of each player is a weak order over the set of all pairs of activity and number of participants. The goal is to find an outcome which satisfies a stability concept given in advance. Darmann et al. (2013) pointed out that GAS games can be considered as special cases of hedonic coalition formation games. Moreover, as analogies from hedonic coalition formation games, they defined several stability concepts for a certain domain of preferences, called binary preferences, and for each of the stability concepts, the complexity status of the existence problem of stable outcomes for GAS game is studied. Here, we first introduce stability concepts in a more general setting of GAS game, and investigate the existence problem for each of the stability concepts.

■ TC-05

Tuesday, 12:30-14:00 - Building CW, 1st floor, Room 8

Theoretical Considerations in Multiobjective Optimization

Stream: Multiobjective Optimization
Chair: *Kerstin Daechert*

1 - Output-sensitive Complexity of Multiobjective Combinatorial Optimization
Fritz Bökler, Matthias Ehrgott, Christopher Morris, Petra Mutzel

We study output-sensitive algorithms and complexity for multiobjective combinatorial optimization (MOCO) problems. In this computational complexity framework, an algorithm for a general enumeration problem is regarded efficient if it is output-sensitive, i.e., its running time is bounded by a polynomial in the input and the output size. We provide both practical examples of MOCO problems for which such an efficient algorithm exists as well as problems for which no efficient algorithm exists under mild complexity theoretic assumptions.

2 - A Modified Scalarization for Characterizing Properly Efficient Solutions in Multiobjective Optimization
Majid Soleimani-damaneh, Kazhal Khaledian

One of the most popular approaches for characterizing the solutions of a multiobjective optimization problem is converting it to a single-objective problem. The techniques which follow such approach are called scalarization techniques.

The scalarization techniques existing in the literature usually fail in investigating properly efficient solutions. In this paper, a modified scalarization problem is presented which is able to characterize properly efficient solutions in multiobjective optimization. A necessary and sufficient condition for these solutions is established. In contrast to the related results existing in the literature, our characterization is done without any convexity or boundedness assumption.

3 - An Exact Algorithm to find All Non-dominated Points of Multi-objective Mixed Integer Linear Programs
Metin Turkay, Seyyed Amir Babak Rasmi

Multi-objective optimization problems are getting more useful for decision makers. We examine these problems with different approaches. One of them is finding all - or partial part of - efficient and non-dominated solutions exactly. Even though a few studies find all efficient solutions in multi-objective (integer) linear problems, in mixed integer linear ones just finding a non-complete part of efficient solutions is possible. In this thesis, we found all Pareto optimal solutions consist of (non) Extreme Supported Non-dominated (ESN) solutions and the efficient unsupported solutions lie over their pairwise convex combination by implementing a procedure including a few single objective sub-problems over potentially integer efficient solutions. The algorithm consists of a filtration of integer feasible solutions and not be dominated by a reference efficient point, extracting extreme efficient solutions by fixing those integer solutions, and examining adjacent extreme solutions. This method finds all efficient solutions of the mentioned type based on a number of given integer solutions for integer variables, and all efficient solutions for the main MOMILP by considering an exhaustive group of integer solutions. Although presenting all efficient solutions in MOMILP is not possible in a few seconds, our algorithm finds them in a quad-objective problem with the size which is large comparing to the studies in the literature.

4 - Efficient Computation of the Search Region in Multi-objective Optimization
Kerstin Daechert, Kathrin Klamroth, Renaud Lacour, Daniel Vanderpooten

Multi-objective optimization methods often proceed by iteratively producing new solutions. For this purpose it is important to determine and update the search region efficiently which corresponds to the part of the objective space where new nondominated points could lie. It can be described by a set of so-called local upper bounds whose components are defined by already known nondominated points. In the bi-objective case the update of the search region is easy since a new point can dominate only one local upper bound. Moreover, the local upper bounds as well as the nondominated points can be kept sorted increasingly with respect to one objective and decreasingly with respect to the other. For more than two objectives these properties do no longer hold. In particular, several local upper bounds might have to be updated at once when a new nondominated point is inserted into the search region. In this talk we concentrate on how to design this update efficiently. Therefore we study a specific neighborhood structure among local upper bounds. Thanks to this structure we can quickly identify all local upper bounds that are affected by a new nondominated point, i.e. that have to be updated. We propose a new scheme to update the search region with respect to a new point more efficiently compared to existing approaches. Besides, the neighborhood structure provides new theoretical insight into the search region and the location of nondominated points for more than two objectives.

■ TC-06

Tuesday, 12:30-14:00 - Building CW, ground floor, Room 2

Complex preference learning in MCDA 2

Stream: Multiple Criteria Decision Aiding
Chair: *Milosz Kadzinski*

1 - Post factum analysis for robust multiple criteria ranking and sorting
Milosz Kadzinski, Krzysztof Ciomek, Paweł Rychły, Roman Slowinski

Providing partial preference information for multiple criteria ranking or sorting problems results in the indetermination of the preference model. Investigating the influence of this indetermination on the suggested recommendation, we may obtain the necessary, possible and extreme results confirmed by, respectively, all, at least one, or the most and least advantageous preference model instances compatible with the input preference information. We propose a framework for answering questions regarding stability of these results. In particular, we are investigating the minimal improvement that warrants feasibility of some currently impossible outcome as well as the maximal deterioration by which some already attainable result still holds. The improvement or deterioration of the sort of an alternative is quantified with the change of its performances on particular criteria and/or its comprehensive score. The proposed framework is useful in terms of design, planning, formulating the guidelines, or defining the future performance targets. It is also important for robustness concern because it finds which parts of the recommendation are robust or sensitive with respect to the modification of the alternatives' performance values or scores.

2 - Heuristics for prioritizing pair-wise elicitation questions with additive multi-attribute value models
Krzysztof Ciomek, Milosz Kadzinski, Tommi Tervonen

Efficient construction of a preference model is an important problem in Multiple Criteria Decision Analysis. It may be performed via direct elicitation of model parameters, which is often difficult, or indirect information in form of holistic judgments. We consider the latter scenario with pair-wise comparisons used to infer an additive value model for multiple criteria ranking. The selection and ordering of questions affect the number of indirect judgments the Decision Maker needs to provide until a complete ranking is obtained. We propose heuristics for prioritizing pairwise elicitation questions. These heuristics are based on robustness analysis whose outcomes are materialized with necessary preference relations, extreme ranks attained by the alternatives, pair-wise preference indices, and rank acceptability indices. We evaluate the quality of proposed heuristics with respect to three metrics of question-answer tree they construct. We also report results of a real-world experiment involving over 100 subjects.

3 - Bipolar robustness control methodology in disaggregation MCDA approaches: Application to European e-government evaluation
Eleftherios Siskos, John Psarras

Robustness analyses and assessments are currently practiced by researchers and decision analysts in the field of multicriteria decision aid, in order to control the resistance of the models against ignorance and instability phenomena, in a systematic or heuristic way. This paper comes to extend and regularize robustness analysis in the disaggregation or ordinal regression approaches such as the UTA-type methods. It proposes a rigorous, systematic, and interactive bipolar procedure, based on consecutive measurements and assessments of robustness. Specifically, the two poles of the algorithm, namely the Disaggregation and Aggregation Pole, interact and provide feedback to each other. A set of robustness tools are proposed and integrated in both poles. They include variation indices, the Most Representative Model (MRM) concept, and visualization measures to control the robustness of the decision model inferred through the disaggregation pole. On the other hand, Extreme Ranking Analysis (ERA), Frequency of Ranking Positions (FRP), and Visualization procedures are implemented to control the robustness of the model's results in the aggregation pole. The whole procedure stops when satisfactory and acceptable outcomes are obtained in both poles. The paper presents an original application of this methodology to the problem of e-government evaluation, where the overall score of the countries is obtained through additive models, assessed via a synergy of MAUT and UTA II techniques.

4 - Disaggregation approach for understanding heterogeneity in consumers' preferences in online markets
Mohammad Ghaderi, Nuria Agell, Francisco Ruiz

Understanding heterogeneity in consumers' preferences is a central concern in marketing decision-making processes (Allenby, 1998). On the other hand, by the advent of online shopping, an increasing amount of preferential information from online shoppers, mainly based on a system of one to five stars, is becoming available (Overby, J. W. & Lee, E-J., 2006). These holistic judgments can be analysed to better understand preferential system of consumers and the heterogeneity level across them. Accordingly, we propose a methodological framework for processing this type of ubiquitous preference information. The methodology follows a sorting model based on preference disaggregation analysis, and leads to a quadratic programming under certain circumstances. An efficient algorithm for solving the proposed model will be suggested.

■ TC-07

Tuesday, 12:30-14:00 - Building CW, 1st floor, Room 123

Spatial Risk Analysis

Stream: Spatial Risk Analysis
Chair: *Nikolaos Argyris*
Chair: *Valentina Ferretti*
Chair: *Simon French*
Chair: *Gilberto Montibeller*

1 - Multi-Criteria Spatial Risk Analysis
Gilberto Montibeller, Valentina Ferretti

There is a broad literature on spatial multi-criteria evaluation in the environmental domain, and some attempts of conducting risk analysis in this context. Most of these attempts neither employ a proper risk analytical framework nor provide a clear conceptual framework for allocating resource on mitigating actions. To address these weaknesses, in this paper we conceptualize a multi-criteria spatial risk analysis framework, based on expected utility, which can support spatial environmental decision-making risk evaluations and the allocation of scarce resources for spatial risk mitigation.

2 - Spatial Risk Analysis in Emergency Management
Simon French, Nikolaos Argyris

In any emergency, there is a great deal of uncertainty, often geographical uncertainty or, more precisely,spatio-temporal uncertainty. For instance, an industrial accident may lead to a plume of contamination, putting populations at risk downwind. Similarly, volcanic ash can disrupt air travel and thus the uncertain movement of the ash cloud is a key factor that air traffic controllers and airport managers must considier. The path of a hurricane and the timing of its landfall provides another example that are of obvious concerns to emergency managers. Estimating spatio-temporal probabilities is usually a difficult task, particularly within the timescales needed in emergency management, but that is not our primary concern in this paper. Rather we ask how analysts can communicate spatio-temporal uncertainty to those handling the crisis. We review the somewhat limited literature on the representation of spatial uncertainty on maps. We note that many cognitive issues arise and that the potential for confusion is high. We then make some suggestions based upon the idea of presenting multiple scenarios.

3 - Adversarial risk analysis for urban security
David Rios, Jesus Rios, Cesar Gil

Several of the world's biggest problems revolve around security issues, including terrorism and organized crime. Most of these phenomena take place in urban settings.

A recent upsurge of interest for security resource allocation was motivated by large scale terrorist events like S-11. These led to large security investments, some of them severely criticized. This, in turn, has promoted many modeling efforts to efficiently allocate such resources. One of them, which is specially promising, is Adversarial Risk Analysis (ARA), a framework to manage risks derived from actions of intelligent adversaries.

We study here how ARA may be used for security resource allocation in urban settings, taking into account spatial issues. We aim at supporting one of the agents, the Police, in allocating resources to protect a city from the attacks of another agent, the Mob, and, eventually, recover from them. We use ARA as a framework to support the Police decision making. Our model reflects resource constraints, the aggregated values attained globally in the city, the dynamic moves that may be undertaken and other aspects in relation with the spatial structure. As an illustration, we choose a novel sequential Defend-Attack-Defend model, which allows for recovery after an attack by appropriately reshuffling defense resources. The model includes three stages: the Defender makes her fist decision; the Attacker performs his attack; then the Defender makes her second decision.

4 - Presenting Geographical Uncertainty in Radiological Emergencies: findings from three workshops
Nikolaos Argyris, Simon French

Much of the uncertainty faced in a radiological emergency is about geographical aspects. Dispersion predictions and consequent public health advice will alter over time to reflect this. Attempts to make probabilistic predictions are highly problematic. Thus there is a need to present information relevant to those making decisions, recognising that knowledge of the situation will inevitably change with time. We report on a project that explored how information on spread of a plume would be presented and discussed within the team of experts advising central UK government; and, secondly, how their assessments would be conveyed to the national emergency management cell within UK government. The project involved three workshops designed to assess how the needs of decision makers would be best met by alternative methods of data presentation. We discuss the findings of the workshops and subsequent recommendations, devoting particular attention to the use of scenarios and how the latter can be used to introduce probabilities in decision support.

■ TC-08

Tuesday, 12:30-14:00 - Building CW, 1st floor, Room 9

IBM Research Applications 2

Stream: IBM Research Applications
Chair: *Marco Laumanns*
Chair: *Susara van den Heever*
Chair: *Martin Mevissen*
Chair: *Xavier Nodet*

1 - Temporal Budget Allocation for Real-time Bidding of Display Advertisements
Pavankumar Murali

We present a simulation model to determine optimal budget allocation strategies for real-time bidding (RTB) in display advertising. RTB allows advertisers to bid on a display ad impression in real time when it is being generated. Bidding is performed by using user data to predefine audience groups, which comprise combinations of user attributes such as age, gender, profession etc., for each advertising campaign. For advertisers, a decision has to be made to buy a set of ad impressions daily to reach as much of the audience group as possible, while being restricted by the daily campaign budget. A common challenge across RTB exchanges is to optimize both budget spend and performance attainment. In this talk, we present a stochastic dynamic programming approach to determine time-based budget caps. A simulation model is constructed to account for all the complexities and non-linearities of a real-time bidding in a display ad campaign setting. Our algorithm was piloted in a real-world bidding system for over 3 months. Empirical results indicate an 18% performance gain compared to existing business-as-usual rules.

2 - SOCP Relaxations for Optimal Power Flow
Bissan Ghaddar, Xiaolong Kuang, Joe Naoum-Sawaya, Luis Zuluaga

The alternating current optimal power flow (ACOPF) problem can be formulated as a non-convex polynomial program that is generally difficult to solve due to the non-linear power flow constraints. A recently proposed approach to globally solve the ACOPF problem is through the formulation of a hierarchy of semidefinite programs that are computationally challenging to solve for large-scale problems. In this talk, we explore a solution approach that alleviates this computational burden by using hierarchies of second order programs and by exploiting the network structure of transmission grids. Furthermore, we show that the first level of the second order cone hierarchy is equivalent to solving the conic dual of a recently proposed approximation, which provides the optimal solution of the ACOPF problem for special network topologies.

3 - Machine Learning and Optimisation Techniques in Managing Operating Theatres
Hamideh Anjomshoa, Olivia Smith, Lianhua Chi

Managing operating theatres has a crucial role in hospitals. Several stakeholders are involved in decisions related to the surgeries and resource requirements. In this talk, we describe clustering techniques to predict the patient demand for resources and mixed integer programming model to find an optimal plan for surgeries. This problem is a multi-objective model with respect to the limited capacity constraints and surgeons availability. Some government regulatory constraints are also considered in the model. This work has been done for a public hospital in Victoria, Australia. Computational experiments are presented.

■ TC-09

Tuesday, 12:30-14:00 - Building CW, 1st floor, Room 12

LP and MIP Software

Stream: Mathematical Programming Software
Chair: *Tobias Achterberg*

1 - Recent improvements in the CPLEX LP solver
Bo Jensen, Roland Wunderling

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

2 - On the efficiency of preconditioners in BlockIP, an interior point package for block-angular problems
Jordi Castro, Stefano Nasini

BlockIP is a package implementing an efficient interior-point method for block-angular structured problems. It solves the normal equations by a combination of Cholesky factorizations and preconditioned conjugate gradient for, respectively, the block and linking constraints. We will show that principal angles between the subspaces generated by the diagonal blocks and the linking constraints can explain why the preconditioner is efficient in some particular class of problems but not in others. This fact will be numerically validated with some generated optimization problems. Computational results will also be provided for multicommodity flows with nodal capacities and equal flow constraints, resulting in instances of up to 127 million of variables and 7.5 million of constraints.

3 - New advances in the SAS/OR Optimization Suite
Imre Polik

We give an overview of the Optimization tools in the SAS/OR product and discuss recent improvements in the MILP solver.

■ TC-10

Tuesday, 12:30-14:00 - Building CW, ground floor, Room 1

AHP and Beyond 1

Stream: Analytic Hierarchy Process / Analytic Network Process
Chair: *Konrad Kułakowski*

1 - Computing interval weights for incomplete pairwise comparison matrices of large dimension - a weak consistency based approach
Jana Krejčí, Vera Jandova, Jan Stoklasa, Michele Fedrizzi

Multiple-criteria decision-making and evaluation problems dealing with a large number of objects are very demanding, particularly when the use of pairwise comparison (PC) techniques is required. A major drawback arises when it is not possible to obtain all the PCs due to time or cost limitations or to split the given problem into smaller sub-problems. In such cases, two tools are needed to find acceptable weights of objects: an efficient method for partially filling a pairwise-comparison matrix (PCM) and a suitable method for deriving weights from this incomplete PCM. We present a novel interactive algorithm for large-dimensional problems guided by two main ideas: the sequential optimal choice of the PCs to be provided by the DM and the concept of weak consistency. The algorithm works both with Saaty's PCMs and fuzzy preference relations. The proposed solution significantly reduces the number of needed PCs by providing sets of feasible values for all missing PCs implied by the weak consistency after each input of a new PC. Interval weights of objects covering all possible weakly consistent completions of the incomplete PCMs are then computed from the resulting incomplete weakly consistent PCM. The performance of the algorithm is validated by a real-life case study and a simulation study. The performed simulation demonstrates that the proposed algorithm is capable of reducing the number of PCs required in PCMs of dimension 15 and greater by more than 60% on average.

2 - On the linguistic level of Saaty's pairwise comparison matrices
Jan Stoklasa, Talásek Tomás

Saaty's AHP is a widely used multiple criteria decision-making tool and it has received much attention of practitioners and researchers since its introduction. Pairwise comparison methods in general can be considered a good tool for capturing the preference structure of the expert (with all its possible inconsistencies). The consistency of the preferences represented by the matrix is however still a subject of ongoing research and new measures of the (in)consistency of pairwise comparison matrices are still being proposed by researchers for various reasons. Since the Saaty's method allows the users to use both quantitative and qualitative criteria, a fundamental scale comprising of the integer values 1,. . . ,9 and their reciprocals was proposed by Saaty to represent the intensities of preferences. To facilitate its use by practitioners, Saaty also proposed a linguistic level of the scale. In the paper we argue, that the linguistic level as proposed by Saaty is either arbitrary or not compatible with the consistency condition commonly used with Saaty's matrices. We analyze the assignment of the numerical meanings of the linguistic terms in the context of additive and multiplicative pairwise comparison matrices and point out several issues that in our opinion should be addressed in future research. The paper is intended mainly as a discussion stimulating contribution, also aiming to contribute to the understanding of the method and its correct use by decision makers.

3 - Inconsistency indices for pairwise comparison matrices: a functional unifying approach
Michele Fedrizzi, Matteo Brunelli

We propose and study a general formulation of an inconsistency index for a pairwise comparison matrix. Starting from the observation that several known inconsistency indices share a common structure, we define a functional form that encompasses and generalizes these known indices. The common structure is as follows. Given that inconsistency is a transitive-like property involving three preferences, first, the 'local' inconsistency is evaluated for each triplet i, j, k of indices using a particular function. Then, all these local contributions to inconsistency are aggregated by means of a second suitable function. The main contribution of our study is to determine a set of properties of the two involved functions in such a way that the obtained inconsistency index satisfies six properties previously introduced to characterize a 'good' inconsistency index. We also study the case where some important classes of aggregation functions are chosen, like OWA functions or triangular conorms.

4 - On the conjoint estimation of inconsistency and intransitivity of pairwise comparison matrices
Matteo Brunelli

In the last years research has focused on properties of consistency and transitivity of pairwise comparisons. Inconsistency and intransitivity indices have been proposed separately to estimate the deviation of preferences from the properties of consistency and transitivity. Recently, some approaches have been proposed to capture the two phenomena at once. A question then arises: can we devise a function which is capable of estimate both inconsistency and intransitivity? In this preliminary study we shall see that this depends on what propeties we want this function to satisfy.

■ TC-11

Tuesday, 12:30-14:00 - Building CW, 1st floor, Room 127

Discrete and Global Optimization 5

Stream: Discrete and Global Optimization
Chair: *Gerhard-Wilhelm Weber*
Chair: *Szymon Wasik*
Chair: *Jacek Gondzio*

1 - A Procedure for Listing FJ Points of a Quadratic Reverse Convex Programming Problem
Syuuji Yamada

In this talk, we propose a procedure for listing FJ points of a quadratic reverse convex programming problem (QRC) whose feasible set is expressed as the area excluded the interior of a convex set from another convex set. It is known that many global optimization problems can be transformed into such a problem. Several types of iterative solution methods for solving (QRC) have been proposed by many other researchers. However, such algorithms are not effective in the case where the dimension of variables is so large. One of the difficulty for solving (QRC) is that all locally optimal solutions do not always satisfy KKT (Karush-Kuhn-Tucker) conditions. In order to overcome this drawback, we introduce an algorithm for listing FJ (Fritz-John) points of (QRC). Moreover, by combining our algorithm into a branch and bound procedure, we obtain most of FJ points of (QRC). It is known that every locally optimal solutions of (QRC) satisfies FJ conditions. Hence, by utilizing our algorithm, we can calculate most of locally optimal solutions contained in the intersection of the boundaries of convex sets defining the feasible set. Moreover, by choosing a calculated locally optimal solution having the smallest value of the objective function, we can obtain an approximate solution of a globally optimal solution is obtained.

2 - A MINLP to Parameters Inference in Chemical Reactions Networks
M. Asuncion Jimenez-Cordero, Rafael Blanquero, Emilio Carrizosa, José Luis Ferrín, Jerónimo Rodríguez, Boglárka G.-Tóth, José Francisco Rodríguez

This work is motivated by a real-world inverse problem, in which the chemical reactions are to be inferred, having as data the empirical concentrations of some species at different time instants. In this talk we address the problem of finding the stoichiometric matrix and the reaction rates that best fit to the empirical concentrations given.

The components of the matrix are integer numbers and the reaction rates are non-negative continuous values, so the proposed model to solve this type of problem is a MINLP with linear constraints whose objective function contains an ODE, because of the laws that the reactions follow.

Since this nonconvex MINLP is very demanding in terms of running times, a heuristic procedure is proposed. Computational results in benchmark data sets are provided.

3 - Assembly Line Worker Assignment and Balancing Problem (ALWABP) with Task Splitting and Operator Skills
Fatih Cengil, Gorkem Yilmaz, Erinc Albey

Preferences of customers are changing from standard products to customized products. Therefore, product variety increases and assembly line balancing and worker assignment becomes more difficult in manufacturing. An unbalanced line and improper assignment of workers causes bottleneck stations and idle time of the workers. In both cases, production efficiency decreases, therefore, labor cost increases. To handle these inefficient situations, the decisions of which worker is assigned to which station of which line and which task is performed in that station by that worker should be defined before an order starts to be produced. A mixed-integer linear programming model (MILP) is developed to solve Assembly Line Worker Assignment and Balancing Problem (ALWABP). In this study, objective is to minimize total number of worker for a given cycle time (ALBP-I). Real-life issues are included which are skill and absenteeism of the workers, multi product, task splitting, parallel assembly lines and production schedule of the lines to reach more realistic and applicable results. This study provides an insight to task splitting in mathematical model. This model can be applied in manufacturing firms using parallel assembly lines to produce multi product and in need of splitting the tasks among stations. With the application of this study, improvements in production efficiency and labor cost is expected.

4 - An Assignment Problem Relaxation for Single Machine Job Scheduling with Preemption to Minimize Total Weighted Tardiness
Michael Tso, Boris Goldengorin, John Keane

We consider preemptive scheduling of a set of jobs with known processing times and release dates on a single machine to minimize total weighted tardiness. A job is considered as a set of distinguishable unit length segments in a discrete time formulation. A branch and bound algorithm is proposed and evaluated that employs successive relaxations to the assignment problem (AP). Our computational study currently outperforms all currently published computational results obtained either by general purpose software or specialized algorithms.

■ TC-12

Tuesday, 12:30-14:00 - Building CW, ground floor, Room 029

VeRoLog: Periodic VRPs

Stream: Vehicle Routing and Logistics Optimization
Chair: *Jose Ribeiro*

1 - An adaptive large neighbourhood search heuristic for an inventory routing problem for liquefied natural gas distribution
Yousef Ghiami, Emrah Demir, Tom Van Woensel, Marielle Christiansen, Gilbert Laporte

The market for Liquefied Natural Gas (LNG) is growing since LNG has a lower price with less emission produced compared to the conventional fuel types. In this study we develop an inventory routing problem (IRP) for an inland distribution network that delivers LNG from storage facilities to filling stations. The distribution is performed by a fleet of heterogeneous vehicles. In this model we take into account the deterioration property of LNG that takes place in storage facilities and filling stations. This paper also presents an adaptive large neighbourhood search heuristic for the IRP.

2 - A Lower Bound Algorithm for the Vehicle Routing Problem with two Types of Visits
Arya Sevgen, Ozgur Ozpeynirci, Ahmet Camcı

We define a new variant of periodic vehicle routing problem (PVRP) named Vehicle Routing Problem with Two Types of Visits. The problem requires a different aimed customer visit in the following day of a regular customer visit day. One can consider the first customer visit for collecting demand information and the second customer visit for delivering goods. The first type visit is realized with small scale, fast and time capacitated vehicles, whereas the second type visit is realized with relatively large scale, slow and physically capacitated vehicles. We try to develop a lower bound for this problem. While finding the lower bound, a branch and cut algorithm is used. For the physically capacitated vehicles, rounded capacity inequalities are used. We combine the time spent on route and customer to use capacity inequalities for the time capacitated vehicles. Also, we define new classes of inequalities for separation algorithm for both vehicle types. After adding the cutting planes, branching procedure is described. The performances of the lower bound algorithm is tested with the modified PVRP instances of Cordeau et al.(1998). *This research is supported by the Scientific and Technological Research Council of Turkey (TÜBİTAK) Grant No: 213M425

3 - A model and a program for selection of agents and logistics of work teams
Jose Ribeiro, Caio Siquitelli, Alexandre Leoneti, André Lucirton Costa

An outsourced services company is responsible for providing cleaning crews, maintenance, support, concierge and surveillance for industries, banks, shopping centers, schools and hospitals. The company selects agents, constitutes work teams and forwards them by public transportation to locations previously contracted. The company's objective is to minimize the transportation cost of agents to workplaces. In this paper we propose a model and a program for work teams setup and logistics. The proposed model is based on the generalized assignment model. The objective function minimizes the transportation cost. The first constraint ensures that each agent is assigned to a single workplace, but not all agents will be compulsorily assigned. The second constraint establishes the number of agents in every working team. The method allows finding the global optimal solution of the problem. This solution, however, has no practical interest because it mixes agents working in different sectors such as supermarkets and hospitals. Agents have different abilities and cannot be exchanged for each other. So it is better solving the problem by specific contracts or areas. The program was written in Microsoft-Excel-Solver and tested in a company providing outsourced services. All tests carried out with company's data provide good results. In the test presented in the paper we performed the assignment of 26 agents to 6 workplaces. The result obtained reduced the transportation cost around 25%.

■ TC-13

Tuesday, 12:30-14:00 - Building CW, ground floor, Room 3

VeRoLog: Stochastic VRPs 1

Stream: Vehicle Routing and Logistics Optimization
Chair: *Michel Gendreau*

1 - Exact solution approaches for the Vehicle Routing Problem with Stochastic Demands and preventive restocking recourse policies

Michel Gendreau, Majid Khoshghalb, Ola Jabali, Walter Rei

The vast majority of the literature on the Vehicle Routing Problem with Stochastic Demands is based on two-stage stochastic programming formulations, in which the recourse action for any vehicle is to perform a back-and-forth capacity replenishment trip to the depot whenever the accumulated demand exceeds the vehicle capacity. It is well-known that this recourse structure is not very reasonable in any practical setting.

In this talk, we examine in a comprehensive fashion several alternate policies based on preventive returns to the depot according to several criteria. Exact solution methods based on the Integer L-Shaped Method, augmented with specialized lower bounding functionals, are described and tested. Our computational results show that our solution approaches are quite effective, while the alternate recourse policies that we propose can lead to substantial economies.

2 - Heterogeneous Fleet Stochastic Vehicle Routing Problem with Time Windows

Gamze Tuna, Charkaz Aghayeva, Melis Alpaslan

The vehicle routing problem (VRP) aims to minimize the overall distribution costs and has been extensively studied in the literature. The majority of these works are deterministic problems in which all information is known in advance. But in real life problems, some input data are partially known as random variables, which realizations are only revealed during the execution of the routes. For this reason, stochastic models are more suitable and beneficial to describe real life problems. In this study, heterogeneous fleet stochastic vehicle routing problem with time windows is considered. The vehicle routing problem with time windows (VRPTW) is a hard combinatorial optimization problem. Therefore, obtaining the optimal solution is very time consuming and difficult. To cope with these drawbacks, in this study, different solution techniques are analyzed and appropriate clustering methods are applied to this problem.

3 - Stochastic single vehicle routing problem with ordered customers

Epaminondas Kyriakidis, Theodosis Dimitrakos, Constantinos Karamatsoukis

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

4 - The waste collection vehicle routing problem with time windows and uncertain demands: Model and solution approaches

Thomas Yeung, Quentin Tonneau, Nathalie Bostel, Pierre Dejax

With more than ten billion kilograms of waste produced every day in the world, waste logistics management has become a major cost reduction and optimization challenge. We address a vehicle routing problem to collect waste (e.g., glass, paper, plastic, etc.) from recycling bins in public spaces or from industrial companies. This problem considers a single depot for the vehicles and a set of intermediate facilities (i.e., disposal sites) where trucks can dump their content in order to continue their collection tour. Each bin must be fully emptied when visited and trucks must also to visit a disposal site before returning to the depot in order to arrive empty. Each node (i.e., depot, facility and bin) is characterized by its own service time and accessibility hours. This problem is known as the Waste Collection Vehicle Routing Problem with Time Windows (WCVRP-TW). We propose a mathematical model and solution methods in order to solve the deterministic version of this problem. A stochastic approach where quantities of waste brought to containers are uncertain is also proposed to improve the solution robustness in real applications. We compare our approach with existing deterministic benchmarks and test realistic scenarios of alternative demand to measure the solutions' performance and robustness. In particular, we apply this approach on real data provided by a French waste transport and logistics company.

■ TC-14

Tuesday, 12:30-14:00 - Building CW, 1st floor, Room 125

Mixed Integer Nonlinear Programming

Stream: Mixed-Integer Linear and Nonlinear Programming
Chair: *Ozlem Defterli*
Chair: *Omar El Housni*

1 - Numerical Solutions to Global Mixed Integer Nonlinear Optimization Problems

João Lauro Faco', Ricardo Silva, Mauricio Resende

Mixed-Integer Nonlinear Programming is used here for modeling and solving one of the most general and hard optimization problems - the scheduling of oil derivatives operations in ports and refineries. These problems include both nonlinear terms and logical decisions (integer variables). Small and medium scale MINLPs are currently addressed using continuous relaxations and solved by a branch-and-bound procedure. Due to the curse of dimensionality, large-scale instances cannot be solved this way. The metaheuristic method Continuous-GRASP solves efficiently general constrained global continuous optimization problems (Facó, Resende and Silva - 2011, 2012, 2013, 2014, 2015) by adapting the greedy randomized adaptive search procedure (GRASP) for discrete optimization to the case of continuous variables. A new version of C-GRASP that considers both discrete and continuous variables is presented. GRASP random search and local improvement phases use independently a discrete and a continuous set. The linear or nonlinear constraints are incorporated in the objective function by quadratic penalty terms in C-GRASP. Numerical solutions to difficult MINLP problems are presented.

2 - A MINLP model for the Hydro-Scheduling Problem. The Case of a Head-dependent Cascaded Reservoir System

Javier Diaz, Luis Moreno

Electric power systems have evolved from centralized monopoly schemes minimizing the expected total cost of the system operation to competitive markets, maximizing their own profits. In this work, a new optimization criterion is applied: maximizing the technical efficiency of the hydroelectric generating units. The main purpose of this work is to show a methodology to support the decision making to optimize the operation and evaluation of a Hydroelectric Generation Company (H-GENCO) technical efficiency in short term electricity markets. This methodology is expressed as a set of algorithms implemented in software prototypes with applications to several cases related to a cascaded reservoir system. Several Mixed Integer Nonlinear Programming (MINLP) models are developed for the integrated operation programming in short-term of an H-GENCO in a pool-based electricity market. The technical efficiency is precisely estimated from the "Hill Diagram" provided by the turbine manufacturer, through a multiple nonlinear regression analysis, as a net head and water discharge quadratic function. These models could serve to a H-GENCO for decision making about questions like the following: When to generate?, associated with the Unit Commitment Problem. How much to generate?, associated with the Economic Dispatch Problem. How to offer?, associated with the Bidding Design.

3 - Piecewise Affine Policies for Two-stage Robust Optimization under Demand Uncertainty
Omar El Housni, Aharon Ben-Tal, Vineet Goyal

We consider the problem of designing good piecewise affine policies for two-stage adjustable robust linear optimization problems under right hand side uncertainty. Such problems arise in many applications where we need to satisfy an uncertain demand with minimum possible cost. It is well known that a piecewise affine policy is optimal although the number of pieces can be exponentially many. One of the significant challenges in designing a piecewise affine policy arises from constructing good pieces of the uncertainty set. We introduce a new framework for constructing piecewise affine policies where we "approximate" the uncertainty set by a simplex and construct a piecewise affine policy based on the map from the uncertainty set to the simplex. Our piecewise affine policy has exponentially many pieces but can be computed efficiently and in many cases, even more efficiently than computing the optimal affine policy. Furthermore, the performance of our piecewise affine policy is significantly better than the affine policy.

■ TC-15

Tuesday, 12:30-14:00 - Building CW, 1st floor, Room 126

Optimal Control of Gas Network Dynamics

Stream: Optimization of Gas Networks
Chair: *Falk Hante*

1 - Improving efficiency of optimization in gas networks using the space-mapping approach
Mapundi Banda

In a gas network, different arcs of the network can be modeled by possibly different models depending on the requisite qualitative detail required: an isothermal Euler system of equations; a linearized model derived from the isothermal Euler system or a steady state model of gas flow also referred to as an algebraic model. A proposal is made to improve the efficiency of optimization in gas networks based on a space-mapping approach. The model hierarchy is exploited to define an appropriate multi-fidelity approach. As a case study, a dynamic compressor optimization problem is considered. Even if we desire to solve an optimization problem with the nonlinear model, this can be very costly. That notwithstanding, we endeavor to bring as much nonlinear effects into the optimization process as possible but solve an optimization problem using a more efficient model. The mathematical formulation and algorithmic aspects of a space-mapping technique are developed. Computational results and comparison between different approaches are presented.

2 - Optimal Switching of a Semilinear Model for Gas Networks
Fabian Rueffler, Falk Hante

The framework of optimal switching of evolution equations is an alluring connection between discrete and continuous mathematics in the sense that it describes systems of dynamics driven by continuous evolution equations, concatenated by time-isolated discrete switching points. In order to optimize such dynamics we ask for the best sequence of switching time points, optimal in number, position and order with respect to a given cost function. Gas dynamics on networks is an excellent example for the use of this framework, in that we need to decide how to switch active elements such as valves and compressors with finite operational states in order to control the complex gas flow. We model this problem by a coupled system of semilinear PDEs obtained from Simplifications of the Euler gas-equations and treat these PDEs using the theory of nonlinearly perturbed strongly continuous semigroups. We present an adjoint-equation based representation for the gradients of the operational cost function with respect to the switching points. The results can be incorporated in a gradient-based descent algorithm to compute optimal valve switching numerically.

3 - Optimal Boundary Control of Hyperbolic Conservation Laws with Switching Controls
Sebastian Pfaff, Stefan Ulbrich

Hyperbolic conservation laws arise in many different applications such as traffic modeling or fluid mechanics. The crucial issue of nonlinear hyperbolic conservation laws is the development of shocks in the entropy solutions in finite time, which leads to the problem that the solution operators are not differentiable in a sufficiently strong sense. This issue has to be overcome in order to apply gradient-based optimization methods.

In this talk we consider optimal control problems governed by initial-boundary value problems for scalar conservation laws in 1D, where the time-dependent boundary data switch between different C1-functions. We consider both the C1-functions and the switching points as controls.

Although the control-to-state mapping is not differentiable in a usual sense, we show Fréchet-differentiability to hold for its composition with a typical objective function and derive an adjoint-based representation of the gradient of the reduced objective function.

The consideration of switching times as additional control variables becomes more important if one considers networks of conservation laws, where the node conditions model switching devices such as valves or gates. We briefly illustrate this fact by an example with on/off-switching, namely a traffic light.

4 - Decomposition methods for mixed-integer optimal control
Mathias Sirvent, Martin Gugat, Günter Leugering, Alexander Martin, Martin Schmidt, David Wintergerst

Real world applications are often faced with a search for an optimal solution for mixed-integer programs with additional constraints given as differential equations. Our new approach is a decomposition of the problem into a masterproblem and a subproblem.

The masterproblem considers integer variables and a relaxation of the feasible set by ignoring the differential equations, whereas the subproblem considers the continuous variables and uses numerical methods to deal with the differential equations. We are developing an information exchange between the problems and are working out an algorithm which solves the problem to global optimality by looping the two problems. The masterproblem improves its relaxation during the algorithm by receiving additional cuts and disjunctions from the subproblem, whereas the subproblem itself evaluates the integer decisions of the masterproblem to generate these cuts and disjunctions. Additional requirements are necessary to ensure the correctness of the information exchanges. A proof of convergence is given under certain assumptions.

Our real world application is a gas network, where we have to consider the Euler equations, which model the gas dynamics and bring in differential equations to our network. We are testing small networks and present numerical results for the abovementioned algorithm.

■ TC-16

Tuesday, 12:30-14:00 - Building CW, 1st floor, Room 128

Patient and Resource Logistics in Healthcare

Stream: Healthcare Logistics
Chair: *Siegfried Voessner*
Chair: *Nikolaus Furian*

1 - Optimization Methods for Patient Transit Dispatching

Nikolaus Furian

The on-time completion of patient transits can be identified as a bottleneck for the efficiency of health care services in major New Zealand hospitals. Delayed transits of patients between wards and treatment or diagnostic facilities lead to increasing waiting times at clinics and inefficient resource utilization (e.g. surgery teams) as appointment times are not met. We present an optimization algorithm to dispatch staff members, orderlies and nurses, to patient transits. The proposed algorithm is based on individual mixed-integer formulations for separated orderly and nurse problems and uses a critical path method for the combination of individual solutions. Solutions for the individual single staff type problems are computed using a column generation method similar to solving strategies for the vehicle routing problem with semi-soft time windows. Thereby, new techniques to speed up the computation of negative reduced cost columns for this problem type are presented, as limited subsequence and specifically designed branching schemes. Furthermore, heuristic methods are used to obtain a set of initial solutions for the column generation approach. These heuristic procedures may also act as standalone algorithms and accurately represent dispatching methods currently in place in the real system. Hence, the performance of the proposed algorithm is compared to the performance of the heuristic methods and results are analysed.

2 - A vehicle routing planning system: case of study of a pharmaceutical Chilean company.

Pablo González-Brevis, Matias Vaccarezza

In this talk we will present a novel methodology to solve the vehicle routing problem of a pharmaceutical company in Chile. The main problem was built as a capacitated vehicle routing problem with time window (CVRPTW) with the objective of minimizing the number of trucks used and some other constraints in order to meet some store demands among other considerations. The proposed methodology was divided in three stages plus an optional stage. In the first one, the stores are grouped in clusters by solving a p-median model so no more than thirty nodes (stores) are assigned to a given cluster. In the second stage a manual reallocation of nodes in the clusters is performed. In the third stage, the CVRPTW model is solved for each cluster. In order to improve the proposed routes obtained at this point, a fourth alternative stage is proposed, consisting on solving the traveling salesman problem with time window (TSPTW) for each route so the distance travelled is minimized. Compared against a real week, the proposed methodology shows savings around 27% on the transportation costs.

3 - Detailed scheduling of radiotherapy treatments with recurring and optional activities on alternative resources

Petra Vogl, Roland Braune, Karl Doerner

The Radiotherapy Patient Scheduling Problem (RPSP) deals with the assignment of treatment appointments to patients suffering from various types of cancer. While photons are used to irradiate patients in classical radiotherapy, specialized centers all over the world use ion beam therapy in order to less harm healthy tissue surrounding the tumorous region. Due to the high demand and large costs of the accelerators used in these centers, optimizing radiotherapy appointments is crucial.

We present a mixed-integer programming model of the real-world inspired patient scheduling problem of the newly built radiotherapy facility near Vienna, Austria. The RPSP is modelled as a Job Shop Scheduling Problem with alternative (preferred) resources, sequence dependent setup times, optional activities that have to take place at least once a week and stable starting times of the recurring daily treatment activities of the patients. Since various activities with different durations compete for the same resources, we incorporate exact starting times instead of block scheduling techniques. Furthermore, we investigate a hierarchical assignment and sequencing heuristic to solve real-world instances.

■ TC-17

Tuesday, 12:30-14:00 - Building CW, ground floor, Room 0210

Retail Inventory Management 2

Stream: Demand and Supply Management in Retail and Consumer Goods
Chair: *Zumbul Atan*
Chair: *Ruud Teunter*

1 - The Repair Kit Problem with positive lead times and ordering costs

Ruud Teunter

The Repair Kit Problem (RKP) concerns determining the optimal set of parts in the kit of a service engineer performing on-site product support. Models developed in the literature have always neglected the lead times associated with delivering parts to the kit, thereby limiting the practical relevance of the proposed solutions. Motivated by a real life case, we develop a model with positive lead times for replenishing the parts to the kit, and study the performance of order level, order-up-to level policies under a service objective (service model). We present a method for exactly calculating job fill rates. The empirical utility of the model is assessed on real data from an equipment manufacturer and useful insights are offered to after-sales managers.

2 - The influence of quality inspections on the optimal safety stock level

Gudrun Kiesmuller, Danja Sonntag

We consider an in-house multi-stage serial production system without interim storage between the production stages but with a warehouse for the final product. Each production stage is related to stochastic proportional yield and a production time. At the beginning of each period the warehouse can place an order according to a linear inflation rule. The demand which has to be fulfilled by the warehouse is stochastic and independent and identically distributed across the periods. Demand which cannot be satisfied is backlogged. At the end of each period holding and backorder costs are charged.

Using an approximate steady state analysis we obtain an analytical expression for a near optimal pseudo order-up-to level under real time yield information. We show how the location of inspections within a production process influences the optimal safety stock level, required to buffer against uncertainties due to demand and yield randomness. We show that in general, for symmetric yields across the system it is best to locate control points equally spaced across the production periods to minimize overall costs. We achieve a maximum safety stock reduction of more than thirty percent in our examples which can be even larger depending on the parameter setting.

3 - An inventory control model for modal split transport: A tailored basesurge approach

Chuanwen Dong, Sandra Transchel, Kai Hoberg

Firms are increasingly interested in transport policies that enable a shift in cargo volumes from fast transport modes (e.g., trucks) to slow transport modes (e.g., trains or barges). While slow modes are, in general, cheaper than fast modes, they lack flexibility in terms of shipment quantity and delivery frequency. This may cause unnecessary inventories and lost sales. To guide the strategic volume allocation, we examine a Modal Split Transport (MST) policy of two modes that integrates inventory controls. While slow mode deliveries can only be used every other period, with a volume to be fixed for a long-term horizon, e.g., one year, fast mode deliveries can be used every period and are flexible in the volume. The objective is to minimize the long-run expected total costs of transport, inventory holding, and backlogging. The MST model has a generalized mathematical structure compared to that of the Tailored Base-Surge (TBS) policy in the dual sourcing literature. We solve approximate problems analytically and provide practitioners an easy-to-implement solution tool. The results provide structural insights on the tradeoff between transport cost savings and holding cost spending and reveal a high utilization of the slow mode. Numerical results indicate that as much as 85% of the expected volume should be split into the slow mode. The numerical tests also show that our approximation is reasonably accurate, with an error of less than 3% compared to the optimal results.

4 - Feasibility of Product Innovation: Issues and Challenges for Indian Society
Sadia Samar Ali, Rajbir Kaur

Innovation calls for differentiated thinking patterns which offer more efficient solutions to complex issues. Organizations are looking for technologies capable of accomplishing multiple tasking, providing economic benefits and an edge over their competitors. Technology related innovations have provided a unique opportunity to organizations to step back from a narrow way of thinking about doing business towards a broad spectrum where business engagements have found their ways entangled with Philanthropy, social welfare and well-being of all the related stakeholders. One such example is Drones or Unmanned Aerial Vehicles (UAVs). Packed with a combination of automation, creative software design, and unperceived mobile computing power, drone technology has arrived to advance human efficiency. The study discusses the possibility of Drone as a next step for the societal benefits especially in Indian Context. The scope of Commercial drone along with its projected growth, its possible absorption in multiple industries and the benefits it can offer have been discussed in this study. Various factors impacting 'Technovation'; the absorption of new technology, leadership for innovation, social and economic environment, customer's perception, regulatory pressures and alliances with national and international organizations have been explored and discussed to find out the suitable outcomes. The technical, commercial and economical or market potential of drone has also been explored.

■ TC-18

Tuesday, 12:30-14:00 - Building CW, ground floor, Room 023

Shop-Floor Management

Stream: Production and Operations Management
Chair: *Krzysztof Fleszar*

1 - Allocating the optimum number of similar machines to operators
Baruch Keren, Yossi Hadad, Lea Friedman

The purpose of this research is to determine the optimal number of operators to be assigned to a given number of machines, as well as the number of machines that will be run by each operator. This determination should be made with the objective of minimizing production costs or maximizing profits. The proposed method calculates the machines interference rate via the binomial distribution function. The optimal assignment is calculated by transformation of a partition problem into a problem of finding the shortest path on a directed acyclic graph. The method enables to calculate the adjusted cycle time, the workload of the operators, and the utility of the machines, as well as the production yield, the total cost per unit, and the hourly profit for each potential assignment of operators to machines.

2 - Finding all optimal solutions for the job shop scheduling problem
Jelke van Hoorn

We described a dynamic programming algorithm to solve the job shop scheduling problem. We improved this algorithm by adding bounds. We will shortly present these results. We create an algorithm based on this dynamic programming algorithm to find all optimal solutions. For almost all small benchmark instances we were able to find all optimal instances. We will see that the number of optimal instances differs quite a lot over the different instances.

3 - Component Lot-Sizing in an Assemble-to-Order System with Zero Setup Costs and with a Capacity Constraint
Mehdi Bijari

In this paper we consider a so-called assemble-to-order environment . There are a number of final products, each of which requires assembling of two or more components. This research is presented a novel production planning approach, not hitherto cited in the literature, for assemble-to-order systems. In this method, components are lot-sized according to manufacturing source capacity constrained at each period. The proposed approach determines components lot size for one period at a time. It is especially suitable when setup cost is relatively small and the lead time for preparing component parts and raw materials is greater than one period.A factory produces m products from components according to customer order. Product assembly operates over one period but the components must be available at the beginning of each period. A family of components are produced in a workshop with limited capacity. This family has n type of components. Lot sizing for this component family is our objective. Demand and lot of component production during the lead time is considered in single period lot-sizing.Although size of production lot is obtained for a component in a product, the stock level for each component is the sum of these quantities and components used in the product assembly without considering calculated lot size . System simulation reveal that this policy yields greater expected profits then the other policy.

4 - A new MILP model for the Accessibility Windows Assembly Line Balancing Problem
Krzysztof Fleszar

We consider a variant of the assembly line balancing problem in which each workstation can reach only a portion of a workpiece, or portions of two consecutive workpieces, through its accessibility window. The cycle of the line is divided into several stationary stages, and in each stage, each workstation can perform only those tasks that are reachable by it during that stage. This problem arises in practice in the automatic assembly of printed circuit boards. The solution of the problem calls for deciding the number and the offsets of the stationary stages, as well as for partitioning the tasks preassigned to each workstation among the stationary stages. The objective is to minimize the cycle time, which is equal to the sum of stage completion times and transportation times. The problem has been introduced in the literature relatively recently. A MILP model and several hybrid algorithms combining metaheuristics and mathematical programming have been proposed. The best of those algorithms, given a one-hour time limit per instance, solves to optimality 81% of test instances of a standard benchmark set and obtains an average gap of 1.13% and a maximum gap of 22%. In this work, we propose a new simpler MILP model. In computational experiments, our MILP model, given a one-hour time limit per instance, solves to optimality 97% of test instances of the same benchmark set and obtains an average gap of 0.01% and maximum gap of 2.24%.

■ TC-19

Tuesday, 12:30-14:00 - Building CW, ground floor, Room 021

Graph Searching 1

Stream: Graph Searching
Chair: *Nancy Clarke*

1 - Cops and Robber with Decoys
Nancy Clarke

We introduce a variation of the Cops and Robber game in which the robber side consists of a robber and a decoy which are indistinguishable to the cops except under certain conditions. The cops win when one of them moves onto the same vertex as the actual robber (i.e. not the decoy) after a finite number of moves. The robber can throw the decoy to a neighbouring vertex on any move beyond his first. The decoy disappears after the cops' next move so there is only a single decoy in play at any time. We characterize decoy copwin graphs, those on which a single cop can guarantee a win, in the case that the cop can distinguish between the robber and decoy only when he is on the same vertex as one of them. We also present results for several other variants.

2 - How much can be rescued from a graph on fire?
Przemysław Gordinowicz

Let G be any connected graph on at least 2 vertices, let k be any positive integer. Suppose that a fire breaks out on some vertex of G. Then in each turn k firefighters can protect vertices of G — each can protect one vertex not yet in fire; Next the fire spreads to all not protected neighbours of burning vertices. The above model was introduced by Hartnell in 1995.

It is not surprising that the number of vertices which can be saved highly depends on a choice of a vertex where the fire has broken out. To manage this problem there was defined some graphical parameter - the k-surviving rate of G, as the expected fraction of vertices that can be saved from the fire by k firefighters, providing that the starting vertex is chosen uniformly at random (Cai and Wang, 2009).

Another evident observation is that the surviving rate depends on a density of a graph, i.e. sparse graphs are less flamable. Hence, it seems to be reasonable to investigate the surviving rate on such graph classes which are not only important from the applications point of view, but also which force sparsity of its members, eg. planar graphs.

During a presentation bounds on the surviving rate for some graph classes will be shown. There also will be discussed few conjectures and open problems regarding to the firefighter problem on graphs.

3 - Undirected graph exploration with (log log n) pebbles
Yann Disser, Jan Hackfeld, Max Klimm

We consider the fundamental problem of exploring an undirected and initially unknown graph by an agent with little memory. The vertices of the graph are unlabeled, and the edges incident to a vertex have locally distinct labels. In this setting, it is known that (log n) bits of memory are necessary and sufficient to explore any graph with at most n vertices. We show that this memory requirement can be decreased significantly by making a part of the memory distributable in the form of pebbles. A pebble is a device that can be dropped to mark a vertex and can be collected when the agent returns to the vertex. We show that for an agent O(log log n) distinguishable pebbles and bits of memory are sufficient to explore any bounded-degree graph with at most n vertices. We match this result with a lower bound exhibiting that for any agent with sub-logarithmic memory, (log log n) distinguishable pebbles are necessary for exploration.

4 - Bovine life history intersection graphs and their use in studying disease resiliency
Jessica Enright

Cattle spend their lives at different farms, and can only be infected with disease by other animal present at the same time and place. Some diseases are only likely to be transmitted by long periods of contact between two animals while some can spread quickly, but are more likely detected.

We present a generalisation of interval tolerance graphs that formalises the movement of animals between locations in which each location is a parallel real line, and each animal is a vertex represented by a number of intervals on those real lines. Given such a representation, we can calculate the resulting intersection graph in which two vertices are adjacent if their corresponding sets of intervals have some minimum intersection - that is, if two animals have spent at least some minimum time period colocated. We discuss the use of this representation and graph for studying the resilience of a livestock trading system over a variety of types of contagion.

■ TC-20
Tuesday, 12:30-14:00 - Building CW, ground floor, Room 022

How OR found its way into universities 2

Stream: How OR found its way into Universities
Chair: *Graham Rand*

1 - Operations Research plus Management Schools equals Analytics
Cathal Brugha

In University College Dublin's Business School a Master of Management Science programme founded in 1978, was replaced in 2008 by an MSc in Business Analytics. Over the years there have been changes in Depth and Breadth. Depth: It started with traditional OR, the foundational industrial structures, and the analysis of production and engineering problems. Its original naming as Management Science reflected including broader management functions in the design of solutions. Analytics focuses on strategic decision-making and implementable choices. Breadth: It started with technical and scientific OR skills: mathematics, and computer programming. This was extended to include business contexts and humanities-informed subjects: management information systems. Analytics includes both, but also decision situations and management practice: multi-criteria decision-making, and methodologies. The original emphasis on hard maths that was a good intellectual training, and computer programming skills that would be useful, has been replaced by usable real large-scale problem-solving, and decision-models that truly reflect the thinking structures relevant to decisions. OR/MS tended to not encroach on computer science. Analytics is so successful that computer science has re-invented itself as 'Big Data'. The true analytics area is more about 'Big Decisions'. OR/MS up to now has suffered from a lack of relevance to management practice. Analytics will correct this flaw for the future.

2 - History of OR in Iceland's universities
Pall Jensson

The first applications of OR in Iceland were in the fisheries industries in the years 1966-1969, right after the arrival of the first computer in the country and the first people with a PhD in OR returning from studies abroad to Iceland. In these years 75% of the export value of the country was fish and fish products. These OR projects, in our main industry at that time, seem to have been successful enough to draw attention to the application potential of OR. In 1975 this, together with the recent availability of computers and OR knowledge, led to the beginning of OR teaching in our university programs, at the University of Iceland, first one introductory course in Mechanical Engineering, later evolving into a total of 6 OR courses in the Industrial Engineering program. The Mathematics program has offered applied math including OR for about 40 years, now with 6 OR courses. The Business Administration program at the same university has also taught OR since 1975. Reykjavik University started an Engineering Management program in 2005 and is now offering 6 OR courses.

3 - How OR found its way into Danish universities
Jakob Krarup

Frederik Johannsen, Managing Director of Copenhagen Telephone Company (KTAS) authored in 1907 the first paper on applied OR in Denmark. Besides, he had a remarkable talent for recruiting the right people including Agner Krarup Erlang, worldwide recognised for his pioneering works as evidenced by his inclusion in 2004 in "IFORS' Operational Research Hall of Fame". Also Arne Jensen was employed by KTAS until he in 1963 became the first professor of OR in Denmark and later President of IFORS (1971-73). Furthermore, an OR division was established in 1959 at the Danish Institute of Computing Machinery (RC) which experienced its 'golden years' up to 1964. Eight former RC-staff members became afterwards full professors of OR or C.S. and spread the message to various Danish universities.

■ TC-21

Tuesday, 12:30-14:00 - Building CW, ground floor, Room 025

Sustainable multimodal urban mobility

Stream: Public Transportation
Chair: *Chistos Zaroliagis*
Chair: *Damianos Gavalas*
Chair: *Grammati Pantziou*

1 - Multimodal Tourist Tour Planning
Damianos Gavalas, Vlasios Kasapakis, Charalampos Konstantopoulos, Grammati Pantziou, Nikolaos Vathis, Chistos Zaroliagis

Tour planning represents a challenging task for individuals visiting unfamiliar tourist destinations, mainly due to the availability of numerous attractions (points of interest, POIs) and the complexity of metropolitan public transit networks. Although several city guides support the provision of personalized tour recommendations to assist tourists visiting the most interesting attractions, existing tour planners only consider walking tours. Herein, we introduce eCOMPASS, a context-aware mobile application which also considers the option of using public transit for moving around. Far beyond than just providing navigational aid, eCOMPASS incorporates multimodality (i.e. time dependency) within its routing logic aiming at deriving near-optimal sequencing of POIs along recommended tours so as to best utilize time available for sightseeing and minimize waiting time at transit stops. Further advancing the state of the art, eCOMPASS allows users to define arbitrary start/end locations (e.g. the current location of a mobile user) rather than choosing among a fixed set of locations. Last, eCOMPASS may assist in scheduling lunch breaks at affordable restaurants, conveniently located along the recommended tours. This paper describes the routing algorithm which comprises the core functionality of eCOMPASS and discusses the implementation details of the mobile application using the metropolitan area of Berlin (Germany) as case study.

2 - An Incentivized Relocation Scheme for Balancing Vehicle Sharing Systems
Grammati Pantziou, Alexandros Angelopoulos, Damianos Gavalas, Charalampos Konstantopoulos, Damianos Kypriadis

The major operational problem in one-way vehicle sharing systems (VSSs) is the vehicle stock imbalance taking place when a large number of vehicles is gathered to certain stations of the VSS while other stations remain without sufficient vehicle stock to satisfy user requests. A common approach to address the problem is to employ drivers to relocate vehicles. An alternative approach employs price incentives to encourage users to pick up their vehicle from a station with stock surplus and/or to drop it off to a station with stock deficit. In this work we propose a new scheme for allocating vehicles to users that employs reservations to address supply-and-demand mismatches; our mechanism offers price incentives to reward users if their trip serves the purpose of the balanced distribution of vehicles across the service (operational) area of the system. Given a set of user requests our scheme computes a set of trip recommendations aiming at maximizing the system's profit i.e., the number of accepted requests taking into account the priorities of the vehicle relocations, the fluctuating demand over time, the budget constraints, and the long-term behavior of the users. The derived trip suggestions are associated with price incentives aiming at encouraging users to accept them. We propose two truthful and budget-feasible mechanisms for incentivizing users to accept the recommended trip options.

3 - How Far You Can Drive: Fast Exact Computation of Isochrones in Road Networks
Valentin Buchhold, Moritz Baum, Julian Dibbelt, Dorothea Wagner

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

Driven by this application, we study the problem of computing isochrone contours in static and dynamic road networks, where the objective is to identify the boundary of the region that is reachable from a given source within a certain amount of time, or alternatively, with a certain battery charge. Although this problem has even a wide range of other practical applications (e.g., urban planning, geomarketing), there has been little research on fast algorithms for large, realistic inputs, and existing approaches tend to compute more information than necessary.

Our contribution is twofold: (1) We propose a more compact but sufficient definition of isochrones, based on which (2) we provide several easy-to-parallelize, scalable algorithmic approaches for faster computation. By extensive experimental evaluation, we demonstrate that our techniques enable fast isochrone computations within milliseconds even on networks at continental scale, significantly faster than the state-of-the-art.

4 - Efficient Traffic Information Updating through Parallelization
George Michalopoulos, Spyros Kontogiannis, Chistos Zaroliagis

The development of practical algorithms for route planning in large-scale road networks which are accompanied by a time-dependent arc-cost metric (Time-Dependent Route Planning - TDRP), has proved to be a grand challenge recently. While there is an analogue of Dijkstra's algorithm to solve TDRP in quasi-linear time, this is already too much for a responsive route-planning application in real-world road networks of continental size. A recent development of landmark-based time-dependent distance oracles, which preprocess traffic-related information from selected landmarks towards all reachable destinations, apart from the provable approximation guarantees, has also demonstrated remarkable speedups with reasonable preprocessing time and space requirements. A core operation of the preprocessing method is to sample min-cost landmark-to-destination functions at certain values, and then construct appropriate approximations (summaries) of these unknown functions. In a realistic scenario, however, we must take into account the live-traffic dynamicity of the metric's characteristics, e.g., due to unforeseen incidents. We provide and experimentally evaluate parallel algorithms for sampling min-cost trees at certain values in time-dependent road networks. Our methods are based on the quite successful (for static metrics) Delta-Stepping algorithm and demonstrate significant improvements in the required preprocessing time for updating the summaries in response to live-traffic reports.

■ TC-22

Tuesday, 12:30-14:00 - Building CW, ground floor, Room 027

Scheduling Models and New Applications 1

Stream: Combinatorial Optimization
Chair: *Eugene Levner*
Chair: *Frank Werner*

1 - Integrated scheduling of maintenance and transportation operations in military supply chains
Eugene Levner, Frank Werner

In order to make a military supply chain demand-responsive and efficient, its components should function in a coordinated and synchronized manner. Our study focuses on scheduling of the maintenance and transportation operations whose coordinated scheduling in the corresponding maintenance module (MM) and transportation module (TM) is carried with the help of a controlling module (CM). The CM controls and analyzes two "meta" performance measure: the time of response (according to which the products are delivered to the end-customer in time) and the military effectiveness (according to which the required quantity of the right products are delivered at the right time). We suggest an iterative solution procedure in which the local-optimal schedules found in the TM and MM serve as inputs for the CM that corrects and revises the input data for the MM and TM after which, in turn, their operations are re-scheduled and improved schedules proceed as new inputs to the CM where two meta performance measures are recalculated. The iterative process is repeated until two performance measures in the CM reach the required levels. The iterative procedure is proved to be more efficient than that of the GAMS/CPLEX solver. The work is performed in co-authorship with Hanan Tell and Dmitry Tzadikovich (both from Bar Ilan University, Israel)

2 - Recent Advances for Parallel Machine Schduling Problems with a Single Server

Frank Werner, Keramat Hasani, Svetlana Kravchenko

The problem of scheduling jobs on a set of identical parallel machines with a single server is considered. Before processing, each job must be loaded on a machine, which takes a given setup time. All these setups have to be done by a single server which can handle at most one job at a time. We survey recent advances to solve such problems done by the authors. For the makespan problem we develop three mixed integer linear programming models (MILP) and two meta-heuristics. These models are compared for instances with up to 250 jobs and outperform all existing results. A simulated annealing and a genetic algorithm are developed and the results are compared with those existing in the literature on a large set of instances with up to 1000 jobs. Two fast constructive algorithms are also proposed which have an excellent performance for instances with up to 10,000 jobs. This superiority is obtained by sequencing the jobs on the two machines such that the machine idle time and the server waiting time are minimized.For the problem of minimizing mean flow time, we give two MILP models and two meta-heuristics including a simulated annealing algorithm and a hybridization of harmony search and simulated annealing. We apply these methods to instances with up to 250 jobs. For minimizing total weighted completion time, we propose an improved approximation algorithm. For the interference problem, a heuristic is proposed and tested on instances with up to 100,000 jobs.

3 - Scheduling of rescue operations under imperfect inspections

Michael Bendersky, Boris Kriheli

The need for the search, detection and rescue of disaster survivors arises in many emergency situations in military and civil applications. Suppose a number of people (targets) are trapped in ruins after an earthquake or tsunami. Their chance of survivability depend on their medical condition, location, detection and rescue times. We consider the case that the prior information on the targets is noisy: a new target is discovered during the rescue operation (false negative detection) and a non-target is classified as a sought target (false alarm). In other words, we have errors of the first and second kind. We suggest a greedy scheduling algorithm for rescue teams working in parallel by dividing the disaster area into equally sub-areas (clusters). Since the disaster area isn't homogeneous (for example, the area around the center of the earthquake contains more targets and their rescue is harder) the values of the rescue times and both errors are set higher for these sub areas than areas that are more far away from the center.

4 - Multiobjective optimization for the car relocation problem in one-way carsharing system

Laurent Moalic, Rabih Zakaria, Alexandre Caminada, Mohammad Dib

In this paper, we present a multiobjective approach for solving the one-way car relocation problem. We fixed three objectives that include the number of remaining rejected demands, the number of jockeys used for the relocation operations and the total time used by these jockeys. For this sake, we propose to apply two algorithms namely NSGA-II and memetic algorithm (MA). The NSGA-II is used as a reference to compare the performance of MA. The comparison of the approximation sets obtained by both algorithms shows that the solutions generated by the MA are much better than the solutions generated by NSGA-II. This observation is proved by the comparison of the different quality indicators values that are used to compare the performance of each algorithm. Results show that the MA is promising to generate very good solutions for the multiobjective car relocation problem in one-way carsharing system. These findings are motivating to continue the research on this approach for solving the car relocation problem in order to explore the capacity of this approach and to work on a decision maker tool that facilitates the decision making for carsharing operators.

■ TC-23

Tuesday, 12:30-14:00 - Building CW, ground floor, Room 028

Green Urban Logistics

Stream: Green Logistics
Chair: *Ulrich Breunig*
Chair: *Nabil Absi*
Chair: *Pamela Nolz*

1 - A simple LNS-based heuristic for Two-Echelon Routing Problems

Ulrich Breunig, Verena Schmid, Richard Hartl, Thibaut Vidal

We address optimisation problems arising in the context of city logistics. The focus lies on two-level transportation systems with a single depot: both the Two-Echelon Vehicle Routing Problem (2E-VRP) and the Two-Echelon Location Routing Problem (2ELRP) seek to produce vehicle itineraries to deliver goods to customers with mandatory transit through intermediate facilities. In the 2EVRP the locations of intermediate facilities - called satellites - are given and their use is not associated with additional cost. The 2ELRP problem class explicitly takes strategical decisions into account: the use of vehicles and satellites incurs additional fixed costs. The first echelon with large trucks operating between depot and satellites can be seen as a VRP with split deliveries. The second echelon corresponds to a multi-depot VRP: smaller vehicles, possibly driven by alternative technologies, operate between several satellites and the customers in the city center. A local-search metaheuristic, based on the principle of destroy and repair from Large Neighbourhood Search, is developed and implemented to find high quality solutions within limited computing time. The proposed algorithm is tested with several different benchmark instances for two-tiered problem classes with a single depot.

2 - Recharging management of electric vehicles for parcel delivery and collection under consistency requirements

Stefan Schwarzbach, Pamela Nolz, Ulrike Ritzinger, Bin Hu

Stemming from a real-world problem, we consider the delivery and collection of parcels to business customers over a predefined time horizon. The business customers rely on regular delivery times and familiar delivery personnel. Therefore, consistency when visiting customers for delivery and collection is to be maintained, implying that the same person should visit the same customer at approximately the same time every day. In order to enable the sustainable delivery and collection of parcels, electric vehicles are used. Each vehicle has to entirely perform the delivery of parcels before a collection tour of parcels can start. Each tour has a maximum length given on the one hand by the allowed working time of drivers and on the other hand by the battery range of the electric vehicles. Between the delivery tour and the collection tour vehicles return to the depot, where recharging is possible. Since fast charging slots are a limited resource, scheduling is necessary and delivery and collection tours have to be combined efficiently. We aim at identifying a set of consistent delivery and collection tours for electric vehicles, optimizing a combination of criteria: minimal travel time, minimal operating time of each vehicle (including waiting time for recharging and recharging time), maximal capacity utilization. We propose a metaheuristic approach based on efficient and effective operators for the charging management of electric vehicles while respecting consistency requirements.

3 - Proactive route guidance to avoid congestion
M. Grazia Speranza, Enrico Angelelli, Idil Arsik, Valentina Morandi, Martin Savelsbergh

A proactive route guidance approach is presented that integrates a system perspective: eliminating congestion, and a user perspective: minimizing distance traveled. The approach assigns paths to users so as to minimize congestion while keeping the increase of the travelled distance limited. By restricting the set of paths considered for an origin-destination pair to those that have a relative difference in length with respect to the shortest path, the so-called travel inconvenience, that is below a given threshold, a maximum level of inconvenience is guaranteed. The approach hierarchically minimizes the maximum arc utilization and the weighted average travel inconvenience. Minimizing the maximum arc utilization, the ratio of the number of vehicles traversing an arc and its capacity is a system-oriented objective, while minimizing the weighted average travel inconvenience, which averages the travel inconvenience of all eligible paths weighted by the number of vehicles that traverse the path, is a user-oriented objective. An important feature of the approach is that it only solves linear programming models. In an extensive computational study, we analyze, for different levels of maximum allowed travel inconvenience and for different networks, the weighted average travel inconvenience. We find that accepting relatively small levels of travel inconvenience can result in a considerable reduction, or even elimination, of congestion.

■ TC-24

Tuesday, 12:30-14:00 - Building BM, 1st floor, Room 119

Scheduling and Coloring

Stream: Project Management and Scheduling
Chair: *Marek Kubale*

1 - Scheduling Applications of the Graph Ranking Problem
Dariusz Dereniowski

In this talk we survey the graph ranking problem, also known under different names like minimum height elimination tree or tree-depth. We focus on selected applications of the problem, particularly on those in the field of chromatic scheduling: parallel assembly of multi-part products or searching in partial orders.

2 - No-Wait & No-Idle Open Shop with Bioperational Tasks
Krzysztof Pastuszak, Michał Małafiejski

In the open shop scheduling problem with bioperational tasks each task consists of two unit operations with a delay between the end of the first operation and the beginning of the second one. No-wait requirement enforces that the delay between operations is equal to 0. No-idle means that there is no idle time on any machine.

We model this problem by the interval incidentor (1,1)-coloring (IIR(1,1)-coloring) of a graph with the minimum number of colors which was introduced and researched extensively by Pyatkin and Vizing. An incidentor is a pair (v,e), where v is a vertex and e is an edge incident to v. In the incidentor coloring of a graph the colors of incidentors at the same vertex must differ. The interval incidentor (1,1)-coloring is a restriction of the incidentor coloring by two additional requirements: colors at any vertex form an interval of integers and the colors of incidentors of the same edge differ exactly by one.

In the paper we polynomially solved the problem of IIR(1,1)-coloring for graphs with the degree bounded by 4, i.e., we solved the problem of minimum makespan open shop scheduling of bioperational tasks with no-wait & no-idle requirements with the restriction that each machine handles at most 4 tasks. The problem remains open for 5 and more tasks.

3 - Bipartite Hypergraphs Edge-Coloring and Clos Networks
Paweł Obszarski

In previous works on Clos networks we have defined a new class of hypergraphs - bipartite hypergraphs. A hypergraph H with the vertex set V and the edge set E is bipartite if there exists a subset X of the vertex set such that for each hyperedge from E there exists exactly one vertex in X that belongs to the edge. The edge-coloring of bipartite hypergraphs can be directly applied to operation of Clos networks. For detailed explanation we refer to our earlier works. We investigate the complexity status for the following three problems associated with bipartite hypergraphs: 1. Determining whether a hypergraph is bipartite We prove that this problem is NP-complete by reducing ONE-IN-THREE 3SAT to it. 2. Coloring of r-uniform bipartite hypergraphs with a fixed degree In our earlier works we examined 3-uniform hypergraphs. Here we prove that the problem of coloring 4-uniform bipartite hypergraphs is NP-hard even if the hypergraph degree is 2. We propose similar result for r-uniform hypergraphs where r > 4. 3. Coloring of bipartite hypergraphs with hyperedges of large cardinality If each hyperedge consists of more than a half of vertices, the edge-coloring problem is trivial as every edge needs to get a different color. We discuss instances in which each edge consists of more than one third of vertices. For such case we propose a polynomial time algorithm that solves the coloring problem to optimality.

4 - Scheduling of Unit-Length Jobs with Bipartite Incompatibility Graphs on Four Uniform Machines
Hanna Furmańczyk, Marek Kubale

In the paper we consider the problem of scheduling n identical jobs on 4 uniform machines with speeds s1s2s3s4, respectively. Our aim is to find a schedule with minimum possible length. We assume that jobs are subject to some kind of mutual exclusion constraints modeled by a bipartite incompatibility graph of degree D, where two incompatible jobs cannot be processed on the same machine. We show that the problem is NP-hard even if s1=s2=s3. If, however, the graph degree D 4 and s112s2, s2=s3=s4, then the problem can be solved to optimality in time O(n1.5). The same algorithm returns a solution of value at most 2 times optimal provided that s12s2. Finally, we study the case s1s2s3=s4 and give an O(n1.5)-time 2-approximation algorithm in all such situations.

■ TC-25

Tuesday, 12:30-14:00 - Building BM, ground floor, Room 19

Studying the micro-processes of OR interventions

Stream: Behavioural Operational Research
Chair: *Leroy White*
Chair: *Ashley Carreras*

1 - Exploring Model-supported Coordination Processes in PSMIs with Micro-level Video Data
Katharina Burger

Micro-level analyses of participant interactions with models are needed to gain insight into the ways in which coordination processes unfold during PSMIs. This study uses micro-level video-based analysis to understand how multiple modalities are employed by three different groups of participants during a PSM workshop to create, structure and change shared action spaces. Joint affordances in the course of the PSMI are studied to explore how communicative understanding is developed and sustained in model-supported collective reasoning processes. The observed diversity in social and informational quality of model-supported interactions suggests that a nuanced view of micro-level coordination processes in PSMIs is needed.

2 - Exploring micro-practices observed during strategy development workshops
Frances O'Brien, Maureen Meadows

This paper uses video data of a strategy workshop, based around tools such as SWOT analysis and scenario planning, to explore the micro-practices that can be observed during a strategy development exercise. The paper addresses a gap in the extant literature concerning how strategy tools such as SWOT are used in practice, and in particular within a strategy workshop setting. The study also suggests that a strategy workshop can be analysed as a number of micro-practices. Our findings are of significance for both academics and practitioners, as they have the potential to influence the future design of strategy tools, as well as their appropriate introduction in workshop settings.

3 - Throwing Out the Baby with the Bathwater: The Undesirable Effects of National Research Assessment Exercises on Research
John Mingers, Leroy White

The evaluation of the quality of research at a national level has become increasingly common. The UK has been at the forefront of this trend having undertaken many assessments since 1986, the latest being the "Research Excellence Framework" in 2014. The argument of this paper is that, whatever the intended results in terms of evaluating and improving research, there have been many, presumably unintended, results that are highly undesirable for research and the university community more generally. We situate our analysis using Bourdieu's theory of cultural reproduction and then focus on the peculiarities of the 2008 RAE and the 2014 REF the rules of which allowed for, and indeed encouraged, significant game-playing on the part of striving universities. We conclude with practical recommendations to maintain the general intention of research assessment without the undesirable side-effects.

4 - Managing the Relationship between Clients and Consultants to Enable Progression in Interventions
Ashley Carreras, L. Alberto Franco

Communication between client and consultant is always a critical factor when using Problem Structuring Methods and facilitated modelling. Both the client and the consultant undergo a process of transformation in their re-spective understandings which, if not carefully managed, can prolong the ability of the team to move forward to the next stage of the intervention. Drawing upon 'Productive Dialogue' we analyse, and compare, the interactions from two real interventions and provide insights.

■ TC-26

Tuesday, 12:30-14:00 - Building BM, 1st floor, Room 109D

Advances in Credit Risk Modelling 1

Stream: Business Analytics and Intelligent Optimization
Chair: *Jonathan Crook*

1 - Modelling Loss Given Default with measures of risk-taking and financial knowledge
Galina Andreeva, Angela De Moraes, Jonathan Crook

Loss Given Default is one of the three credit risk components that are estimated for loan loss provisions, for regulatory and economic capital calculations following Basel II and III guidelines on banks' capital adequacy. It is usually measured as Recovery Rate (proportion of debt recovered from defaulted borrowers). Normally the inputs to the model consist of personal and loan characteristics available from the application form, credit bureau data, account transactions. It is reasonable to suggest that borrowers' personality is at least partially responsible for repayment performance, yet research on this topic is limited. This talk will explore a potential value of personality measures in risk assessment and LGD modeling. It will describe the preliminary results from the project based on a unique Brazilian dataset that combines traditional loan characteristics with survey data that includes measures of borrowers' attitudes towards risk-taking and their financial knowledge. Several modelling approaches will be compared based on measures of model fit and predictive performance.

2 - A mortgage scoring model with spatial contagion
Raffaella Calabrese, Kelley Pace, Meagan McCollum

Due to the spatial dependence of house price, mortgage scoring models often display spatial dependence but the vast majority of the models used in the literature assume that mortgage defaults are independent. Only recently Zhu and Pace (2014) find that allowing spatial dependence greatly improved the predictive accuracy of mortgage scoring model. The main drawback of the model used by Zhu and Pace is that it is built under the assumption that the number of defaulted and non-defaulted mortgages is almost the same. To overcome this drawback, we propose a spatial regression model for imbalanced binary data sets. We use the Geweke-Hajivassiliou-Keene algorithm to perform maximum simulated likelihood estimation for large sample sizes. Finally, we apply the proposed spatial model to a large data set (almost 300,000 observations) from Las Vegas in Nevada.

3 - Accounting for heterogeneity and macroeconomic variables in the estimation of transition intensities for credit cards
Jonathan Crook, Viani Djeundje, Mindy Leow

Currently banks used credit risk models to predict the probability that a credit customer will default in a given window of time. The literature has considered intensity models that give predictions of the probability, for each customer, that he/she will transit from one state of delinquency to another between any two months in the life of the loan. The transitions include not only transitions into further delinquency but also transitions to lesser states of delinquency, that is cure. We now extend this work by including frailty terms relating to the individual cases and for socio-demographic profiles. This means that any statistical bias that may exist because of the omission of unobserved effects due to these types of variation should be removed. Results of applying the method to a large dataset relating to credit card holders will be illustrated.

■ TC-27

Tuesday, 12:30-14:00 - Building BM, ground floor, Room 20

Case Studies in OR

Stream: Case Studies in OR
Chair: *Joaquim Gromicho*

1 - Optimizing Heliostat Positions of Solar Lower Power Plants
Andreas Reinholz

The life cycle costs of solar tower power plants are mainly determined by the investment costs of its construction. Significant parts of these investment costs are used for the heliostat field. Therefore, an optimized placement of the heliostats gaining the maximal annual power production has a direct impact on the life cycle costs revenue ratio. We present a two level local search method implemented in MATLAB which is using the Monte Carlo raytracing software STRAL with a specific annual time scheme for the evaluation of the annual power output. The algorithm was applied to a solar tower power plant with a heliostat field of size 624. Compared to former work of Buck, we were able to improve both runtime of the algorithm and quality of the output solutions significantly. Using the same environment for both algorithms, we were able to reach the best solution of Buck with a speed up factor of 10.

2 - Statistical Data Analyses on Recent Elections in Japan
Tatsuo Oyama

We try to investigate the recent national elections in Japan quantitatively by applying various types of statistical methods and mathematical models. Firstly we examine the regional characteristics that affect voting turnouts and efficiency of the political parties of Japan. We find the high income and most urbanized prefectures are categorized in the same cluster of voting turnouts. The voting efficiency according to prefectures and different parties also show certain patterns. The relation between vote share and seat share for all political parties were examined by applying mathematical models with both polynomial and exponential functions. Actual data obtained from recent national elections for both House of Councilors and House of Representatives from 2005 to 2014 of Japan have been used with their results. The outcome of the recent national elections described that an exponential model can approximate seat shares as a function of vote shares obtained by the parties of respective elections. We conclude exponential model can be used to predict seat shares for the contesting parties in an election where many parties take part in the election process. Additionally, we investigated pass votes and fail votes regarding how each political party is facing.

3 - Improving Coordination Between Order Generation and Routing in Vendor Managed Routing
Joaquim Gromicho, Loes Knoben, Jacob Kooijman, Leendert Kok, Marc Uetz

Vendor managed routing, also known as inventory routing, comprises on one hand the estimation of demand - and hence inventory levels - at site storage and on the other hand routing the required replenishment before shortage occurs. Commonly followed approaches generate two types of orders: those that must be replenished immediately and those that may be replenished if convenient. From our experience with companies operating in two areas, namely supplying industrial gasses and fuels, we know that expert planners are usually able to restrict the set of orders that may be replenished to those that are 'really convenient' to do now and improve long term performance. In order to make long term performance - measured as miles driven per gallon supplied - less dependent of planner's expertise we implemented strategies to emulate this expertise. In order to do that, we consider algorithms that try to link short-term performance as well as possible to long-term performance, by carefully crafting alternative short-term objectives. The information that we take into account to do that, is geographical information, information from past performance, and from anticipating the effect of postponing replenishment. First results indeed show improved long term performance.

■ TC-29

Tuesday, 12:30-14:00 - Building BM, ground floor, Room 7

Soft OR and Problem Structuring Methods in Management Science

Stream: Soft OR and Problem Structuring Methods
Chair: *Doris Behrens*
Chair: *Jennifer Morgan*

1 - The Development of Management Sciences / Operational Research Themes and Concepts: Surveying the Trends in the Last Four Decades
Alberto Paucar-Caceres, Mischel Carmen N. Belderrain, Toni Burrowes-Cromwell

This paper presents a study of the development of Management Science/Operational research (MS/OR) using a text-mining tool for visualizing the structure of concepts and themes populating the field over the last 35 years. We mapped and analysed MS/OR concepts and abstracts in six top MS/OR Journals between 1980-2014. More than 20,000 abstracts published in: European Journal of Operational Research, Interfaces, Journal of operational Research society, Management Science, Omega and Operations Research were mapped and key themes over the last 3 decades analysed using leximancer. Findings were contrasted with a theoretical framework containing three MS/OR paradigms: (1) Positivist/Normative; (2) soft/interpretive; and (3) critical/pluralistic. We report on the findings of current MS trends. From an initial mapping of the 20,000 abstracts of six top MS/OR journals we identified articles adhering to the interpretive, critical and constructivist paradigms published between 1980 and 2014. Results seem to indicate strong links between the particular scope and editorial based of each journal. US based journals show a strong bias towards a positivistic paradigm whereas UK and other European journals veer towards the interpretative and critical/pluralistic camp. Conclusions based on the proposed framework and publication trends, together with some points for further research, are offered.

2 - Soft Operational Research to Redesign the Working Environment in a Brazilian Company
Leila Abuabara, Mischel Carmen N. Belderrain, Alberto Paucar-Caceres

Harmony and balance in the workplace can be considered differential characteristics for a strategic team to achieve high performance, especially in high competitive business. However perceived and evident problems do exist in any team. We need to identify and treat them. A seemingly well-structured work team of a strategic department of a Brazilian organization was analyzed in order to assist the recently appointed team leader to take effective actions. Complexity in such case is indubitable due to the presence of multiple actors, the differing perspectives, the interests conflicting, the intangibilities and the uncertainties. A variety combination of soft operational research tools was applied in different phases of the Problem Structuring process. Strategic Options Development and Analysis (SODA) was fundamental for the understanding of the work environment. Following Value-Focused Thinking (VFT) assisted us to structure the means and ends objectives. Finally, Value Focused Brainstorming (VFB) encouraged the generation of the alternative potential solutions. Counting on a joint and collective work of a previously defined working group, it was reached satisfactory and compromise solutions. The present study of case contributes as an empirical example of association of soft OR methodologies in a democratic participation of a group to address real management issues.

3 - VSM and the Quest for Resilience
Stephen Harwood, Maurizio Tomasella

Stafford Beer's Viable System Model (VSM) and 'Indices of Achievement' provide a coherent framework for evaluating organizational complexity and issues of viability, i.e. the ability to survive. Implicit in this notion of survival, is the notion of resilience, i.e. the ability to deal with disruption that is out-with the everyday routine, e.g. to absorb minor crises (such as a machine breakdowns) or to recover from extreme events (such as the 2011 flooding in Thailand). Only recently discourse has emerged that attempts to explain resilience in terms of the VSM. These works propose methods and tools of a quantitative, often multi-criteria, nature, to support the creation and sustainment of organisational resilience, whilst capturing the cybernetic strengths and weaknesses of an organization through VSM-related principles. However, little has been proposed as to answer some quite fundamental questions. How to operationalise resilience within an organization on a daily and ongoing basis? What is it that is explicitly constitutes resilience within an organisation? What are the criteria that define the evidence for resilience? In this paper we develop a viewpoint to answer these and other related questions, and we use Beer's 'Indices of Achievement' to support our proposition.

■ TC-30

Tuesday, 12:30-14:00 - Building BM, 1st floor, Room 110

Healthcare Services Research and Policy 1

Stream: Operational Research for Health and Social Care

Chair: *Burcin Bozkaya*

1 - Planning of Midwives
Charlotte Vilhelmsen, Jesper Larsen

At a hospital in Denmark around 40 midwives support the pregnancy of approx. 6000 pregnant women every year. Their role is to monitor the pregnancies and prepare the women for labour. Based on the due date of a woman, authority guidelines prescribe specific and mostly rather narrow time windows within which the pregnant woman should have consultations with a midwife. Therefore, once a pregnant woman enters the system, here sequence of consultations for the time period until labour is fairly fixed. There is a clear goal that, as far as possible, each pregnant woman should see the same midwife at every consultation. Every week the newly arrived pregnant women are assigned an arbitrary free time slot belonging to a specific midwife. In turn this midwife is expected to have consultations with this woman in specific weeks according to the authority guidelines. This random assignment of pregnant woman to specific midwives, without any concern to the midwives' future schedules, means that each midwife has a very unbalanced workload over the year. Furthermore, it means that there is an imbalance between the workloads of the different midwifes. The aim of this project is therefore to devise a method that can make a fair distribution of pregnant women among the midwives. The distribution should result in a balanced work load for each midwife and a balanced work load among the midwives while at the same time making sure that the time windows for consultations are not violated.

2 - Modelling Outpatient Follow-up Behaviour
Jennifer Morgan

Anticipating demand and allocating appropriate resources is essential for safe and cost effective healthcare service delivery. Outpatient demand consists of newly referred patients, patients requiring treatment or diagnosis in an outpatient setting and patients identified by a clinician as requiring follow-up care. Therefore a proportion of demand can be anticipated based on the number of new referrals and their likelihood of requiring follow-up care.

The objective of this work is to develop an outpatient service model to help one of the UKs largest healthcare providers understand the impact of service constraints on timely follow-up care. The first phase of this work was to validate a large number of patient records to identify desired future appointment dates. The systematic capture of text-based clinical information alongside text mining models has to date enabled over 10,000 dates to be allocated. This improved information allows a demand model to be created based on desired rather than observed follow-up behaviour, and resource allocation to minimise delay.

This paper describes ongoing work to improve outpatient demand and capacity modelling in order to improve patient care. The challenges and potential utility of applying discrete event simulation to obtain expected steady state system demand and its utility as a model for master schedule planning and system exploration will be discussed.

3 - A Multi-Objective Districting Approach for Designing the General Practitioners' (GP) Scheme
Burcin Bozkaya, Seda Yanık, Jörg Kalcsics, Stefan Nickel

A critical issue of the GP scheme is directing the patient admissions to the GPs instead of hospitals. While some countries enforce patients to visit a GP first, the ease of access to a GP is the main factor in determining the effectiveness of the scheme. Also, the doctors are selective in locating their practices since their income is proportional to the number of patient visits. In a well-planned effective scheme, the primary care service that is distributed over a geography should be available and easily accessible, and should respect equity for the patients and the doctors.

In the presence of the availability, access and equity requirements, the problem of the design of GP scheme is formulated as a multi-objective districting model in this study. One objective ensures the ease of access of the patients by minimizing the distances. Another objective equalizes the attractiveness of each district for the doctors by aligning their income, as in sales territory design applications.

In our districting model, we incorporate the gradual (i.e. partial) assignment of the patients, a likely situation as patients get further away from the center of districts. We also introduce variable capacities of GP's at the centers. We formulate a MIP model with binary location decision variables and a relaxed allocation decision variable for the gradual assignment. The model is solved optimally and tested on real-case scenarios of Istanbul, Turkey.

■ TC-31

Tuesday, 12:30-14:00 - Building BM, 1st floor, Room 111

Decision-making in Humanitarian Operations

Stream: Humanitarian Operations
Chair: *Tina Wakolbinger*

1 - Estimation of deprivation cost functions with stated preference methods
Xihui Wang, Luk Van Wassenhove

The deprivation cost is an innovative and potentially powerful concept to assess the performance of a humanitarian logistics operation and help build optimization models. The main challenge is the estimation of the deprivation cost function. This paper proposes a way to estimate deprivation cost functions using stated preference methods with numeric rating scale data. By comparing and analyzing the data collected from respondents with and without disaster experience, the results show that individuals without any experience of disasters estimate deprivation costs differently from actual relief beneficiaries. In addition, this research extends the time range of the study from 48 hours to 7 days and demonstrates that the deprivation cost can be expressed as logistic growth functions which lead to S-shape deprivation costs. The results of this study are consistent with the expectations of existing literature about transferability of the deprivation cost. With these findings, practicality and universality of the deprivation cost concept are given more support.

2 - Impact of coordination strategies on disaster management performance
Gerald Reiner, Christian Wankmüller

The complexity and dynamics of catastrophic events in recent years has demonstrated that a working disaster management is crucial in order to alleviate the suffering of the affected population and to recover from these destructive incidents. Several catastrophes, such as the tsunami in the Indian Ocean, indicate that humanitarian operations often lack adequate coordination among relief chain partners due to an inherently chaotic post-disaster relief environment, a high number of different actors involved in the crisis management and the absence of efficient resource allocation. For enhancing the efficiency of disaster relief operations, the scientific literature provides various coordination strategies (Balcik et al. 2010). Depending on the "lifecycle" of the disaster management, i.e. preparedness, response or recovery stage, the appropriate coordination strategy goes into action in order to establish a continuous flow of relief items, information and goods in the disaster prone area. The impact of different types of humanitarian coordination (information sharing, risk sharing etc.) on process bottleneck relaxation within the relief network, i.e. improved responsiveness, is still unexplored and needs to be investigated with scientific methods in more detail. The proposed coordination strategies are going to be analyzed by applying system dynamics simulation regarding efficient resource utilization and overall supply performance.

3 - Funds allocation in NPOs: The role of administrative cost ratios
Tina Wakolbinger, Christian Burkart, Fuminori Toyasaki

Performance measurement of Non-Profit Organizations (NPOs) is of increasing importance for aid agencies, policy-makers and donors. A widely used benchmark for measuring the efficiency of NPOs is the overhead cost ratio, consisting of the total money spent on administration and fundraising relative to the budget. Such easily accessible measurements face severecriticism, since variations of overhead costs are not necessarily linked to changes in the impact achieved. Additionally, the focus on such information can lead to increasing pressure to reduce expenses, with potential negative effects on administrative capacities. Unlike fundraising expenses, administrative costs do not help advertise the actions of an NPO. Reducing administrative expenses is a logical consequence from a financial viewpoint and might, hence, not only negatively affect NPOs but also beneficiaries. This work provides an analytical framework for analyzing NPO decision making concerning administrative costs. The paper provides answers to important recent research questions on the optimal level of administrative spending, the influencing factors and the effects of available information on NPOs and beneficiaries. The results show, that administrative expenditures do not necessarily reduce utility created, but their effect depends on a variety of factors including the amount of financial information, the impact on the efficiency of increased administrative spending and the structure of donations.

4 - Airborne Recovery of the Emergency Communication Network in Disaster Response
Burak Sever, Recep Berk Ozgur, Sezgin Kaplan

Cellular communication networks can be partly or completely cut off due to many types of disruption in the technological infrastructure as a result of natural disasters. However, maintenance of the communication systems has a vital importance, especially in the first 72 hours, to avoid interruptions in the response operations of emergency teams and data backhaul to the command-control center. In this study, the role of unmanned aerial vehicles (UAVs) as an alternative to the damaged base stations has been examined in the airborne recovery of the cellular communication network. A mixed integer linear programming model has been formulated to determine the loitering locations of a certain number of relay UAVS to maximize the coverage of emergency response teams subject to be continuously connected with each other and also to the center. Finally, the results obtained by the proposed model have been demonstrated for various randomly generated disaster damage scenarios.

■ TC-33

Tuesday, 12:30-14:00 - Building BM, 1st floor, Room 113

Emerging Applications of Data Mining and Computational Statistics 7

Stream: Computational Statistics
Chair: *Glauco da Silva*

1 - Manufacturing Data-based Adaptive Segmentation for Storage Efficiency
Seung Hwan Park, Jun-Geol Baek

According to an explosive increase of data in a semiconductor manufacturing process, it is a critical issue to deal efficiently with the manufacturing process big data. In particular, a Fab(Fabrication) process data need to be segmented and summarized to reduce a database resource. The Fab process generates sensor signals including the step information determined by the process recipe, and the existing method segments the signals by the process steps. However, as these technique does not reflect a data pattern, it has poorly explicability on the summarization. Therefore, this study proposes a new adaptive segmentation technique, which is devised by using both the recipe step information and data types. First, a change point detection algorithm is used for a data-based segmentation, this detection algorithm utilizes the step information as parameters. After that, we establish a representative statistics on each segment to describe the original data. To validate the storage efficiency of the proposed algorithm, the performance index considers both the number of segments and an explicability for each segment simultaneously.

2 - Multifractals and Forecasting in Stock Markets
Natália Diniz, Antônio Carlos Silva Filho, Fabiano Guasti Lima

In this work we propose, through multifractal spectrum of power law exponents obtained by the robust Multifractal Detrended Fluctuation Analysis (MFDFA) method, to check if the volatility or the prediction error decreases in the forecasting of financial data applying the method of Artificial Neural Networks with and without Wavelets. The data chosen for analysis were the minute IBOVESPA (São Paulo Stock Market Index) of April 2001, with a total of 8466 data points. The series was swept in windows of 2117 points each. We measured the forecasts accuracy in each window with the MAPE (Mean Absolute Percentage Error). We will call the multifractal parameters used here as DHq (obtained from the generalized Hurst exponentes, Hq). From them we define the parameter hq and finally, the width, which is the difference between the highest and lowest values of hq for each window. Next, we set up a cutting parameter to this width by dividing their values into two sets: one with values lower than the cut and one with the values higher. The most interesting parameter to cut the analyzed data was 4.9, with a gap (distance between adjacent windows) of 100 points. We got a 0.000824 p-value for discriminating the two sets forecasting without Wavelets and 0.00001 (significant to 99,999% level) with Wavelets. These results show that the DHq parameter is effective to separate the forecasts made for time series financial market into two groups, where the reliability of forecasts is greater in one.

3 - Modelling Customer Lifetime Value in the Ferry Industry
Mee Chi So, Christopher Bayliss, Christine Currie, Antonio Martinez Sykora, Julia Bennell

Customer Lifetime Value (CLV), which estimates the long-term contribution of customers to an organisation's profit, is of particular relevance in industries in which there is a mix of regular and occasional customers, and it needs to be taken into account to generate realistic prices. Working with two large ferry operators in UK, we aim to use real application data to model the CLV of different segments of customers with the objective to develop a pricing strategy in order to balance between immediate profit and CLV. In the ferry industry, customers' segments are dependent on the product being sold but it can typically divide into three segments: occasional purchaser, regular consumers and contractual business operators (e.g. tourist coach, lorries of retailers). Using customers' past purchasing behaviour (e.g. recency, frequency) as input variables, we will first apply the Pareto/NBD models to estimate the CLV. The second approach we will use is survival analysis. By using the Cox Proportional Hazard (PH) model, survival analysis is able to include censored data and time-dependent covariates. The PH model will be able to capture the customers' individual characteristics. The model will then be used to estimate the attrition rate of different groups of customers. The results of this study will not only be valuable to the two commercial partners but will also provide insights to researchers about the use of different approaches in estimating CLV in the ferry industry.

4 - Evaluating Attributes Selection Techniques in the Classifiers Construction Process
Glauco da Silva, Marta Barros, Helder Gomes Costa, Altina Oliveira, Marcos Santos

We discuss Attributes Selection Techniques (AST) to build classifiers. In classification task is common the existence of redundant data which confuses the process when operating with a large amount of data. Therefore, AST help to improve the results. A sample set (27 instances, 15 attributes), evaluated by correlation (r) between the attributes which correlations of several intensities, was identified. Then, it was evaluated the importance of attributes to determine the classes (ReliefF method), working from the random selection of an instance and location of the nearest neighbors of the same class and opposite classes. In the 3rd step, it was evaluated the correlation among the attributes and the determination of the class with Correlation-based Feature Selection (CFS), which search for the best set of activities with low correlation with each other and high correlation with the class.

CFS highlighted four key attributes. Building the classifiers, the training method Leave-One-Out was chosen due to the small number of instances. Without AST, a classifier based on decision tree (J48) reached an accuracy of 37%. With CFS heuristics, the J48 reached 59% of accuracy. The classification task was repeated for the algorithms Naive Bayes (NB) which without AST accuracy was 48 and with AST 56%. An analysis of the results based on the low accuracy of classifiers suggest an intra-class heterogeneity which hinders the construction of classifiers.

■ TC-34

Tuesday, 12:30-14:00 - Building BM, 1st floor, Room 116

Logistics of Technical Systems

Stream: Supply Chain Scheduling and Logistics
Chair: *Ulf Lorenz*

1 - Quantified Integer Programs in Road Networks
Michael Hartisch

Quantified Integer Programs (QIPs) are integer programs with variables being either existentially or universally quantified. They are comparable to multi-stage robust integer problems with a cubic uncertainty set. Finding such robust solutions in real world programs becomes more and more important: Small perturbations in the parameters can render optimal solutions of static programs suboptimal or even infeasible in practice.

Exemplarily, a graph is considered which we want to traverse at low costs. However, some edges might become unusable and thus we must adapt to such scenarios. In terms of a QIP the existentially quantified variables in this example are comparable to the decision which edge to traverse next. The universal variables can be interpreted as the selection of unusable edges. Thus, we are interested in a strategy on how to respond to possible failures.

However, such an optimal strategy in a worst-case setting is far too pessimistic. Further, with respect to our example, in a real world problem it is very unlikely that an arbitrarily malicious set of edges in a road network will be blocked at the same time. And if this is the case any optimization is useless anyway. Thus, we are interested in further restricting the universal variables. Therefore, a technique is presented to restrict these variables to some polytope instead of the hypercube created by their variable bounds.

2 - Gearbox Design via Mixed-Integer Programming
Thorsten Ederer

Gearboxes are mechanical transmission systems that consist of multiple gear wheels and shafts. By changing the connection of these components or their size, the possible transmission ratios can be affected. As a central element of the drive train, gearboxes are highly relevant for the efficiency and durability of motor vehicles. Nonetheless, they have to adhere to very strict requirements regarding weight, production costs and available space. A traditional approach to such problems is to manually identify and compare a selection of promising system designs based on engineering experience. This approach often leads to good designs, but one cannot make any statement about the optimality of such a system. Mathematical optimization methods are capable of finding good solutions and - given enough time - proving global optimality without enumerating the whole solution space. In this work, we present an approach on how to formulate a gearbox design problem as a mixed-integer program. We show how different degrees of freedom, objective criteria and sets of restrictions influence the complexity of the model but also the quality of solutions.

3 - Primal Solutions and Dual Bounds via Dynamic Programming and Lagrangian Relaxation: An Application Example in the Context of Engineering
Lena Charlotte Altherr

Being part of the chair of fluid systems at the department of engineering, we specialize in problem-suited modeling of water networks. To reduce investment and energy costs, we optimize their topology and control via mixed-integer programming. The presentation will show primal and dual methods in order to tackle time-dependent problems that arise in this context. An efficient primal heuristic is dynamic programming, Lagrangian relaxation can be used to calculate dual bounds in order to assess the quality of the primal solutions.

4 - Heat Distribution and Source Scheduling for Energy Efficient Buildings
Philipp Pöttgen, Thorsten Ederer, Ulf Lorenz, Peter Pelz

The conference center darmstadtium in Darmstadt is a prominent example of energy efficient buildings. Its heating system consists of different source and consumer circuits connected by a Zortström reservoir. Our goal was to reduce the energy costs of the system as much as possible. Therefore, we analyzed its supply circuits. The first step towards optimization is a complete examination of the system: 1)Compilation of an object list for the system, 2)collection of the characteristic curves of the components, and 3)measurement of the load profiles of the heat and volume-flow demand. Instead of modifying the system manually and testing the solution by simulation, the second step was the creation of a global optimization program. The objective was to minimize the total energy costs for one year. We compare two different topologies and show opportunities for significant savings.

■ TC-35

Tuesday, 12:30-14:00 - Building BM, ground floor, Room 17

Genes and Genomes

Stream: Computational Biology, Bioinformatics and Medicine
Chair: *Aleksandra Swiercz*
Chair: *Jacek Blazewicz*

1 - Binarization of Single Cell Gene Expression Data Does Not Lead to Information Loss
Tomasz Ignac, Alexander Skupin

The recent advancements in single cell gene expression (GE) analysis allows for an increased resolution in deciphering the dynamics of gene regulatory networks (GRNs). Previously used microarray data were able to capture the main structure and essential rules of GRNs dynamics but could not quantify diversity and strength of interactions due to the averaging over many cells. Typically, the resulting continuous gene expression data were binarized for the application of Boolean networks to represent the GRN dynamics. Due to the specific problems of microarray techniques, such as averaging over heterogeneous cells and plate effects, binarization of GEs was a nontrivial and hardly controllable procedure. In the current work we present three approaches to binarization of single cell gene expression data and investigate the effect of information loss potentially induced by the data processing. Therefore, we validate our methods on experimental data from a study on cell fate decision of the murine multipotent hematopoietic precursor cell line EML into an erythroid and myeloid cells when stimulated by EPO and GM-60 CSF/IL-3. We use information theory based tools as well as machine learning approaches like logistic regression and naïve Bayesian classifiers to demonstrate that information loss is negligible for the experimental data considered in this work. Moreover, we show that binary GEs contain sufficient information to recover the dynamics of the cell differentiation process.

2 - Stochastic Gene Switching Role in Determining the Pharmacodynamics of Certain Drugs
Krzysztof Puszynski

Assuming deterministic dynamics of the intracellular network that is targeted by a certain drug, the experimental in vitro dose-response curves would necessarily be of the type 'all or nothing'. In reality they are more complicated. The mechanism underlying the dose-response curves requires some random heterogeneity of the cell microenvronment and/or an inherent stochasticity of the target intracellular network. As a consequence, evaluating the impact of intracellular stochasticity is of the outmost relevance to understand the drug pharmacodynamics (PD).

Because many drugs targets transcription factors we focused on transcriptional networks. Our aim was investigate some basic circuits in order to understand which is the elementary role of gene switching noise in determining drug PD under a particularly simple assumption: the level of a protein, A, targeted by the drug D, has to be kept below a given threshold Th for time T.

Our numerical simulations suggests that the gene switching plays a primary role in determining the shape of dose-response curves. Moreover, the simulations showed that qualitative sigmoid shape of the dose-response is not strictly linked to the complexity of the network targeted by a drug. Instead it can be explained basically by means of the inherent randomness of the gene switching between active and inactive states.

This work was supported by the Polish National Science Center grant DEC-2012/05/D/ST7/02072

3 - A New Approach to NGS Map Reads to the Reference Genome

Pawel Wojciechowski, Michal Kierzynka, Wojciech Frohmberg, Piotr Zurkowski, Jacek Blazewicz

G-MAPSEQ is a tool for mapping Next Generation Sequencing reads to the reference genome. The goal of the first step of the method is to find quickly a potential genome positions which are similar to the read. It is obtained by comparing of k-mer characteristics generated for a read with those generated for fragments of the reference genome. The second step is an alignment calculation for all found pairs. Thus, the solution connects two basic ideas - fast heuristic to determine candidates for similar pairs of sequences (where one is the read, and the second is a fragment of reference sequence) and exact, ultrafast semiglobal pairwise alignment method which is performed on GPU, to check if the candidates are real mapping positions. G-MAPSEQ supports both: single and pair-end reads. Extensive test shows the properties of the method, which finally was compared to other substantial solutions.

4 - GRASSHOPPER - de novo DNA Assembly with Accurate OLC Strategy Achievable in Reasonable Time Even for Large Genomes

Wojciech Frohmberg, Michal Kierzynka, Pawel Wojciechowski, Aleksandra Swiercz, Marta Kasprzak, Piotr Zurkowski, Jacek Blazewicz

Last decade brought a significant progress in the area of sequencing. A number of yet unknown genomes was successfully read giving scientists a chance to better understand life. Yet, although a stable sequencing pipeline was developed, there is still a place for improvements. The most computationally complex step here is assembly, that can be perceived as integration of raw data (nucleotide strings called reads) from sequencers. Goal of the assembly is to merge input reads into sequence that is possible close to genome of an organism the reads was taken from. Main problems of assembly are repetitions in genome causing ambiguities in result. To overcome this, assembly methods provide cutoffs whenever two or more alternative results could be produced. Each method uses its own cutoff procedure but two general strategies can be distinguished. Overlap-layout-consensus (OLC) strategy treats each read as a node of a digraph. If the reads overlap, nodes are connected with an arc. Finding cutoffs in such graph is rather complex. An alternative for OLC is labeled graphs strategy that splits reads into equal-length pieces forming arcs. As sequences are held in arcs, cutoffs can be easily found. The first strategy is perceived more accurate while the latter one - more efficient. By our approach we are trying to prove that using OLC strategy does not necessary implies ineffective assembler.

■ TC-36

Tuesday, 12:30-14:00 - Building BM, ground floor, Room 18

Information and Intelligent Systems 2

Stream: Information and Intelligent Systems
Chair: *Gerhard-Wilhelm Weber*
Chair: *Vahid Eghbal Akhlaghi*

1 - An Accelerated Hyperbolic Smoothing for Solving the Multisource Fermat Weber Problem

Adilson Elias Xavier, Vinicius Layter Xavier

The work considers the Multisource Fermat Weber problem, which is also known as the continuous location-allocation problem. A particular case of the problem is the minimum sum-of-distances clustering problem, also known as the continuous p-median problem. The mathematical modelling of the problem leads to a min-sum-min formulation which, in addition to its intrinsic bi-level nature, is strongly nondifferentiable. Moreover, it has a large number of local minimizers, so it is a typical global optimization problem. In order to overcome the intrinsic difficulties of the problem, the so called Hyperbolic Smoothing methodology, which follows a smoothing strategy using a special differentiable class function, is adopted. The proposed algorithm applies also a partition of the set of observations into two non-overlapping groups: data in frontier and data in gravitational regions, which drastically simplify the computational tasks. For the purpose of illustrating both the reliability and the efficiency of the method, a set of computational experiments making use of traditional large test problems described in the literature was performed. Apart from consistently presenting similar or even better results when compared to related approaches, the novel technique introduced here was able to deal instances with up to 1243088 cities, never tackled before in the context of the Multisource Weber problem. Indeed, this instance is more than 1000 times the previous largest one.

2 - Designing a Massive Dataset Framework for the Grammatical Evolution System

Miguel Nicolau

Data is ubiquitous. Most activities nowadays are logged in some way, such as taking a bus, connecting to wi-fi, paying dinner with a card, or even reading a book. Even mechanical devices such as light bulbs or bicycles are becoming connected, data-generating devices.

This provides fantastic opportunities to improve business processes, while posing challenges on how to extract intelligence from such amounts of data. Computer modelling is used extensively to achieve this; yet, with all the number-crunching power available, the intuition of human analysis to make sense of the underlying models is often desirable.

Genetic Programming algorithms are well suited as model-building techniques that sit between data and analysts. By generating symbolic solutions (such as mathematical formulas), they provide insight into relationships between predictors and complexity of models, and such models are easier to analyse and even modify. Variants such as Grammatical Evolution (GE) further add to this utility, by specifying the syntax of the generated solutions through a grammar.

In this study, a GE-framework is built, in an effort to apply it to huge datasets. Combining statistical techniques such as appropriate error measures and data splitting, population-based improvements such as mass parallelisation, and even specific techniques such as grammar design and repeat management, GE is applied for the first time to massive datasets, such as the Higgs dataset (eleven million samples).

3 - A Semi-supervised Method for Sentiment Diffusion in Social Networks
Enza Messina, Elisabetta Fersini

The extraction of subjective information from texts in natural language is crucial to create structured and actionable knowledge to be used by a decision maker. The analysis of sentiment is particularly challenging when dealing with online social networks, where decisions (e.g., in business and government intelligence) should take into account sentiment behind thousands of text messages posted by interconnected users. In this work we address the problem of defining a diffusion model of sentiment in social networks by proposing a probabilistic approach that obeys to the Markov assumption: the sentiment of a user is determined both by the sentiment of his/her text messages and by the sentiment of his/her neighbors. The latent variables of the model, related to the importance of text messages and neighbor influence, are estimated by means of a gradient based method [1] that maximizes the likelihood of the user sentiment labels in the network. The proposed model has been experimentally investigated to understand the relative importance of textual information and social network structure in determining the sentiment of the users by considering different types of relationships between them.

[1] Wick, M., Rohanimanesh, K., Culotta, A., McCallum, A.: Samplerank: Learning preferences from atomic gradients. In: NIPS Workshop on Advances in Ranking (2009).

4 - Social Media Mining for Open and Distance Education System
Zehra Kamisli Ozturk, Zeliha Ergul, Zeynep İdil Erzurum Cicek

Social media is a Web 2.0 platform that allows you to share content and information without the limitations of time and space. Social media networks has managed to become a part of today's lifestyle and represents an increasingly gained importance when viewed from a state perspective. Featured social media types can be listed as social and professional networking sites, blogs, microblogging, video and audio sharing sites, location sharing services, and social bookmarking. In this study, we will concentrate on one of the big data analysis subjects came forward in recent years. Although there are many studies in the literature about big data analysis, yet there isn't enough number of studies about social media mining and sentiment analysis, especially in the field of education. Depending on the large number of students and their properties, studies on the educational data mining have increased in recent years. Open and distance education systems (ODE) have terabytes of data related to the students and graduates. Here, Anadolu University (AU) which has approximately two millions of students and more than two millions of graduates, is considered. The discarded messages for the last six mounts on worldwide most commonly used microblogging TWITTER related to AU ODE system will be collected first, then analyzed by statistical and data mining techniques. Finally, they will be visualized. The students' perception of this system will be tried to be determined.

■ TC-38

Tuesday, 12:30-14:00 - Building BM, 1st floor, Room 109M

GUEST-OR: Linking Lean Business and OR

Stream: Workshops and roundtable
Chair: *Guido Perboli*

1 - GUEST-OR: Linking Lean Business and OR
Guido Perboli

MS&OR specialists managing real projects work in multi-disciplinary teams and multi-stakeholder environments. On the one hand, this process is a source of innovation for the MS&OR community. On the other hand, it touches a scientific nerve: how can we transfer our results to non-OR people? How can we describe to non-OR people a mathematical model or a heuristic solution, and be sure that we are solving their problems? How can we reduce the time needed to move from the first meeting to the delivery of the solution while reducing backtrackings? This workshop introduces GUEST-OR, a Lean business methodology developed for MS&OR projects, and discusses two case-study applications of GUEST-OR to real case studies. The analysis of the KPIs shows how, the overall effort in time and human resources needed to converge to a factual implementation of the projects can be reduced up to 40%. Those workshop participants with experience of practice will be invited to discuss how this compares with their own current approaches and outcomes. The workshop will be of interest to practitioners wishing to explore how OR professionals can improve project and client management, and to compare experiences, as well as to people with less experience of practice who would like help in designing their relationship with the problem-owners.

■ TC-39

Tuesday, 12:30-14:00 - Building WE, 1st floor, Room 107

Decision Supporty Systems

Stream: Decision Support Systems
Chair: *Isabelle Linden*
Chair: *Boris Delibasic*

1 - Modeling Design Issues of DSS
Gil Greenstein

This research presents an analytical model in order to better understanding of the "knowing how" mechanisms of Decision Support System (DSS) design. The model is based on a normative approach. The different principles are examined and integrated into a comprehensive framework for assessing a value of DSS. The model is an extension of the Information Structure Model which is widespread in Information Economics and allows to explain, inter alia, a decision maker's behavior under the assumptions of bounded rationality. The research analyzes the DSS performance during a whole life-cycle. The model accounts for the following principles: - Persistent improvement, which leads to a persistent and systematic increase of the value of every system version, even when a previous optimal decision rule is still used for a certain period. Thus, smooth implementation is provided. - Availability and fail-safe, that relate to decision situations when a DSS is not available. Thus, the value of a backup (or less valued) DSS is assessed. - Multi-criteria approach, that is the analysis of decision situations when a decision-maker cannot formulate a joint utility function constituted from different criteria which are completely inestimable or estimable partly.

2 - Effects of the internal and external factors on decision consistency
Anett Rácz, Tibor István Rácz

Saaty's AHP technique is an algorithm easy to implement for multi-criteria group decision processes. It is a widely applied method by the professional decision support systems. Consistency of Decision Makers (DMs) could be a very crucial issue if we use AHP in decision making. In this research we attempt to define those external circumstances that can influence the consistency of the pairwise comparison process. Generally software solutions provide different interfaces to perform the pairwise comparison; they also have different design elements in order to make the process easier for users. Not only the computational environment but the work conditions and the external and internal intuitive factors, as well can have an effect on productivity and mechanism of DMs. Although decision making is a mathematical process in a scientific point of view, psychological factors triggered out by the environment cannot be ignored. In order to analyze this kind of factors we developed web-based questionnaires with two different qualities of Graphical User Interface and prepared two rooms with different interior designs. Moreover, surveys contained pairwise comparisons with different evaluation modes (verbal, numerical and sliders).

We analyzed the pairwise comparison matrices that were obtained and tried to find connections between the circumstances mentioned and the consistency of participants.

3 - Educational marketing decision system based on multi-criteria analysis: The e-Marketing Online platform
Nikolaos Matsatsinis, Evangelos Grigoroudis

e-Marketing online is a web application that aims to familiarize students or potential entrepreneurs with innovative marketing techniques and product development decisions. Offering a virtual market environment of products that simulates real-world situations, e-Marketing Online adopts the MARKEX methodology in order to enable users (or user teams) following modern marketing strategies. Through this approach, users gradually learn how to effectively implement MCDA methods in order to take essential decisions about product marketing or new product development.

4 - Detecting ETL Bottleneck Points Using Process Mining
Vasco Santos, Orlando Belo

Data Warehouses are designed and built to store data in an integrated and consistent manner. These repositories are known for storing subject-oriented data dedicated to support business intelligence processes. However, keeping them updated is a complex and time-consuming process that usually involves multi source, multi format data that not invariably needs to be cleansed and transformed. The management and execution of this process is handled by the Extract-Transform-Load (ETL) system. The data intensive tasks, managed by the ETL system, normally execute in a limited time window and their computational requirements tend to grow in time as more data is dealt with. The common approach to deal with this constraint is the acquisition of new and more powerful hardware. This expensive approach disregards other possibilities like the analysis and optimization of the ETL tasks. The ETL system manages a complex data gathering and transformation process that is normally designed and implemented as a workflow of tasks, or sometimes viewed as a weighted directed graph. Several approaches have been used to optimize workflows and graphs and in this work we use Process Mining to do it. The ETL system is known to adequately log several states of the tasks that manages, and these logs are the center piece to Process Mining. Through log analysis, we use Process Mining to represent task workflows and identify bottlenecks and possible optimizations to the original workflow.

■ TC-40

Tuesday, 12:30-14:00 - Building WE, 1st floor, Room 108

Applications of Game Theory in OM

Stream: Game Theory and Operations Management
Chair: *Gokce Esenduran*

1 - Energy Efficiency Contracting in Supply Chains under Asymmetric Bargaining Power
Sam Aflaki

Evidence shows that suppliers refrain from investing in energy efficiency (EE) measures because they fear that a buyer with greater bargaining power will use the EE-related cost reductions to push prices down in the purchase bargaining process, and thereby further reduce the supplier's profit margin. Suppliers are also discouraged from EE investment by the uncertainty associated with new technologies. These issues are studied via our model of the bargaining process, in a two-tier supply chain, between a single supplier and buyer; we analyze how the supplier's EE technology adoption is affected by the buyer's relative bargaining power and also by technology uncertainty. We compare various contracting arrangements commonly used in industry to overcome these obstacles, including price commitment by the buyer and shared investment contracts while characterising their optimal properties with respect to different criteria—in particular, supply chain profit and the equilibrium level of EE investment. In terms of both criteria, we find that shared investment contracts perform better than price commitment contracts, although the latter increase supplier profit when a buyer's bargaining power is relatively high. We also show that, in a two-player model, the bargaining process between firms moderates how uncertainty affects supplier's investment behaviour.

2 - Assortment Selection When Customers Have Limited Attention
Frank Huettner, Tamer Boyaci, Yalcin Akcay

Facing an abundance of product choices and related information, but with only limited time and attention to evaluate them, consumers have to come to grips with how much and what type of information to pay attention to (and what to ignore), and make product choice and purchase decisions based on this partial information. Utilizing rational inattention theory, we characterize the choice behavior of customers who optimally acquire information about available options through different channels with different costs. We discuss the implications on the variety a seller (e.g., retailer) should offer to its customers.

3 - Competition in Carbon-Offset Markets
Gokce Esenduran

Customers who want to counteract their carbon emission can purchase voluntary carbon offsets from retailers. Such retailers generally act as middlemen between the customers and carbon-offsetting project owners/developers. Due to increasing customer awareness in environmental issues, globally-traded carbon market has been expanding quickly over the past years. One of the most fundamental issues with carbon offsetting is additionality, i.e. whether the project would have happened even if it were not funded through this market. In this paper, we model the competition between carbon-offset retailers and identify conditions under which additionality problem is mitigated. We also analyze the conditions under which carbon-offset supply chain is coordinated.

4 - Supply chain of virtual products: making marketing decisions under bi-criteria
Tatyana Chernonog, Tal Avinadav, Tal Ben-Zvi

We consider a two-echelon supply chain of virtual products that faces uncertain demand. The demand distribution is a function of the selling price and the sales-effort investment. The objectives of the manufacturer and the retailer are to optimize one or more profit criteria by controlling the wholesale price, the profit margin and the sales-effort investment. By using the Stackelberg game approach and stochastic dominance property, we show that the problem can be analytically solved for a common structure of the demand function combined with certain profit criteria. We find that the retailer's bi-criteria preferences may introduce a new source of uncertainty in addition to demand uncertainty. We analyze the case from two perspectives: perfect and imperfect information regarding the retailer's choice mechanism. Under the assumption of perfect information, probabilistic choice theory is used, whereas under imperfect information, normative and behavioral approaches are utilized. Finally, we propose a method to find the efficient sets of decisions for each supply chain member under bi-criteria analysis and provide some numerical results.

■ TC-41

Tuesday, 12:30-14:00 - Building WE, 2nd floor, Room 209

ESG and Corporate Responsibility in Asset Valuation

Stream: Financial Mathematics and OR
Chair: *Gordon Dash*
Chair: *Nina Kajiji*

1 - Backtesting and Estimation Error: Value-at-Risk Overviolation Rate
Georges Tsafack

Financial institutions and regulators use the Value-at-Risk (VaR) as the standard tool for market risk management. It is therefore critical to appropriately assess the quality of VaR forecasts by comparing the actual violation rate with the expected level of violation. The VaR estimation error creates an additional risk. We show that even an unbiased estimator of VaR is likely to produce a systematic overviolation. We then propose an adjustment to account for the issue. A Monte Carlo study illustrates the overviolation problem and the eectiveness of the adjustment. An application to Fama French portfolios returns series highlights the need to further accounting for tail behavior in the data. Applying the adjustment to the Normal distribution performs relatively well for a less prudential level (5% VaR), but is unable to provide enough buer to overcome the overviolation for more prudential levels (1% or 0.5% VaR). Using the empirical distribution for more prudential levels improves risk forecasts.

2 - Optimizing Hierarchical Goal ESG Portfolios with ICA Common Factor Indexes
Gordon Dash, Nina Kajiji

ESG factor indexes are obtained through independent component analysis (ICA) of the Thomson Reuters social responsibility portfolio. Based on ICA factors, ESG smart betas along with ESG production-theoretic returns-to-scale are estimated by a feed-forward neural network. Including sub-additive CVaR metrics, all terms are incorporated into an augmented specification of the Sharpe multi-index portfolio model. A behaviorally-biased lexicographic combinatorial nonlinear goal programming model produces stable risk-adjusted inter-temporal portfolio performance of the augmented Sharpe model

3 - Estimating the Production of Behavioral Spillover Effects in the Municipal Bond Market
Nina Kajiji, Domenic Vonella

Previous research has documented the effectiveness of multivariate nonparametric radial basis function artificial neural networks to model the simultaneous bi-directional volatility spillover effects among European economies. This paper extends prior research findings by examining the effect of volatility spillover in the U.S. government bond market to trades of state-denominated bonds. By employing a multivariate radial basis function artificial neural network and the canonical correlation method the results presented in this manuscript are compared and contrasted with findings presented in international research studies. Preliminary findings clearly demonstrate the overall effectiveness of the single-layer multivariate neural network design to map complex real-valued and measurable function of bond volatility.

■ TC-42

Tuesday, 12:30-14:00 - Building WE, 1st floor, Room 120

Decabornizing electric systems (Part I: System supply and grid)

Stream: Long Term Planning in Energy, Environment and Climate
Chair: *Edi Assoumou*

1 - Robust Optimisation for a Smart Grid
Aurélien Havel, Sophie Demassey

Smart grid are advanced electrical grids that enable a joint control of the supply and the load. The supply may come from centralized or decentralised power plants or even from an external network. The loads can aggregate several users of various nature. With the decreasing price of renewable energy sources, the engagement of companies to become more environment-friendly and the deregulation of energy markets, an increasing number of actors want to diminish their energy bill by installing batteries, solar panels or wind turbines. Thus, it is essential to assess what the optimal capacities and the potential gains would be. A wide range of optimization methods have been used in such complex decision problem to find an optimal setting. In this paper we focus on the use of robust optimization for capacity planning in smart-grids in the presence of uncertainty.

2 - CHP and electric heater in a highly renewable electricity system
Gerda Schubert, Benjamin Pfluger

The increasing electricity production from fluctuating renewable sources such as wind and solar power causes a need for more flexibility. At the same time a decarbonisation not only of the power system but also of the heating market is necessary. The combination of these challenges leads to certain frictions, but it also offers new opportunities for synergies. Rising shares of fluctuating renewable electricity on the electricity market compete with electricity produced in combined heat and power (CHP) plants already today and this competition will intensify within the next decades. At the same time heat storages can increase flexibility of CHP plants and power-to-heat technologies can help to integrate renewable electricity from the electricity market into the heat market. The assessment in this paper is based on an integrated least-cost optimization of the heating and electricity market in an hourly resolution up to the year 2050 with an extended version of PowerACE-Europe. Interactions between renewable electricity, CHP and electric heaters can be assessed, as the capacity development of renewables is integrated in the optimization. Different scenarios with a focus on Germany are analyzed. The results show that economically optimized CHP shares are high in the medium term, but decrease with increasing CO2-prices and renewable shares on the electricity market. Power-to-heat technologies in heat grids evolve significantly in systems with high renewable electricity shares.

3 - Long term transition and balancing for the French power mix
Edi Assoumou, Jerôme Gutierrez, Nadia Maïzi

A deep transformation of our power systems is a key condition of the transition toward more sustainable energy systems. The drivers of this transition are economic (cost of competing technologies, fossil fuel prices), technical (decommissioning rhythm of current power plants, efficiencies, variable renewable sources) and political (intensity of nuclear policy, environmental constraints). Yet the cost optimal pathway will not only depend on the balancing conditions for a given target year in the future but also on the successive investment and operation decisions made at each intermediate time period. On the other hand a transition of power systems should also respect balancing constraints that call for models with higher time resolution. Using a bottom-up TIMES optimization model of the French power system with detailed time resolution and dynamic constraints; we analyze the implications of CO2 taxes or quantitative cap on emissions on the future French power Mix.

■ TC-43

Tuesday, 12:30-14:00 - Building WE, ground floor, Room 18

DEA and Performance Measurement 1

Stream: DEA and Performance Measurement
Chair: *Emmanuel Thanassoulis*

1 - Data Envelopment Analysis, scale construction and Choquet integral
Salvatore Greco, Salvatore Corrente, Ali Emrouznejad, Alessio Ishizaka

We present a new model of Data Envelopment Analysis taking into consideration two points that did not receive attention in the domain: the definition of a common scale for input and output units and the interaction between inputs, between outputs and between inputs and outputs together. Since the common scale between inputs and outputs can be defined in different ways and it is always arbitrary to some extent to consider only one of these scales, we propose to take into consideration the whole set of efficiency measures obtained by each unit in the whole set of feasible scales. With respect to the possible interactions, we extend the DEA using the Choquet integral. The proposed model is used to measure the information and communication technology (ICT) of 183 economies.

2 - A Lexicographic Radial Projection in Data Envelopment Analysis

Pekka Korhonen, Akram Dehnokhalaji, Nasim Nasrabadi

A well-known problem of using radial projection in Data Envelopment Analysis (DEA) is that the solution on the boundary of a production possibility set is not necessarily efficient. It may be only weakly efficient. Unfortunately, not even the value of the (in)efficient score does not make a distinction between an efficient and only weakly efficient target point. In practice, to guarantee that the final target point is efficient, extra terms are inserted into the objective function - such as the sum of slack variables associated to input- and output-variables. The final solution is efficient, but it is not necessarily a radial projection. Our aim is to overcome this drawback by developing a straightforward approach which finds an efficient target point in the spirit of the radial projection. The approach is lexicographic and based on the idea to apply radial projection by stepwise dropping component(s) from the radial projection vector until the efficient frontier is reached. The final target point is efficient. Another desirable feature in the approach is that it produces individual (in)efficiency scores for all controllable variables. The individual score provides the user with the information how much each controllable variable has to be radially improved before the unit is efficient. A numerical illustration is used to demonstrate the approach.

3 - Modelling Different Degrees of Centralization in the Context of Incentivising Operation Units: A DEA-based Approach

Mohsen Afsharian, Heinz Ahn, Emmanuel Thanassoulis

The paper focuses on centrally managed organisations with a large set of operation units. While the central body in such organisations faces asymmetry of information concerning the operating costs of the units, it may wish to incentivise them through benchmarking and target setting to operate as efficiently as possible. Considering standard DEA for this purpose, each operating unit could estimate its own individual targets. However, this decentralized scenario is not desirable for a centralised scenario in which a central body wishes to optimise the performance of the system of units as a whole. On the other hand, a uniform set of targets is often not suitable as they would be either too demanding for many units or too undemanding for others. This paper therefore proposes a DEA-based approach for incentivizing the units of a centrally managed organisation under different degrees of centralisation. The units are clustered in such a manner that they are incentivised to gain further in efficiency, seeking to optimise the performance of the units of each cluster collectively while at the same time the targets are not too demanding for inefficient units. The approach will be illustrated by means of a panel of German savings banks.

4 - A DEA-based Incentives System for Centrally Managed Multi-Unit Organisations

Emmanuel Thanassoulis, Mohsen Afsharian, Heinz Ahn

Abstract. In multi-unit organisations such as a bank and its branches or a national body delivering publicly funded health or education services through local operating units, the need arises to incentivize the units to operate efficiently. In such instances, it is generally accepted that units found to be inefficient can be encouraged to make efficiency savings. However, units which are found to be efficient need to be incentivized in a different manner. It has been suggested that efficient units could be incentivized by some reward compatible with the level to which their attainment exceeds that of the best of the rest, normally referred to as "super-efficiency". A recent approach to this issue (Varmaz et. al. 2013) has used Data Envelopment Analysis (DEA) models to measure the "super-efficiency" of the whole system of operating units with and without the involvement of each unit in turn in order to provide incentives. We identify shortcomings in this approach and use it as a starting point to develop a new DEA-based system for incentivizing operating units to operate efficiently for the benefit of the aggregate system of units. Data from a small German retail bank is used to illustrate our method.

■ TC-47

Tuesday, 12:30-14:00 - Building WE, 1st floor, Room 115

New Results in Robust Optimization

Stream: Robust Optimization
Chair: *Marc Goerigk*

1 - Approximation of Ellipsoids Using Bounded Uncertainty Sets

André Chassein

In this talk we discuss the problem of approximating ellipsoid uncertainty sets with bounded (Gamma) uncertainty sets. Recall that robust linear programs with ellipsoid uncertainty lead to quadratically constrained programs. Whereas robust linear programs with bounded uncertainty sets remain linear programs which are generally easier to solve. We call a bounded uncertainty set an inner approximation of an ellipsoid if it is contained in it. We consider two different inner approximation problems. The first problem is to find a bounded uncertainty set which sticks close to the ellipsoid such that a shrinked version of the ellipsoid is contained in it. The approximation is optimal if the required shrinking is minimal. In the second problem we search for a bounded uncertainty set within the ellipsoid with maximum volume. We present how both problems can be solved analytically by stating explicit formulas for the optimal solutions of these problems. Further, we present in a computational experiment how the derived approximation techniques can be used to approximate shortest path and network flow problems which are affected by ellipsoid uncertainty.

2 - Robust Counterparts of Ambiguous Stochastic Constraints Under Mean and Dispersion Information

Krzysztof Postek, Aharon Ben-Tal, Dick den Hertog, Bertrand Melenberg

We consider ambiguous stochastic constraints under partial information. Whereas the past literature used the variance as the dispersion measure, here we use the mean absolute deviation (MAD). This makes it possible to use the old result of Ben-Tal and Hochman (1972) in which tight upper and lower bounds on the expectation of a convex function of a random variable are given. We use these bounds to derive exact robust counterparts of expected feasibility of convex constraints and to construct new safe tractable approximations of chance constraints. Numerical examples show our method to be applicable to numerous applications of Robust Optimization, e.g., where implementation error or linear decision rules are present. Also, we show that the methodology can be used for optimization the average-case performance of worst-case optimal Robust Optimization solutions. These results are currently applied to Stochastic Programming problems where the optimal value of the optimization problems solved in later stages are convex functions of the uncertain parameters.

3 - The Robust Recoverable Spanning Tree Problem with Interval Costs

Mikita Hradovich, Adam Kasperski, Pawel Zielinski

In the talk we consider the robust recoverable spanning tree problem with uncertain edge costs modeled by a scenario set. In a robust recoverable model a complete solution is formed first and is later modified to some extent after actual cost scenario reveals. Thus the approach has a two-stage nature. We assume that the second stage cost of each edge is known to belong to the closed interval. Hence the scenario set is the

Cartesian product of these edge cost intervals. The complexity of the problem under consideration has remained open to date. We show that the problem is polynomially solvable, by using an iterative relaxation method. The idea is to construct a linear programming relaxation of the problem and show that at least one variable in each optimum vertex solution is integer. Such a variable allows us to add an edge to the solution built and recursively solve the relaxation of the smaller problem. We also present a generalization of this idea to the robust recoverable matroid basis problem. We propose polynomial algorithms for both robust recoverable problems under the interval uncertainty representation.

4 - First Ideas on Inverse Robust Optimization Problems
Marc Goerigk, André Chassein

In most robust optimization settings, one typically assumes a set of relevant scenarios to be given. As constructing such a set can be challenging, a recent stream of literature has been concerned with efficient methods of designing sets that are neither too conservative, nor too relaxed.

In this talk I look at the problem from the opposite direction: Given some robust solution, to which uncertainty sets does it fit? Applications of this approach include a new way of sensitivity analysis, the identification of fragile solution aspects, and it occurs as a subproblem in recent solution approaches of the forward robust problem.

We follow two different approaches for inverse robust combinatorial problems: In the first setting, we distribute uncertainty along elements such that the given solution is optimal for the regret criterion. In the second setting, we consider the worst-case criterion, and are interested in the smallest set of solutions that contains an optimal solution in each scenario.

First models and algorithms are presented for both settings of inverse robustness. As this is work-in-progress, we will also report on most recent results beyond the scope of this abstract.

■ TC-48

Tuesday, 12:30-14:00 - Building WE, 1st floor, Room 116

Energy Management

Stream: Energy/Environment and Climate
Chair: *Philip Berntsen*

1 - Quantitative Analysis of Market Opportunity Utilization in Electric Power Companies
Miki Tsutsui, Kaoru Tone

In European countries, the wholesale power markets are well developed enough to be utilized by many electric power companies. These companies usually have a trading division (TD) which intensively handles all of the transactions with fuel and power markets standing between a generation division (GD) and a retail division (RD), even if they were vertically integrated before liberalization. Contrary to European countries, the system reform of the electricity power industry in Japan is now underway; e.g. the retail electricity markets for households will be opened in April, 2016. The government expects that the reform will promote new market entries, resulting in revitalization of the competition not only in the retail market, but also in the wholesale power market. Japanese incumbent power companies have been vertically integrated, similarly to those in Europe before liberalization. In these companies, GD sends most of the electricity generated to RD directly as a matter of course. However, this will be changed in accordance with the increase of the market liquidity in the wholesale power market. In fact, some Japanese power companies are attempting to establish TD in preparation for the effective use of market, however, the others are skeptical about the utilization of market mechanisms through TD. Therefore, this study quantitatively evaluates the effects of the potential use of market opportunities in order to help these companies to consider introducing TD.

2 - A generic multi-commodity energy market design model
Eugeniusz Toczylowski

To support ambitious EU energy policy objectives, further methodological progress is required for development of the competitive EU energy market in order to harmonize and achieve the efficient, competitive and incentive-compatible solutions at the national, regional and EU levels.

A generic multi-commodity energy market model is a powerful design concept that is a good theoretical base for supporting long-term evolutional development and integration of the heterogenic market designs at the EU level. It allows us to achieve incentive-compatible solutions for economic efficiency of the energy systems over long term perspective by gradual improving economic efficiency and security of supply requirements and harmonizing them with the environmental targets.

The functional requirements can be gradually improved in all areas of the energy market by implementing trade of many commodities and services in various market segments, including various forms of energy carriers (electricity, gas), market products that reflect decarbonisation and other environmental requirements, as well as ancillary and balancing services related to security of supply and transmission rights to control inter- and cross-border flows.

3 - Double Auction Used for Fair Coordinated Charging of Electric Vehicles
Izabela Zoltowska

Recently electric vehicles (EVs) receive growing perception as one of most promising market participants, who can provide demand response. The challenge for the competitive market is to provide rules and include the EVs' bids in such a way, that the most efficient market dynamics are achieved. This paper examines new possibility for minimizing EVs charging costs: a centralized auction with shifting bids. It gives the answer how the charging requirements of EVs can be included in the pool-based centralized auction and solves the following problems: (a) coordination (market operator uses auction as coordination tool), (b) optimization (no decision support needed: EVs simply submit their driving patterns to aggregator). We use recently developed auction modeled of type of multi-period optimal power flow (OPF DC) model with generation units characteristics (start-up cost, time, etc.) and transmission constraints. For such an auction we provide simple rules for independent EVs float aggregators to transform driving patterns into common, step-wise, price-responsive bids. The applications are studied on the 5-node PJM system under different market conditions (season change, transmission constraints, market penetration by EVs, etc.) in a 36-hour horizon. The solutions to each case were obtained with Cplex 12.3 on a personal computer in time no longer than 30s. The results show that both the market and EVs can gain thanks to coordination through auction.

4 - Modeling to reveal the vast range of future Swiss electricity scenarios under deep uncertainty.
Philip Berntsen, Evelina Trutnevyte

Bottom-up energy system optimization models are widely used for energy and climate policy analysis at the national and international level. Energy scenarios produced with such models have been shown to underestimate the uncertainty inherent in the real-world transition. The models generate a small set of scenarios, too sparse to cover the broad range of possible future energy transitions. This presentation introduces the EXPANSE model (EXploration of PAtterns in Near-optimal energy ScEnarios). EXPANSE is a deterministic bottom-up, technology-rich energy system optimization model that aims to offer greater insights about the alternative future energy systems. After defining the supply-demand, technology and resource - constraints for the future energy system, like in any conventional optimization models, a Modeling to Generate Alternatives (MGA) approach is used to sample a large number of energy scenarios. A maximally diverse subset of these scenarios can then be selected to better understand the spread. The EXPANSE will be demonstrated by applying it to the Swiss electricity sector in 2035 and 2050 after the planned nuclear phase out. Future research shall focus on developing an interactive user-driven interface where stakeholder preferences are added to the model as further constraints, subsequently combining both hard and soft operational research methods.

■ TC-51

Tuesday, 12:30-14:00 - Building PA, Room D

Algorithmic Nonsmooth Optimization 1

Stream: Nonsmooth Optimization
Chair: *Andreas Griewank*
Chair: *Andrea Walther*

1 - Optimality Conditions for Nonsmooth Optimization Problem
Andrea Walther, *Andreas Griewank*

For nonsmooth target functions there is so far only a very limited number of results on optimality conditions. Here, we consider nonsmooth optimization problems where the nonsmoothness is caused by univariate piecewise linear elemens like min, max or abs. Then the optimisation problem can be stated in the so-called abs-normal form yielding a piecewise linear model that is of second order. We will exploit this representation to derive constructive necessary and sufficient conditions of first and second order for local optimality.

2 - On the minimization of discontinuous functions by a smoothing method
Ernesto G. Birgin, *Natasa Krejic*, *José Mario Martínez*

A general approach for the solution of some discontinuous optimization problems by means of smoothing will be proposed. It will be proved that limits of sequences generated by the suggested method satisfy a suitable optimality condition. Numerical examples will be given.

3 - Numerical Experiments on Dynamically Choosing Cutting Models and Scalings in Bundle Methods
Christoph Helmberg

Bundle methods are frequently employed for minimizing the sum of convex functions. Large scale problems of this type arise e.g. in Lagrangian relaxation of resource constraints that couple a multitude of objects involved in some scheduling task. If a few objects turn out to be critical in this process, it may be worth to provide more detailed cutting models for those while the others are subsumed in a common model. Which ones are critical is typically not known in advance and may well change throughout the optimization process. We report on experiments within the callable library ConicBundle for dynamically identifying critical parts and adapting the bundle choices and scaling information accordingly.

4 - Successive Piecewise Tangent or Secant Linearization - Newton-like Methods for Solving Piecewise Smooth Equation Systems
Tom Streubel, *Andreas Griewank*

We will discuss how the inherent structure of piecewise smooth equation system can be exploited to propagate piecewise linear approximations algorithmically. To that end only a slight modification of standart AD-Tools is neccessary. These PL models approximate the underlying system function with a second order error and are Lipschitz-continuous w.r.t. to the reference point. Furthermore any piecewise linear Function can be represented in the so called abs-normal Form. It consists of a structured block matrix and thus can be stored efficiently in any numerical linear algebra package. In the second half we'll take a closer look at secant succsessive linearization of smooth equation systems. We show that it converges with the order of golden ratio irrespective of the problem dimension.

■ TC-52

Tuesday, 12:30-14:00 - Building PA, Room C

Vector and Set-Valued Optimization II

Stream: Vector and Set-Valued Optimization
Chair: *Marcin Studniarski*

1 - Vector Critical Points and Efficiency in Nondifferentiable Constrained Vector Optimization Problems
Tadeusz Antczak

In our considerations, definitions of vector critical points in the sense of Fritz John and Karush-Kuhn-Tucker for a considered constrained vector optimization problem are presented. The necessary and sufficient optimality conditions for a characterization of critical points in the considered nondifferentiable constrained vector optimization problem are established. Namely, the relationships between vector critical points and (weakly) efficient solutions in the considered nonsmooth multiobjective programming problem are derived. Thus, the presented results extend similar results earlier established in optimization theory to a new class of nonconvex nondifferentiable constrained vector optimization problems.

2 - Higher-Order Optimality Conditions in Set-Valued Optimization with Respect to General Preference Mappings
Anna Michalak, *Marcin Studniarski*

In economic equilibrium theory and in qualitative game theory, the preferences of economic agents or players are often described by general preference mappings which do not necessarily lead to pre-order relations. As the authors of [1] state, "All one needs to assume is that the deciding agent in state x is able to specify those states P(x) which he prefers to x. The only order conditions on preferences which is needed is irreflexivity (meaning x does not belong to P(x))." In this paper, we present some new higher-order necessary and sufficient optimality conditions for a general set-valued optimization problem where optimization is understood with respect to a general preference mapping. These conditions are formulated in terms of some higher-order directional derivatives of multivalued mappings.

[1] Gale, D., Mas-Colell, A.: On the role of complete, transitive preferences in equilibrium theory. In: Schwödiauer, G. (ed.) Equilibrium and Disequilibrium in Economic Theory, pp. 7–14. D. Reidel Publishing Company, Dordrecht (1977)

3 - A New Global Scalarization Method for Multiobjective Optimization with an Arbitrary Ordering Cone
Marcin Studniarski, *El-Desouky Rahmo*

We describe a new scalarization method which consists in constructing, for a given multiobjective optimization problem, a single scalarization function, whose global minimum points are exactly vector critical points as defined in [1] for the original problem. This equivalence holds globally and may enable one to use global optimization algorithms designed for scalar-valued problems for solving the original multiobjective problem. We also show that, if the ordering cone is polyhedral and the function being optimized is piecewise differentiable, then computing the values of a scalarization function reduces to solving a quadratic programming problem.

[1] C. Gutiérrez, B. Jiménez, V. Novo, G. Ruiz-Garzon, Vector critical points and efficiency in vector optimization with Lipschitz functions, Optim. Lett. 10 (2016) 47-62.

■ TC-53

Tuesday, 12:30-14:00 - Building PA, Room A

Path and Routing Problems

Stream: Metaheuristics
Chair: *Daniel Tuyttens*

1 - Advanced Variable Neighborhood Search on Capacitated Vehicle Routing Problem
Behzad Sepehrian Bahary Nejad

Variable neighbourhood search (VNS) has been used recently for a range of combinatorial optimisation problems. It combines an adaptive local search over variable neighbourhoods with a shake procedure to escape local optima. It has been shown to work well for problems with simple problem structure and neighbourhood structure. Here we consider VNS applied to the capacitated vehicle routing problem (CVRP), in which we deliver to a number of customers from a single depot using vehicles of identical capacity. We find that the performance of VNS depends on both the problem structure and the choice of neighbourhood structure. In current CVRP VNS implementations is that the operations that define neighbourhoods of different depths do not define non-intersecting neighbourhoods. This causes duplication in local search. A second important issue is problem structure. The single-vehicle subtours that appear in a globally optimal solution typically appear in many locally optimal solutions. We develop advanced novel VNS methods to avoid intersection and take advantage of information from locally optimal solutions in seeking a globally optimal solution.

2 - Annealing Metaheuristic Approaches to the 3D Printer Head Problem (3DPHP)
Seán McGarraghy, Terry Harrison, Adrian Doyle, Peter Hannon

3D printer head moves may be non-extrusion (reposition head) or polymer extrusion (boundary or fill of area between boundaries). We formulate the 3DPHP, to reduce 3D printing time by minimising the head's non-extrusion distance travelled. It is a constrained CO problem closely related to the TSP. A tour is a sequence of extrusion moves, viewed as "extended vertices". The start and end of an extended vertex need not be the same point: thus the direction of an extrusion move affects the head location on completing that move, and so affects the total non-extrusion travel time. Extrusion moves cannot be omitted or shortened; however, their sequence may be reordered subject to constraints, and an extrusion move's direction may be reversed. Constraints are: each extrusion move is carried out exactly once; related boundary moves are grouped; a fill move must succeed the two boundaries between which it fills; non-extrusion moves are assumed to be straight lines. For each slice of the 3D object, the objective function to be minimised is the sum over i of Euclidean distances between the end point of extrusion move i and the start point of extrusion move i+1. We apply Simulated Annealing (SA) and Quantum Annealing (QA), with neighbours generated using k-opt. We find that the total non-extrusion distance can be optimised by both SA and QA. QA outperforms SA both in terms of algorithm runtime and printer time savings realised, provided good metaheuristic parameters have been found.

3 - Exact and Heuristic Methods for Time-Dependent TSP with Multiple Time Windows
Jarosław Hurkała

In the real-life traveling salesman problems the traffic has significant impact on the total travel time as well as the visit times at each location. We can also easily show many practical situations in which the need for multiple time windows arise naturally and has to be taken into account. In the literature the combination of those two issues to the best of our knowledge has not yet been fully examined. We present a mathematical model for this problem, which we recognize as time-dependent TSP with multiple time windows. The model is implemented in commercial optimization software and tested on instances of different size based on real-life data. Because of the problem complexity, only small instances can be solved to optimality in reasonable time. We therefore decompose the problem into two problems. The master problem aims at finding the best sequence of locations to be visited, while the subproblem goal is to compute the minimum route duration for a given sequence. The latter is solved to optimality by a specialized algorithm that we have already introduced, and for the former problem we compare well-known heuristic algorithms and show that practical solutions can be effectively computed.

4 - Exploring GRASP-based Metaheuristics to solve the Traveling Salesman Problem.
Daniel Tuyttens, Mohand Mezmaz, Gautier Vaillant, Nouredine Melab

In this work we consider the GRASP metaheuristic and the classical Traveling Salesman Problem. The paper proposes three variants of the GRASP method. These variants can be seen as a generalization of the construction phase used in GRASP. A first variant adds elements at the beginning and at the end of a partial solution unlike GRASP's construction phase which adds elements only at the beginning. The second variant builds group of partial solutions simultaneously unlike GRASP's construction phase which builds them separately. In a the third variant, a bound evaluates a partial solution like in a Branch-and-Bound procedure. Experiments on standard instances of the TSP show that some combinations of the variants improve, on average, the obtained results compared with the classical GRASP method. As a future work, we plan to test these variants on other optimization problems.

■ TC-54

Tuesday, 12:30-14:00 - Building PA, Room B

Nonlinear optimization and applications

Stream: Convex Optimization
Chair: *Ya-xiang Yuan*

1 - A Gradient Reflection Method for Orthogonal Constrained Optimization Problems
Xin Liu

The orthogonal constrained optimization is very important but usually difficult to solve. In this talk, we propose a gradient reflection method which consists with two parts. In the first part, a gradient reflection step, based on Householder transformation, is calculated by a closed-form formula. The second part, a symmetrization step is employed to symmetrize the Lagrangian multiplier of the orthogonal constraint. Global convergence for this approach is established. Preliminary experiments illustrate that the new algorithm performs well and is of great potential.

2 - On a fractional matrix problem
Cong Sun

We investigate a complex matrix problem, with a fraction objective function and nonlinear constraints. We have applied an approach to approximate the objective function, which guarantees the objective function to converge. By using the fractional optimization technique and the alternating direction method, the problem is decomposed into a series of subproblems as quadratic constrained quadratic programmings. New methods with idea of quadratic approximation are proposed to solve the subproblems. In the applied simulation tests from signal processing, it shows that the approximation performs very well compared to other approaches, and the new methods significantly reduce the computing time compared to the existing software.

3 - A Parallel Line Search Subspace Correction Method for Composite Convex Optimization
Ya-xiang Yuan, Qian Dong, Xin Liu, Zaiwen Wen

In this talk, we investigate a parallel subspace correction framework for composite convex optimization. The variables are first divided into a few blocks based on certain rules. At each iteration, the algorithms solve a suitable subproblem on each block simultaneously, construct a search direction by combining their solutions on all blocks, then identify a new point along this direction using a step size satisfying the Armijo line search condition. They are called PSCLN and PSCLO, respectively, depending on whether there are overlapping regions between two immediately adjacent blocks of variables. Convergence results are established under mild assumptions. We compare PSCLN and PSCLO with the parallel version of the fast iterative thresholding algorithm and the fixed-point continuation method using the Barzilar-Borwein step size and the greedy coordinate block descent method for solving the 1-regularized minimization problems. Our numerical results show that PSCLN and PSCLO can run fast and return solutions no worse than those from the state-of-the-art algorithms. It is also observed that the overlapping domain decomposition scheme is helpful when the data of the problem has certain special structures.

■ TC-56

Tuesday, 12:30-14:00 - Building CW, 1st floor, Room 122

Optimization of Execution of Large Scale Simulation Experiments in the Cloud

Stream: Workshops and roundtable
Chair: *Przemyslaw Szufel*

1 - Optimization of Execution of Large Scale Simulation Experiments in the Cloud
Przemyslaw Szufel, Bogumił Kamiński

Do you have a simulation experiment that takes many days to compute on your laptop? Why not reduce that time to minutes or hours? This can be achieved through utilization of cloud computing.

During the workshop we will show how to transfer computational jobs from your desktop to Amazon Elastic Compute Cloud. We will give special focus to optimization of computing costs by showing how to utilize spot market for computing power. The workshop will present two example scenarios. In the first we show how standard simulation experiment designs (eg. used to collect data for metamodeling) can be distributed in the cloud. In the second a parallelization of sequential knowledge gradient algorithm used for simulation optimization will be presented.

No previous experience with cloud computing is required from the participants. It is recommended that they have basic knowledge of Linux.

■ TC-58

Tuesday, 12:30-14:00 - Building CW, Room 024

Mentoring Session 2

Stream: Mentoring Sessions

1 - Mentoring Session 2
Galina Andreeva

Have you ever thought of talking to someone outside your normal circle of work colleagues and friends for help with solving a problem? The mentoring session is the perfect opportunity to do just that. EURO2016 mentoring enables you to sign up for a 20 minute one-to-one session with an experienced OR professional. It is designed to help you with the issues you might be facing in your practice, career or development. You may use it to gain valuable advice; to help you identify the skills and expertise you need, and where to go for information; to see new perspectives; and to build your network. You must sign up in advance to talk to a specific mentor. Details of how to do this, and the latest mentor line-up, can be found on the EURO2016 website, at: http://www.euro2016.poznan.pl/mentoring/ To get the most from the session, please prepare in advance: what is the problem you'd like help and advice on, what would you like to know from your mentor. Be ready to ask the questions!

Tuesday, 14:30-16:00

■ TD-01

Tuesday, 14:30-16:00 - Building CW, AULA MAGNA

Keynote Pablo Moscato

Stream: Plenary, Keynote and Tutorial Sessions
Chair: *Ivana Ljubic*

1 - Infortmation-Based Medicine and Combinatorial Optimization: Opportunities and Challenges
Pablo Moscato

Operations Research (OR) methodologies, as well as their practitioners, are in high demand. They can address new problems that arise from the disruptive technologies that will have the highest economic impact in the future. Disruption comes hand-in-hand with new technologies for Next-Gen Genomics, mobile internet, automation of knowledge work, the Internet of Things, the Cloud, Advanced robotics and Autonomous and near-autonomous vehicles. These areas bring great challenges but also great opportunities.

One spin-off that will change the world is that these new technologies will generate large-scale datasets allowing an unprecedented ability for OR practitioners to "personalise" solutions. One clear example comes from the field of Personalised Medicine which seeks to consider the best interests of the patient/individual at the centre of all decisions. Personalization will disrupt institutional practices, and drugs and treatments will necessarily be "tailored" to the individual profile. Obviously, one of these disruptive technologies (Next-gen Genomics) is a keystone for the changes ahead, but the automation of knowledge work will also prove vital for cost-effective decisions. The future of OR will be shaped by its new role as a nexus between disciplines.

The interdisciplinary nature of this new area of large-scale data-driven decisions has led to the emergence of a new name for a field of research: Data Science. There are many challenges in this field and they generally involve large scale optimization. However, personalization brings a particular challenge: the development of new mathematical models and powerful algorithmic approaches for large scale instances. Based on the lessons we learned when introducing these new mathematical models, which were developed to provide new diagnostic and treatment methods, I will discuss our personal journey in Information-based Medicine, with examples of the application of techniques of Combinatorial Optimization, Artificial Intelligence, Machine Learning and Machine Teaching to the area of Data Science and Large-scale Data Analytics.

■ TD-02

Tuesday, 14:30-16:00 - Building CW, 1st floor, Room 7

Rough Sets in Decision III

Stream: Rough Sets in Decision
Chair: *Marcin Szelag*

1 - A kernel trick approach to rule-based classifiers
Yoshifumi Kusunoki

Rules or patterns, which are logical conjunctions of attribute values, are important in data analysis from the viewpoint of readability. This is research on rule-based classifiers, particularly, classifiers of the sum of weighted rules. Classification accuracy of rule-based classifiers is not good and is unstable comparing to common classifiers in machine learning, since they depend on heuristic rule generation methods. It is difficult to construct (optimal) classifiers considering exponentially many possible rules. To overcome this difficulty, the author has proposed a kernel trick approach, which deals with all possible rules based on the kernel method and Boolean functions. A feature space of the proposed kernel is given by the set of (pseudo-)Boolean functions whose domain is the family of rules. Each object is mapped to a Boolean function, whose truth values are the rules satisfied by the object. We use Boolean functions to provide weights on rules, which introduce heuristics of rule generation, such as excluding inconsistent rules. Then, we calculate the inner product of feature vectors of objects with the provided weight function, and obtain a Boolean function kernel. Using the Boolean function kernel, we can implicitly obtain a rule-based classifier. It is true that we cannot obtain rules explicitly, however the kernel-based classifier is useful to know what classification accuracy we can achieve by rule-based classifiers if we are free from computational limitations.

2 - Proposal of statistical rule induction method from a decision table

Yuichi Kato, Tetsuro Saeki

The conventional Rough Sets method (CRSM) defines a decision table (DT) which consists of a sample set (SS), condition attributes (CA), a decision attribute (DA), a set of attribute values and an information function. CRSM derives an approximation of a concept of the DT, and uses it for inducing if-then rules hidden behind the DT. However, CRSM has not paid attention to the fact that the DT is obtained from a population, and just arranges the data set, which fails in the rule induction. Then, we propose a statistical rule induction method which recognizes the CA and DA as random variables, the SS as an instance of their variables, and uses an idea that the rule makes partiality of the distribution of values of DA, developing the idea into a criterion to estimate rules. Specifically, assuming a condition part (CP) of an if-then rule, whether the CP makes the partial distribution of DA or not is determined by a statistical test under use of the SS. All rules can be induced by changing and arranging CP systematically and efficiently. We study and present the following: 1) An algorithm STRIM, 2) the relationship between CRSM and STRIM, for example, VPRS and STRIM, accuracy and partiality, 3) the necessary data size for STRIM, 4) application for reduct and a missing data set.

3 - Dynamic programming approach for construction of association rule systems

Beata Zielosko, Mikhail Moshkov, Fawaz Alsolami, Talha Amin, Igor Chikalov

An application of dynamic programming approach for optimization of association rules from the point of view of knowledge representation will be studied. The presented algorithm can be considered as a simulation of a greedy algorithm for construction of partial covers. For each decision table obtained from the information system, we construct a system of exact rules in the following way: during each step, we choose a rule which covers the maximum number of previously uncovered rows. We stop the construction when all rows of the table are covered. If the obtained system of rules is short enough, then it can be considered as an intelligible representation of the knowledge extracted from the decision table. Otherwise, we can consider approximate rules, and stop the construction of the rule system when the most part of the rows (for example 90% of the rows) are covered. Experimental results present cardinality of the set of association rules constructed for information system and lower bound on minimum possible cardinality of rule set based on the information obtained during algorithm work.

4 - Ensemble rule decision models for ordinal and non-ordinal classification problems

Jerzy Blaszczynski, Roman Slowinski

We present different types of ensemble rule decision models, which are constructed on the basis of data structured by Dominance-based Rough Set Approach (DRSA). These ensemble models are designed to deal with problems characterized by a considerable amount of inconsistency in the input data. The input data are examples of classification decisions described by a mixture of non-ordinal and ordinal attributes. The models are composed of decision rules with a syntax involving dominance relation in the condition part. Such rules are typically used for ordinal problems with monotonic relationships between conditions and decision. We show that the rules are also useful for non-ordinal problems because they provide comprehensible pros and cons arguments for assignment of examples to classes. We give examples of application of the ensemble rule decision models and we prove their usefulness in a comparative experiment.

■ TD-03

Tuesday, 14:30-16:00 - Building CW, 1st floor, Room 13

Preference Learning 4

Stream: Preference Learning
Chair: *Marco Cinelli*

1 - Estimating Preference Parameters from Rankings vs. Evaluations: Systematic Differences

Rudolf Vetschera

Decompositional methods of preference elicitation estimate preference parameters like weights from holistic responses from decision makers such as choices or cardinal evaluations. It is a well known phenomenon that subjects behave inconsistently between these two response modes. In this paper, we analyze whether the models commonly used to estimate preference parameters from these different input types will also generate systematic differences, independently of the actual response mode and behavioral biases that might be involved. We present evidence both from actual experimental data and from computational experiments that shows that there are indeed such differences. Models to estimate preference parameters from pairwise comparisons typically maximize the utility difference between alternatives for which preference was indicated, or in case the preferences cannot fully be reproduced, minimize violations. In case of violations, this leads to preference models with very small utility differences. In contrast, if cardinal evaluations are provided as input, utility differences are given and the model reproduces these differences as closely as possible. We study the effect of this conceptual difference on the estimated parameters and develop alternative model formulations that can help to avoid this problem.

2 - Using aggregation operators to infer semantic preferences

Miriam Martinez-Garcia, Aida Valls, Antonio Moreno

User profiling is required in many decision support systems. Nowadays it is becoming more common to find decision problems involving non-numerical data, such as multi-valued semantic criteria, which take as values the concepts of a given domain ontology. We propose to create a semantic user profile by storing preference scores into the ontology. This preferential information may be later exploited to rank and recommend the most suitable alternatives for each user. Ontologies give a formal and explicit description of a domain and model taxonomic and semantic relations between concepts. A numerical interest score attached to the most specific concepts permits to distinguish better the preferences of the user, improving the quality of the decision. Provided that ontologies usually have hundreds of concepts, it is not feasible to obtain all their scores at the beginning. Therefore, given concept c with an unknown preference, an inference procedure has been designed. The basic idea is to find a subset of concepts semantically similar to c and to aggregate their scores using the WOWA (Weighted Ordered Weighted Average) operator with two weighting factors: OWA weights define the andness/orness aggregation policy, while criteria weights give different importance to the values aggregated in terms of their semantic distance to c. A recommender system of touristic activities will be used to test this learning procedure, in projects SHADE(TIN-2012-34369) and URV(2014PFR-URV-B2-60).

3 - HPC-ranking big performance tableaux from multiple incommensurable criteria with missing data

Raymond Bisdorff

In the context of the ongoing GDRI-Algodec "Algorithmic Decision Theory", supported o.a. by the CNRS (France) and the FNR (Luxembourg), we develop multiple criteria ranking algorithms for large sets of potential decision alternatives: up to several thousand of alternatives evaluated on multiple incommensurable ordinal performance criteria with potential missing data. This research is motivated by the development of a visualization tool - a heat map - for performance tableaux showing the decision alternatives linearly ordered by decreasing preference, and the marginal performances coloured by their optimistic quantiles equivalence class.

4 - Co-Constructive Development of a Sustainability Assessment Model

Marco Cinelli, Milosz Kadzinski, Krzysztof Ciomek, Stuart Coles, Mallikarjua Nadagouda, Rajender Varma, Kerry Kirwan

Sustainability assessments are complex decision-making processes characterized by evaluation criteria which represent multiple and often divergent perspectives and preferences. This presentation will discuss the holistic contribution that Multiple Criteria Decision Aiding (MCDA) can provide to advance the practice of sustainability evaluations in the synthesis of materials. An MCDA methodology for classifying synthesis protocols is proposed encompassing a set of predefined and ordered green chemistry-based classes, and its application for the production of silver nanoparticles is provided as a case study. The approach is based on the paradigm of Ordinal Regression which infers compatible models composed of an additive value function and extrapolates class thresholds from the assignment examples provided by nanotechnology experts. The learning process empowered by MCDA to co-construct the classification model will also be discussed, distinguishing between stages of problem structuring, preference elicitation, preference modeling and problem solving. Furthermore, key insights will be advanced on the benefits that MCDA has on: (i) the MCDA analysts who master a new decision-making challenge; (ii) the decision makers who can explore their preferences models thus clarifying their assumptions and value judgments; and (iii) the readership community, which can discover the capabilities of MCDA for the advancement of research on sustainability assessment.

■ TD-04

Tuesday, 14:30-16:00 - Building CW, ground floor, Room 6

Sustainable Urban Transport: Transition towards Zero Emissions

Stream: Environmental Sustainability in Supply Chains
Chair: *Hans-Otto Guenther*
Chair: *Matthias Kannegiesser*

1 - Single vehicle availability control of electric vehicles in station based car sharing systems with spontaneous booking

Natalia Agata Stepien, Kerstin Schmidt, Thomas Volling, Thomas Spengler

We consider the availability control of electric vehicles in station-based car sharing systems (e-car sharing). In this kind of car sharing systems customers are able to rent vehicles flexibly in time at defined rental points. Our focus is on station-based car sharing systems with round-trips, i.e., cus-tomers are obliged to return the rented vehicles at the start station. We present a novel dynamic programming approach for the spontaneous booking availability control of a single electric vehicle in such a system. The proposed availability control accounts for stochastic demand and the strong intertemporal interdependencies between acceptance decisions that arise from the limited flexibility of electric vehicles. Based on a numerical study we show that an acceptance-denial policy significantly outperforms the first-come-first-served approach currently used in industry.

2 - System Analysis of Wireless Charging Electric Vehicle for Urban Transport

Jinhyeok Park, Young Jae Jang

A wireless charging or inductive charging electric vehicle (EV) is a type of EVs with a battery that is charged from a charging infrastructure, using a wireless power transfer technology. Wireless charging EVs are classified as stationary or dynamic charging EVs. Stationary charging EVs charge wirelessly when they are parked, and dynamic charging EVs can charge while they are in motion. The online electric vehicle developed at the Korea Advanced Institute of Science and Technology is an example of a commercially available dynamic charging transportation system. One of the benefits of dynamic charging is that it allows a smaller and lighter battery to be used, due to frequent charging using the charging infrastructure embedded under roads. In this paper, we quantitatively analyze the benefits of dynamic charging with an economic model of battery size and charging infrastructure allocation, using a mathematical optimization model. Particularly, we analyze by how much battery size can be reduced and what the cost saving of reducing the battery size is with the model. We also show that the dynamic charging can be beneficial to battery life.

3 - Pathway to Zero Emissions: The Time-to-Sustainability Approach to Optimize the Transition Towards Sustainable Urban Transport Systems

Matthias Kannegiesser, Hans-Otto Guenther

We propose a long-term strategic network design model for urban transport systems based on the time-to-sustainability optimization method in order to provide decision support for policy makers and city planners. The approach is based on a structural transport network representation covering most relevant data on transport demand, user groups, transport infrastructure and services including vehicle fleet sizes and powertrains used. The model minimizes the time until predefined targets for sustainability indicators such as CO2, air pollution, and costs are all met steady-state. It delivers results on capacities and usage intensity of transport modes and their infrastructure and reveals which service and technology could be essential under current technology assumptions to meet overall sustainability targets. The objective of the model is to reveal fundamental dynamics in the transition towards the sustainability steady-state and to better understand the levels of magnitude in action to be taken by city planners. Considering a long-term planning horizon of 20-30 years, the model hence indicates possible transition paths to meet the increasing demand for urban mobility in a sustainable way, i.e. balancing economic, environmental and social objectives. We present a basic model formulation from which a more detailed city-specific model can be derived.

■ TD-05

Tuesday, 14:30-16:00 - Building CW, 1st floor, Room 8

Multiobjective Optimization Methods

Stream: Multiobjective Optimization
Chair: *Maciej Nowak*

1 - Solution Approaches to Multiobjective Quadratic Assignment Problems

Merve Uluel, Zehra Kamisli Ozturk

The multi-objective quadratic assignment problem (mQAP) is a non-deterministic polynomial-time complete (NPC) problem with many real-world applications. Because of the fact that the multi objective structure of real life problems, mQAPs have attracted the attention of researchers from the 2005's. These studies are about especially, heuristics and metaheuristic algorithms. Conic scalarization method's effectiveness is proved in solution of multi objective problems with non-linear structure. So, in this study, first of all, we consider to solve mQAPs from the literature with the conic scalarization technique. After that, we solve same problems with multi objective genetic algorithm of NSGA-II. When we compare the quality of solution sets, the obtained results show that conic scalarization method reaches more pareto points than NSGA-II. Therefore, in the second part of the study we propose a new hybrid NSGA-II algorithm with conic scalarization by taking into account the strengths of both methods. Obtained results are compared with the results obtained from just conic scalarization and NSGA-II methods and from the other methods in the literature. Finally, the performances are compared. The performance of hybrid NSGA-II is competitive to that of other algorithms.

2 - Optimization Model with Piecewise Linear Nonconvex Objective Function
Robert Hlavatý, Helena Brozova

We present a new approach to solution of a specific class of constrainted optimization problems where the objective function is piecewise linear nonconvex while considering the search space to be represented by a convex polytope. The matter of nonconvexity is generally known to pose problems in a search for the optimal solution. The presence of piecewise linear objective function causes the search space to have some interesting properties we describe before the algorithm itself. We propose the way of transformation of a nonconvex problem into a multiobjective optimization problem and we further utilize modified multiobjective simplex algorithm to reach the optimal solution. In addition, it is shown that the solution of the multiobjective optimization problem is indeed the solution of the nonconvex optimization problem. Our aim is to show an alternative way to existing algorithms that does not involve the use of integer variables while it is still capable to reach the optimal solution after a finite number of steps.

3 - Interactive Approach in Multicriteria Dynamic Decision Processes
Maciej Nowak, Tadeusz Trzaskalik

We consider discrete problems, in which both the sets of states and the sets of decisions are finite. We assume that the process is evaluated with respect to multiple conflicting criteria. Our goal is to propose effective tools to help the decision maker to identify the most preferred strategy. Decision support requires the collection of information about decision maker's preferences. According to many researchers, the most effective and the most friendly way of its acquisition is an interactive method. We will discuss the following groups of methods: a) the methods based on a direct paradigm, which assumes that the decision maker expresses his/her preferences in relation to the values of the criteria, b) the methods based on an indirect paradigm in which preferences are articulated in relation to trade-offs between criteria. We will also characterize some potential real-life applications of the proposed techniques in business management. Among them, first of all strategic management issues and especially project portfolio management problems will be considered. The aim of the presentation is a brief characteristics of our recent results. The results obtained in our previous research allow us to formulate the hypothesis that the methods based on an interactive approach will be an effective tool supporting decision makers in solving multiperiod decision making problems.

■ TD-06

Tuesday, 14:30-16:00 - Building CW, ground floor, Room 2

Support software for the MCDA process

Stream: Multiple Criteria Decision Aiding
Chair: *Patrick Meyer*
Chair: *Vincent Mousseau*

1 - diviz : designing, processing and sharing Multicriteria Decision Aiding algorithms
Patrick Meyer, Sebastien Bigaret

In this presentation we highlight diviz, a platform for designing, processing and sharing Multicriteria Decision Aiding (MCDA) algorithms and experiments. One of its main features is the possibility to design complex MCDA algorithms by combining elementary calculation components via an intuitive graphical user interface. The target user community of diviz reaches from researchers to teachers, students and MCDA analysts solving real-life decision problems. The diviz software also eases the comparison of results produced by different algorithms on the same decision problem instance and facilitates the dissemination of MCDA methods and experiments.

2 - Modeling of the Multicriteria Decision Aiding process: methodology and practice
Tatiana Mironova, Patrick Meyer, Jacques Simonin

The multi-criteria decision aiding (MCDA) process can be applied in many fields of our life to make "better" decisions: health-safety, financial and banking systems, environmental management, planning of urban infrastructures, space engineering, etc. This process involves many actors, including the decision aider (or analyst) and the decision maker. The main purpose of this work is to formalize and model the MCDA process via model-driven engineering techniques, and to test it on a few use-cases. We motivate this work by showing why the MCDA research community could benefit from a meta-approach to decision aiding. Some of the questions which will be answered by this work are thus: How can the analyst be assisted in the choice of the MCDA method? How can the expertise of analysts be modeled? How can the dialogue between the decision maker and the analyst be guided? This work thus tries to create a step-by-step guide to the aiding process, which will be useful for both novice and advanced researchers. This model is designed in UML, which will help us in the future to create model-based support software and make connections with other applications.

3 - ChemDecide 2016: A MCDA software for the Speciality Chemical and Pharmaceutical Industries
Richard Hodgett

ChemDecide is a suite of software tools which incorporates three Multi-Criteria Decision Analysis (MCDA) techniques: Analytical Hierarchy Process (AHP), Multi-Attribute Range Evaluations (MARE) and ELimination Et Choix Traduisant la REalité trois (ELECTRE III). The software has been used for addressing decisions such as route selection, equipment selection, resource allocation, financial budgeting and project prioritisation by companies such as AstraZeneca, Proctor and Gamble, Pfizer, Fujifilm and GlaxoSmithKline. This presentation will showcase the ChemDecide software and demonstrate how it has been used with a real industrial equipment selection decision problem.

4 - A free software tool for the fuzzy AHP method
Pavel Holeček, Jana Talasova

The AHP method became very popular in multiple-criteria decision-making and it found its applications in diverse fields. Over the time, several fuzzifications of the method have been devised. The presentation introduces a free software tool that implements such a fuzzy method. The elements of the pair-wise comparison matrix are allowed to be expressed by triangular fuzzy numbers. The classical non-fuzzy methods based on the eigenvectors or the geometric means are also included in the software. The software makes it possible to design the (fuzzy) pair-wise comparison matrix in a user-friendly way and to derive the priority vector from it. Various consistency indicators are also calculated.

■ TD-07

Tuesday, 14:30-16:00 - Building CW, 1st floor, Room 123

Academic-practitioners Roundtable

Stream: Workshops and roundtable
Chair: *Galina Andreeva*

1 - Making an Impact Roundtable: Academics and Practitioners Working Better Together
Ruth Kaufman, Hans Geog Bock, David Lane, Gerrit Timmer, Michael Trick

An exchange of views on academic-practitioner collaborations with the objective of designing a blueprint for successful partnerships. A panel of academics and practitioners with extensive experience in collaboration will provide their views, and then invite the audience to ask questions and share their own views and experience. The main question to be addressed are: • What is the rationale for academic-practitioner collaboration? Is it strong enough to overcome the barriers/inertia? • What can be done to: - Strengthen the case - Make collaboration easier and better

■ TD-08

Tuesday, 14:30-16:00 - Building CW, 1st floor, Room 9

Teaching OR/MS 1

Stream: Teaching OR/MS
Chair: *José Fernando Oliveira*

1 - Teaching multi-objective optimization using iMOLPe - an interactive MOLP explorer
Carlos Henggeler Antunes, Maria João Alves, Joao Clímaco

In addition to the exposition of essential concepts and methods, teaching multi-objective optimization to engineering and economics & management student should involve a hands-on approach enabling experimentation and reflection on the results. Computational tools should enhance the discovery of nondominated solutions in a constructive manner that may clarify the nature of the trade-offs involved. iMOLPe - interactive multi-objective linear programming explorer - has been used to offer students an intuitive environment as the entrance door into multi-objective optimization, in which the main theoretical and methodological concepts can be apprehended through experimentation as well as representing a realistic decision support setting. iMOLPe integrates interactive MOLP methods using distinct solution computation techniques, search strategies, preference elicitation requirements, visual interaction mechanisms and result displays. The intertwining of computation and judgment steps allows for a progressive shaping of preferences as the selective characterization of the nondominated solution set unfolds. iMOLPe allows students playing the role of actual decision makers exploiting different search strategies and unveiling trade-offs between the competing objective functions leading to distinct nondominated solutions. It has revealed to be a valuable tool to develop the students' interest in the topic, enhance their technical skills and provide training as decision makers.

2 - Introducing optimization modeling using an energy supply game
Jeroen Belien

A major challenge in teaching Operations Research Management Science (OR/MS) courses, especially to students for whom OR/MS is not the primary field of study, is to motivate them to recognize the need for OR/MS tools in decision making. Many OR textbooks fail to motivate students to formulate, solve, and use optimization models. The main reason for this is that the textbook exercises to practice optimization modeling almost always take the form of an assignment that includes text that fully defines a fictional, small business problem in which the objective function and constraints are clearly described. Innovative teaching approaches like the use of case studies and educational games have proven to increase both students' interest and teaching effectiveness, but instructors often have difficulty finding suitable, relevant, and topical cases or educational games. The objective of this contribution is threefold. First, I present a concrete example of a self-developed classroom that was published in the open-access journal INFORMS Transactions on Education (ITE). Second, I will share my experiences with submitting articles to ITE in order to inspire authors who want to publish their work in ITE. Third, from my role as editor, I will provide suggestions and guidelines for publishing cases and educational games in ITE.

3 - Teaching Sustainable Supply Chain Concepts in a Master of Science Program
Stefan Treitl, Patricia Rogetzer, Werner Jammernegg

Students in the Master of Science Program "Supply Chain Management" at WU Vienna University of Economics and Business can choose among several elective courses in their second year of studies. One of these electives is dedicated to the topic of sustainable supply chains, on which we want to share our experience.

During this course, the students will deal with (almost) all stages of a supply chain and some of their associated sustainability aspects. The content of the different sessions is based on the lecturers' current or past research. A kind of "inverted classroom" teaching concept is used where the students have to read and summarize academic articles beforehand, so that during the sessions in-depth discussions are facilitated.

We start with an introductory session on general concepts of sustainability since most of the students are confronted with this topic for the first time. Afterwards, each session is dedicated to a certain sustainability topic, in particular sustainable sourcing, network design, transportation planning and sustainability reporting. Wherever possible we emphasize the importance of integrating sustainability aspects into decision models and also implement some environmentally-extended models in class. Finally, the students independently prepare presentations on special topics of sustainable supply chains and thus gain the ability to argue, discuss and defend their work in front of others.

4 - Operational Research applied to the resolution of logistical problems
Maria Alejandra Castellini

An experience of a course of 10 hours, as part of a University Degree in Logistics, is presented. Attended the same about 50 people, workers in organizations in which logistics is a central process. They responded to different training profiles, such as professionals in economics and engineering, not professionals with extensive experience in their work, as well as advanced students of Industrial Engineering. The challenge was to transmit applications of some models of operations research (OR) related to their activities. The proposal was based on the book Operation Management of Chase Aquilano & Jacobs, where the organization is presented as a set of related processes, showing in some of them the potential of OR models. Namely: 1) definition of the strategies of operations and supplies, showing applications of linear programming models (LP) and PERT-CPM, 2) design and selection of processes, suggesting the use of waiting lines models, 3) design supply chain through Just in Time, 4) Administration and Control of the supply chain, using LP models, Inventory Control and Planning of material requirements. It worked interactively, using commercially available software in organizations (Excel) and those with academic licenses (Win QSB). Attendees were very interested, continuing by mail with some of them. It was a challenge to teach a course outside the curricula of undergraduate degree and with varying profiles of attendees

5 - An Optimization-based Encapsulation Approach for Mathematics Courses in Engineering Graduation Programs
Joao Miranda

The encapsulation of various Mathematics courses in bachelor Engineering programs through an Optimization-based approach is presented. These Mathematics courses are also known as part of the "common core" for Engineering programs, along with other introductory courses on Physics, Chemistry, Statistics, Computer Science. In the Technology and Management College of Portalegre Polytechnics (ESTG/IPP, Portugal), the course Calculus-I occurs in the first term of the Engineering program and addresses Real Numbers, Differential Calculus and Integral Calculus. In the second term, Calculus-II is addressing Sum Series, multivariate Differential Calculus, Differential Equations, and Laplace Transform, being this topics' set very common too in other higher education institutions. The Numerical

Methods and Optimization course is included in the third term of ESTG/IPP Engineering programs: the usual numerical topics on Roots of Equations, Linear Systems of Equations, Differential Equations, are complemented with Optimization methods, featuring Linear Programming. The courses syllabuses are presented, illustrative examples that show the specificities of each course and the key interconnection points are detailed too. Following the Problem/Project Based Learning (PBL) principles, Optimization-based problems are encapsulating the courses' set and supporting the learning methodology. The evaluation procedures, the approach impact, and prospects of other applications are also discussed.

■ TD-09

Tuesday, 14:30-16:00 - Building CW, 1st floor, Room 12

Applications in Portfolio Selection

Stream: Emerging Applications in Portfolio Selection and Management Science
Chair: *Wlodzimierz Ogryczak*

1 - Linear Programming Models based on Reward-Risk Ratio with Multiple CVaR Measure for the Enhanced Index Tracking Problem
Wlodzimierz Ogryczak, Gianfranco Guastaroba, Renata Mansini, M. Grazia Speranza

The Enhanced Index Tracking problem (EITP) aims at minimizing the index tracking error of a selected portfolio from a portfolio outperforming the market index by a predefined amount. Modern performance measures assess performance against a benchmark accounting for asymmetry in returns distribution separating upside and downside, like Sortino ratio or Omega ratio. In this paper, we propose new mathematical formulations for the problem using the reward-risk ratio based on multiple Conditional Value-at-Risk measures. There are considered two models where the measure is computed with respect to a given value (market index mean value) and a random target, respectively. We show how each formulation, non linear in nature, can be transformed into a Linear Programming model. We further extend the models to include real features as cardinality constraints and buy-thresholds on the investments obtaining mixed integer linear programming problems. We analyze both the theoretical properties of the optimal portfolios and their performances.

2 - A hybrid approach combining iterated greedy heuristics and quadratic programming to track the 1/N portfolio
Oliver Strub, Norbert Trautmann

Investors who apply the 1/N portfolio strategy invest an equal amount of their investment budget in all N stocks from a given investment universe. It was empirically shown that this simple strategy compares favorably in terms of risk and return to other, more sophisticated investment strategies like the mean-variance approach and extensions thereof. However, if N is large, the 1/N portfolio strategy causes substantial management costs. Therefore, we consider the problem of optimally tracking the returns of the 1/N portfolio by selecting a small subset of the N stocks and by determining each selected stock's weight in the tracking portfolio. This problem can be formulated as a mixed-integer quadratic program (MIQP) that uses the weights of the stocks in the 1/N portfolio, i.e., 1/N, as input. However, this MIQP becomes computationally expensive when N grows large. In this paper, we therefore develop a hybrid approach that combines an iterated greedy heuristic for selecting the subset of the N stocks and a quadratic program for determining the optimal weight of each selected stock. We demonstrate in a computational experiment that our hybrid approach outperforms a commercial MIQP solver in terms of solution quality and CPU time. Moreover, the portfolios we construct compare advantageously with well-known index-tracking approaches, which can be used to replicate the returns of any portfolio, in terms of tracking accuracy.

3 - Bank ownership, risk taking, and bank performance: A stochastic metafrontier approach
Chi-Chuan Lee

Using the stochastic metafrontier framework of Huang et al. (2004), this study proposes to compare and measure the cost efciency and cost frontier gap between banks with different ownership structure in China for the period 2000-2014. It further identies environmental variables that determine bank's cost frontier gap between different types of banks. This newly metafrontier approach differs from Battese et al. (2004) and O'Donnell et al. (2008) mainly in the second step, where a SFA model is formulated and applied to obtain the estimates of the metafrontier, instead of relying on programming techniques. In this regard, the so-derived estimators have desirable statistical properties, allowing researchers to draw statistical inferences, and being able to associate the TGRs with a set of environmental variables. Empirical results show that both TGR and metafrontier cost efficiency (MCE) are underestimated by programming techniques. Our ndings suggest that foreign banks have in general the superior cost frontier of production, but inferior cost efciency of operation than private banks (joint stock commercial banks and city commercial banks). Finally, the regression results show that the off balance sheet items (OBS), non-performing loans (NPLs), and nancial market structure are signicant determinants of the cost gap between the cost frontiers of banks.

■ TD-10

Tuesday, 14:30-16:00 - Building CW, ground floor, Room 1

AHP and Beyond 2

Stream: Analytic Hierarchy Process / Analytic Network Process
Chair: *Matteo Brunelli*

1 - A Decision Support Tool for Optimal Personnel-Branch Assignment
Nurdinç Şenay, Okan Arslan, Özkan Özcan

Graduating officers from the Turkish Air Force Academy are to be assigned branches (such as supply, intelligence and infantry etc.). This decision has an important impact on the officer's life and his/her motivation. So the assignment process has to be fair, take the individual's will into account and eventually serve the purposes of the Air Force. In this talk, our objective is to find the 'best' assignment of personnel to their branches. In this regard, we analyzed the somewhat vague definition of the 'best' by Analytical Hierarchy Process (AHP) and built a decision support tool using spreadsheets to generate three different assignment alternatives.

2 - Random spanning trees to elicit preferences from pairwise comparison judgements for multiple criteria decision aiding
Sajid Siraj, Salvatore Greco, Michele Lundy

The spanning trees approach is a recently emerging idea for use with the pairwise comparison method where the entire set of prioritization vectors that are compatible with the originally provided information, are generated and analysed. While this approach has a number of benefits over the most widely used methods such as eigenvector and geometric mean; the obvious limitation is that as the number of alternatives and/or criteria increases, the subsequent increase in the number of trees quickly makes the process intractable. With this in mind, we propose and investigate the random sampling procedure to address the issue. Taking an approach similar to Stochastic Multi-criteria Acceptability Analysis, we propose using a representative sample of the entire set of prioritization vectors, and to estimate the probability that any alternative is ranked in any given position. Moreover, for each pair of alternatives, we also estimate the probability that one is ranked better than the other. We demonstrate its usefulness through a practical case study.

3 - Sales forecasting based on the Heuristic Rating Estimation method
Konrad Kułakowski, Jacek Szybowski, Katarzyna Peter-Bombik

Having a reliable sales forecasting method is the Holy Grail of management decision making. Such a method would make possible minimization of operating costs and maximize revenues. The presented work includes the proposal of using the Heuristic Rating Estimation (HRE) method to sales forecasting. The HRE method unlike AHP uses both: pairwise comparisions provided by experts and the results of previous rankings. In the proposed approach the sales volumes for one group of goods is estimated based on the known sales volumes of the other but similar goods. The given estimation scheme is accompanied by a Montecarlo simulation showing how the proposed model may work in practice.

4 - Deriving Priorities From Inconsistent PCM using the Network Algorithms
Marcin Anholcer, Janos Fulop

In several multiobjective decision problems Pairwise Comparison Matrices (PCM) are applied to evaluate the decision variants. The problem that arises very often is the inconsistency of a given PCM. In such a situation it is important to approximate the PCM with a consistent one. This can be done by minimizing the distance between the matrices. In the talk we consider the problem of minimizing the maximum distance. After applying the logarithmic transformation we are able to formulate the obtained problem as a Shortest Path Problem and solve it more efficiently. We analyze and completely characterize the form of the set of optimal solutions. We also present an algorithm that results in a unique, Pareto-efficient solution.

■ TD-12

Tuesday, 14:30-16:00 - Building CW, ground floor, Room 029

Combinatorial Optimization for Routing and Scheduling

Stream: Combinatorial Optimization
Chair: *Richard Eglese*

1 - An integer linear programming model for flexible assignment of airport gates
Jiyin Liu, Shuo Liu, Wen-Hua Chen

We study the airport gate assignment problem and develop a new integer linear programming model. The model not only considers the basic assignment constraints that require a safety time gap between serving any two aircrafts by the same gate, but also avoids possible conflicts in the taxi-in, taxi-out or push-back operations of aircrafts assigned to neighbouring gates. The aircrafts can be classified into different types based on their sizes and so as the gates. Although it is ideal for an aircraft to be assigned to a gate most suitable for its type, we allow maximum flexibility in the gate assignment. An aircraft can be assigned to a gate exactly matching with the aircraft type or to a larger gate. A larger aircraft can also be served in the gate area combining two adjacent smaller gates. Such flexibility can potentially improve the utilisation of the gates and reduces the need for assigning aircrafts to remote apron stands. The objective of the assignment is to minimise the number of aircrafts assigned to remote stands, to minimise the number of aircrafts assigned to gates not exactly matched, or a combination of these. Computational test of the model on example problems will also be presented.

2 - Relaxation type algorithms for the continuous p-centre problem
Said Salhi, Becky Callaghan, Jack Brimberg, Gábor Nagy

This paper aims to solve large continuous p-centre problems exactly by investigating two well known relaxation algorithms namely the reverse relaxation and the binary relaxation. The reverse relaxation is re-examined and developed by adding four mathematically supported enhancements to improve efficiency and the overall computational time. The revised reverse relaxation algorithm yields a vast reduction in computational time and is used to solve larger data sets where n larger than 1000 nodes and p=10 to 100 optimally.

3 - Heuristic approach for a one-commodity pickup-and-delivery problem with split demands
Juan José Salazar González, Hipolito Hernandez Perez, Beatriz Santos Hernandez

This article proposes and analyzes several approaches to design min-cost routes for a capacitated vehicle moving a commodity between a set of customers, allowing two characteristics uncommon in the pickup-and-delivery literature. One characteristic is that a customer is allowed to be visited several times. The other characteristic is that customers may be used as intermediate locations to temporarily collect and deliver product. We describe a math-heuristic approach that iteratively applies a constructive phase and an improvement phase. The constructive phase represents each customer by a set of nodes (each one associated with a potential visit), decomposes each customer demand into partial demands associated to its nodes, and solves a one-commodity pickup-and-delivery traveling salesman problem within a variable neighbourhood search. The improvement phase is a branch-and-cut procedure to optimize some partial routes of a given initial solution. Exhaustive computational results on benchmark instances demostraste the good performance of the approaches when solving instances with up to 500 customers.

4 - Combinatorial Optimization Models for Green Vehicle Routing
Richard Eglese

The subject of this presentation concerns models used to plan routes for road freight vehicles where environmental effects are taken into account. Greenhouse Gas (GHG) emissions for conventionally powered vehicles will be considered. The types of models that are used to estimate GHG emissions are presented and compared in terms of the inputs needed and their complexity. Their use within vehicle routing models will be explored particularly considering the role of the speeds of the vehicles within the models. For illustration, a model is presented for routing a fleet of delivery vehicles that minimizes the fuel emissions in a road network where speeds depend on time. In this model, the path for each vehicle between customers must be determined, and also the speeds of the vehicles along each road in their paths are treated as decision variables. The vehicle routes are limited by the capacities of the vehicles and there are time constraints on the total length of each route. The objective is to minimize the total emissions in terms of the amount of GHG emissions produced, measured by the equivalent weight of CO2 (CO2e). A column generation based tabu search algorithm is adapted to solve the problem. The method is tested with real traffic data from a London road network. The results are analyzed to show the potential saving from the speed adjustment process.

■ TD-13

Tuesday, 14:30-16:00 - Building CW, ground floor, Room 3

VeRoLog: Stochastic VRPs 2

Stream: Vehicle Routing and Logistics Optimization
Chair: *Melis Alpaslan*

1 - A literature review on the vehicle routing problem for relief logistics in disasters
Kiatkulchai Jitt-Aer

Disasters can be both natural and man-made and are defined as any sudden event that seriously disrupts the functioning of a community or society causing human, property, and economic or environmental losses. Disasters, which include hurricanes, floods, earthquakes, and terrorist attacks, are collectively increasing in frequency across the world. Relief supplies such as food, shelter, and medicine must be sent from the relief distributor to the affected areas efficiently and impartially to support rescue operations and alleviate suffering people. This needs an efficient logistics approach to achieve those goals.

In the logistics domain, the vehicle routing problem (VRP) has been extensively studied in the optimisation literature. Nevertheless, disaster relief logistics using the vehicle routing approach has not attracted much attention and therefore literature on this topic is relatively rare. In addition, VRP is classified as an NP-hard problem; in particular, the increase in complexity results from the stochastic nature arising from disaster situations. In this paper, therefore, we have conducted a literature review on the recent developments and publications involving the VRP for relief logistics in disasters. This review considers papers published between 1995 and 2015, in which stochastic elements of VRP are studied such as demand, location of customer, and travel time.

2 - The Heterogeneous Fleet Split Delivery Stochastic Vehicle Routing Problem
Melis Alpaslan, Charkaz Aghayeva, Gamze Tuna

The vehicle routing problem is a one of the most studied combinatorial optimization problem in the literature. Deterministic models are widely used in today's world but stochastic models are more suitable and beneficial to describe and analyze real life problems such as vehicle routing problem. In this study, heterogeneous fleet split delivery stochastic vehicle routing problem is considered. Vehicle routing problem is a NP-hard problem. Because of this reason, to obtain the optimal solution, there may be a long solution time. Different solution techniques are studied to see the differences between deterministic and stochastic models in a shorter solution time and clustering methods are applied to this stochastic problem.

3 - Service scheduling to minimise the risk of missing appointments
Chenlu Ji

This research focuses on the stochastic vehicle routing problem, in which engineers drive to customer sites to provide services. We assume that service times and travel times are stochastic, and a time window is associated with the start time for service, for each customer. Most previous research uses a chance-constrained approach to the problem. Some consider the probability of route duration exceeding the threshold of the engineer's workload while others set restrictions on the probability of individual time window constraints being violated. Their objectives are related to traditional routing costs whilst we take a different approach. We define the risk of missing a task as the probability that an engineer's arrival time to a customer site is later than the time window. We seek to minimise the risks given a certain amount of resources. Each task has an uncertain duration following a known normal distribution. However the distribution of arrival time to a customer site will not be normally distributed because of the time window constraints. Therefore we have derived a multiple integral expression of risk, and this expression works even when the task distribution is not normal. Various searching methods could be used to solve the problem. This new approach allows firms to pay more attention to increasing customer satisfaction and become more competitive in the market.

4 - The Planning of Walking School Bus Routing and Scheduling
Jenn-Rong Lin, Wei-Ming Wu

The purpose of this study is to formulate and analyze a planning model for walking school bus (WSB) routing and scheduling under stochastic travel times and operations constraints. The key planning decisions considered are: the number of WSB routes, where (which bus stops) each route should begin at, the WSB routing between bus stops and school. The objective is to minimize the total cost which is the sum of fixed costs of dispatching WSB, variable traveling costs of children walking on the routes and variable waiting cost for picking up children at bus stops. The planning decisions are made with concern for both total system cost and service levels (measured by the desired failure possibilities for not picking up children on time, a route duration exceeding the maximum allowed duration, and a bus cannot arrive at school on time). Numerical examples are created to illustrate and to test the proposed model.

■ TD-14

Tuesday, 14:30-16:00 - Building CW, 1st floor, Room 125

Maritime transportation and logistics

Stream: Maritime Transportation
Chair: *Marielle Christiansen*

1 - Generalized vehicle routing formulation for mass rescue operations in ocean waters
Rui Deus, Luís Gouveia

Mass rescue operations (MRO) in maritime areas, particularly in ocean areas, are a major concern for the authorities responsible for conducting search and rescue (SAR) activities. A mass rescue operation can be defined as a search and rescue activity characterized by the need for immediate assistance to a large number of persons in distress, such that the capabilities normally available to search and rescue are inadequate. In this paper we deal with a mass rescue operation within ocean areas and we consider the problem of rescuing a set of survivors following a maritime incident (cruise ship, oil platform, ditched airplane) that are drifting in time. The recovery of survivors is performed by nearby ships and helicopters. We also consider the possibility of ships capable of refueling helicopters while hoovering which can extend the range to which survivors can be rescued. A linear binary integer formulation is presented along with an application that allows users to create instances of the problem. The formulation considers a discretization of time within a certain time step in order to assess the possibility of travelling along different locations. The problem considered in this work can be perceived as an extension of the generalized vehicle routing problem (GRVP) with a profit stance since we may not be able to recover all of the survivors. We also present different heuristics along with some optimal results using state of the art Mixed-integer linear programming solvers.

2 - Maritime traffic disruptions in liner ship fleet deployment models: an application to the Suez and Panama canals
Manuel Herrera Rodriguez, Per Agrell, Casiano Manrique-de-Lara-Peñate

In this paper the problem of the operational costs of a set of intermodal routes is studied. We initially apply a mixed-integer liner ship fleet deployment (LSFD) model in order to assign container liner shipping fleets to a network of routes connecting the Far East with the East and West coasts of North/South America, via Panama Canal, and with Europe either via Panama Canal or Suez Canal. Both canals are considered as potential restrictions to the network flow. These restrictions to the traffic are analyzed in a different mix of scenarios, including delays due to operational conflicts. Multimodality is involved through a set of railway routes in the United States and Europe, and the Trans-Asian rail network. In a first step, a mixed-integer LSFD model is applied to minimize an objective function comprising the operational costs, considering two different possibilities: same or different handling costs at every port. In a second step, time is introduced in order to generate a more realistic result. The problem now involves nonlinear terms. Introducing a new vector, the model is transformed to an equivalent mixed-integer linear programming model using the big-M modelling method. The application simulates delays in different specific sections of the network (ports in the US West Coast, Panama Canal, Suez Canal and ports in the Malacca strait), allowing the analysis of the resulting economic and operational impacts.

3 - Dealing with uncertainty in a maritime inventory routing problem
Filipe Rodrigues, Agostinho Agra, Marielle Christiansen, Lars Magnus Hvattum

We consider a single product maritime inventory routing problem in which the production and consumption rates are constant over the planning horizon. The problem involves a heterogeneous fleet and multiple production and consumption ports with limited storage capacity. Maritime transportation is characterized by high levels of uncertainty. The weather conditions are the principal uncertainty source since they have a great impact on sailing times. In this paper, uncertainty in sailing times is analyzed according to three different approaches: deterministic, robust and stochastic. In the deterministic approach, where sailing times are assumed known and fixed, safety stocks are considered to account for uncertainty. In the robust approach, the sailing times are assumed to belong to the well-known budget uncertainty polytope. In the stochastic approach, the sailing times are assumed to follow a log-logistic distribution. For each approach a mathematical formulation is proposed. The two last approaches assume two stages of decisions where the routing and the order the ports are visited, as well as the quantities to load/unload, are fixed before the uncertainty is revealed, while the visit time to ports can be adjusted to the scenario. To solve these two approaches, decomposition algorithms based on separation schemes are used. A computational comparison of the three approaches, in terms of the solution structure and costs, is presented.

4 - Considering uncertainty in the berth allocation problem
Xavier Schepler, Dominique Feillet, Nabil Absi, Eric Sanlaville

The operational berth allocation problem is about allocating berthing positions and mooring times to incoming ships. It is an important problem for container terminals, which has received significant attention in the literature. Although there is uncertainty on its data such as dates of ship arrivals, almost all of the studies have deterministic optimization approaches. We will consider a stochastic version of the discrete berth allocation problem, in which dates of ship arrivals are assumed to observe discrete probability distributions with finite supports. The objective is to minimize expected weighted turnaround times (waiting times + service times). As the expected value of a solution can be computed exactly and efficiently, a tabu search heuristic will be introduced for the stochastic optimization problem. Numerical experiments on instances obtained by adapting the ones of the literature's benchmark set will allow us to evaluate the benefits of the stochastic optimization approach.

■ TD-15

Tuesday, 14:30-16:00 - Building CW, 1st floor, Room 126

Simulation of Gas Networks

Stream: Optimization of Gas Networks
Chair: *Caren Tischendorf*

1 - Perturbation analysis of hyperbolic PDAEs
Christoph Huck

We consider hyperbolic partial differential-algebraic equations describing flow transport networks. First we discuss the modeling of water transport networks. We show that such a network can be described by a combination of hyperbolic partial differential equations for each pipe and linear constrained equations for junctions. We study the PDAE system as an operator DAE and derive perturbation estimations for perturbed PDAE systems including perturbations of the equations, of the initial values as well as of the boundary values.

2 - Structure preserving model order reduction for a semidiscretized gas transport network
Bjoern Liljegren-Sailer

We consider gas-pipe-networks and aim for an efficient simulation with the help of Model Order Reduction (MOR) tools. For each pipe the flow is modeled by a semilinear simplification of the Euler-equations with friction, boundary and coupling conditions lead to additional algebraic equations. As the equation system is of hyperbolic type, efficient MOR is a challenging task. The system of partial differential algebraic equations is first appropriately space-discretized and then examined with index- and decoupling-concepts for differential algebraic equations. For the arising input-output system we construct an explicit representation of the strictly proper and the remaining system only depending on the topology. Choosing the output at the ports, the remaining system, as well as the strictly proper systems are passive. We seek for surrogate models of the strictly proper system. In this talk the capability of structure preserving MOR will be shown for a linear simplification of the above described gas transport system.

3 - Analysing and solving gas network applications with compressor stations
Tanja Clees, Kläre Cassirer, Bernhard Klaassen, Igor Nikitin, Lialia Nikitina

Natural gas pipeline systems are an essential part of our energy supply. Systems can have several thousands of kilometers of pipes and several thousands of network elements such as pipes, valves, regulators, compressors etc.

For simulation, they can be modeled based on isothermal Euler equations. De facto, nonlinear ODE or DAE systems are usually solved in practice. Our MYNTS software computes several fields in space (steady-state mode) or space-time (time-dependent mode), namely for pressure, mass flow (volume flow, power), temperature, and 21 main components of natural gas.

In this talk, we address several issues when solving practical applications, including modeling aspects, graph analysis, hierarchical coarsening, acceleration and robust (Pareto) optimization. We outline solution methods and discuss some novel methods, realized in MYNTS, in more detail.

In particular, we present a new approach for efficiently solving nonlinear problems arising here by means of an NLP solver based on an interior-point method with an adapted line search algorithm. This method has originally been developed for piecewise linear systems arising in electrical engineering. Our tests show that it works for slightly non-linear piecewise smooth ones as well. Moreover, it can be shown that, under relevant conditions, adequate approximations of the systems considered possess a single solution which can be found with this new approach.

4 - Linear implicit theta methods for flow network DAEs
Caren Tischendorf, Tom Streubel

In this talk a new class of linear implicit methods derived from theta methods and their special case the trapezoidal rule for differential algebraic equations of the form A(x(t), t) * x'(t) = b(x(t), t) will be introduced. Such DAE systems arise e.g. from modelling gas or water flow networks. We show error estimations depending on the choice of theta and whether the linear coefficient matrix function A(x(t), t) is constant or not. Finally, the methods are discussed for some example networks.

■ TD-16

Tuesday, 14:30-16:00 - Building CW, 1st floor, Room 128

Healthcare scheduling and rostering

Stream: Healthcare Logistics
Chair: *Karl Doerner*
Chair: *Petra Vogl*

1 - Adaptive Large Neighborhood Search for the Nurse Rostering Problem
Alexander Kiefer, Richard Hartl

Nurse rostering involves the assignment of nurses to shifts, taking into account their skills, preferences and contract types. The second international nurse rostering competition enhanced academic interchange in this field by stating a problem formulation and providing benchmark instances. The particular problem consists of successively creating rosters for a sequence of periods that minimize violations of the soft constraints and satisfy a set of hard constraints. We developed a mixed integer programming model for this problem, which is then applied within an adaptive large neighborhood search (ALNS) framework to solve the instances of the competition. ALNS is based on repetitively destroying and re-building relatively large parts of the incumbent solution. The initial solution is generated by a simple heuristic that tries to satisfy the requested number of scheduled nurses for each shift first and performs other assignments in a greedy way. The destroy operators used within ALNS remove complete rosters of some nurses. The employed repair operators include the mentioned heuristic and an exact method based on the model, while the latter is solved via CPLEX. A simulated annealing acceptance scheme is used for deciding whether a generated solution is used as new incumbent. The algorithm is applied to the benchmark instances of the competition and performs about equally well as the approach of the fifth-ranked participant.

2 - First Approaches for a Patient Scheduling Problem in Radiotherapy
Johannes Maschler, Martin Riedler, Günther Raidl

We present a new Radiotherapy Patient Scheduling Problem (RPSP) that can be seen as a generalization of resource constrained project scheduling. This problem arises in the mid-term planning at modern cancer treatment facilities like MedAustron in Austria. The goal is to schedule patient therapies consisting of daily treatments (DTs) that have to be assigned sequentially to days. The DTs in turn consist of series of activities, which require specific resources and have to be scheduled at the respective days considering minimum and maximum time lags. Resources have regular and extended availability time windows on weekdays. The goal of the RPSP is to find a feasible schedule that minimizes required extended resource availability times, and the finishing days of therapies. We propose a construction heuristic with a forward looking mechanism, which first assigns all DTs to days and afterwards schedules the activities of each day. Different combinations of priority criteria are considered. Moreover, this construction heuristic is used as core within an Iterated Greedy metaheuristic and a GRASP. Experimental comparisons are performed on a set of artificial benchmark instances roughly modeling characteristics of real-world instances expected at MedAustron. The construction heuristic and both metaheuristics are further compared to a MIP model at the day assignment level.

3 - Optimisation and privacy concerns in e-health
Georg Weichhart, Alexander Hämmerle

We consider a future distributed e-health system where patients are enabled to register personal examinations. The envisioned system will optimise schedules across multiple hospital departments - from a hospital point of view. In e-health, data management with respect to privacy of patient data is of high priority. Only abstract data should be transmitted, and shared among system parts as little as possible. Centralised approaches violate this need. We describe a new distributed approach based on a linear program for flexible job shop scheduling with transportation times between departments. By relaxing department capacity constraints, a Lagrange problem is formulated. The overall problem is decomposed in independent one job scheduling problems. Each of these sub-problems is solved using dynamic programming and variable neighbourhood search. The global Lagrange problem is solved with an iterative auction protocol. We explain the underlying motivation of the mathematical foundation and analyse the algorithms in order to build a distributed architecture, which allows a distributed optimisation of department schedules.

■ TD-17

Tuesday, 14:30-16:00 - Building CW, ground floor, Room 0210

Retail Logistics Planning 1

Stream: Demand and Supply Management in Retail and Consumer Goods
Chair: *Rob Broekmeulen*

1 - Improving the efficiency of cross-docking operations in supply chain management: a case study
Maria Pereira, Rui Oliveira

Organizations involved in supply chain management face increasing pressures to reduce inventories and lead-times and to improve global efficiency. Cross-docking operations are being increasingly adopted as part of a strategy to concentrate inventories and to reduce the number of stock-keeping locations, a trend that requires flexible, well-coordinated and expeditions flows of goods along the logistic chain. This paper reports preliminary results of an on-going project to improve the efficiency of processes associated with cross-docking operations in a logistic center of a major logistic operator in Portugal. A simulation model of the operations that take place at this facility was developed with the purpose of testing and evaluating alternatives in managing cross-docking operations. These include truck-bay assignment, truck unloading and loading scheduling, floor space allocation, staff and equipment allocation and other related operations (such as order and load preparation/picking) scheduling. Conclusions are presented herein.

2 - Coordination of a retail supply chain distribution flow due to a stock market volatility
Tea Vizinger, Janez Žerovnik, Tomaz Kramberger

Retail supply chains are very sensitive by their nature and need to adapt to several situations with the aim to increase its reliability, flexibility and convenience. There are many factors affecting the effectiveness of a distribution flow, from perishability, capacities of storage areas, lead times, untimely deliveries and others. Hence the latter especially depends from the planned and realized distribution and not from the demand side perspective, we partially neglect them in this first phase of the testing procedure. We focus only on the demand satisfaction, without considering any pricing policies, perishability factors, etc. The idea is to obtain a preferable distribution plan with minimal distribution cost, as well as having minimal expected costs of over and under stock levels. While considering stochasticity on the demand side, the multi objective optimization approach is introduced to cope with the minimization of transport and warehouse costs, minimization of over stock levels and the maximization of customers' service level. The optimization problem that arises seems to be a NP-hard problem. Despite the approach is still in the testing phase we believe that it provides a good basis for modelling such a complex issue. The efficacy of the model is going to be explained using a numerical example.

3 - The heterogeneous vehicle routing problem with intermediate storage facilities: a case study from the construction industry
David Lai, Wout Dullaert, Sander de Leuw

Wholesalers of construction materials often need to transport large amounts of materials and heavy equipment from their depots to different construction sites and retail shops using a heterogeneous fleet of vehicles with limited sizes, different transportation capacities and vehicle configurations. Motivated by the case of a large construction wholesaler in the Netherlands, we consider a heterogeneous vehicle routing problem where there are intermediate storage facilities available for material transshipment and temporary storage. This research focuses on formulating the operational requirements, and analyzing the impact of storage facilities on vehicle utilization and routing strategies. The problem is formulated as a mixed integer programming model and solved efficiently using a metaheuristic. Computational results are presented on benchmark instances and real-life problem data.

■ TD-18

Tuesday, 14:30-16:00 - Building CW, ground floor, Room 023

Facility and Process Design

Stream: Production and Operations Management
Chair: *Hanife Taylan*

1 - Optimal Production Strategy in a Production Firm with Committed Lead Time
Taher Ahmadi, Zumbul Atan, Ton de Kok, Ivo Adan

In this paper, we study the impact of the committed lead time on the production strategy in a continuous review setting. We consider a production firm which faces a Poisson demand and uses a base-stock policy to replenish its inventories from an outside source with a fixed production lead time. The firm decides to use a preorder policy in which the customers should place their order before their actual need based on a predetermined time window which is called committed lead time. Consequently, the firm has to pay them a discount according to the length of the committed lead time. We characterize the optimal length of the committed lead time and its corresponding base-stock level such that a long-run average cost function consisting of holding cost, penalty cost and committed lead time cost is minimized. Based on the parameters of the problem, we find a threshold for discount unit price. When discount unit price is less than the threshold, then the optimal production strategy is a make-to-order strategy (the optimal committed lead time is equal to production lead time and the optimal base stock level is zero) and when discount unit price is more than the threshold, the optimal production strategy is a make-to-stock strategy (the optimal committed lead time is zero and optimal base stock level is non-zero). Moreover, we show that the threshold is increasing in the unit holding and shortage costs and decreasing in the cumulative demand during the production lead time.

2 - Modified Holt Winters Forecasting Method
Hanife Taylan, Güçkan Yapar

In this study, a new extrapolative forecasting framework will be introduced as an alternative to all major extrapolative techniques. This new framework will be called modified exponential smoothing since it is obtained by modifying the smoothing parameter of a traditional exponential smoothing model. The performance of the proposed method is compared empirically with the most popular forecasting algorithms based on the exponential smoothing and Box- Jenkins ARIMA using the M-Competition and the M3-Competition data sets.

3 - Incorporating Collaborative Freight Transport Operations in an Urban Context: First Insights from the Agricultural Products Sector in the Metropolitan Area of Milan
Theodora Trachana, Giuseppe Galli, Vasileios Zeimpekis, Enrico Pastori, Eleni Zampou

In response to the increasing demand of incorporating environmental and social practices into a firm's supply chain, enterprises are transforming their strategies to meet global trends in sustainability. As a consequence, the collaboration in freight transport operations in urban environment has gained ground not only for the academia, but also for the business sector. By conducting a case study in the Milan metropolitan area, this paper is focusing on proposing, discussing and evaluating collaborative logistics practices across the agricultural products' supply chain while, at the same time, addressing all the special characteristics that underline their importance. Within this context, three alternative logistics models were analysed and an attempt to assess their impact on economic, social and environmental KPIs has taken place. The importance of parameters, such as family businesses, constrained resources, own delivery means and unplanned production, which now remain unaddressed, has been underlined by the data collection process and a set of questionnaire-based short interviews with farmers aiming to clarify the problematic areas and the factors driving the success of collaborative logistics practices. Thus, the significance of incorporating collaborative practices, such as urban consolidation centers and transport pooling techniques has been highlighted. The results underline the great interest lying on the field and the countless business opportunities that arise.

■ TD-19

Tuesday, 14:30-16:00 - Building CW, ground floor, Room 021

Graph Searching 2

Stream: Graph Searching
Chair: *Dariusz Dereniowski*

1 - Distributed decision and verification by mobile agents
Evangelos Bampas, David Ilcinkas

We consider decision problems that are solved in a distributed fashion by synchronous mobile agents operating in an unknown, anonymous network. Each agent has a unique identifier and an input string and they have to decide collectively a property which may involve their input strings, the graph on which they are operating, and their particular starting positions. Building on recent work by Fraigniaud and Pelc [LATIN 2012, LNCS 7256, pp. 362-374], we introduce several new and natural computability classes allowing for a finer classification of problems below co-MAV or MAV, the latter being the class of decision problems that are verifiable when an appropriate certificate is distributed to the agents. We provide inclusion and separation results among all these classes. We also determine their closure properties with respect to set-theoretic operations. Our main technical tool, which is of independent interest, is a new meta-protocol that enables the execution of a possibly infinite number of mobile agent protocols essentially in parallel, similarly to the well-known dovetailing technique from classical computability theory.

2 - An Algorithm for Deploying Robotic Agents Inside a Non-convex Polygon
Mahdi Moeini, Daniel Schermer, Oliver Wendt

The Art Gallery Problem (AGP) is one of the well-known and classic problems in Computational Geometry. For a given art gallery, represented by a polygon, the AGP seeks for the minimum number of guards that are necessary for overseeing the entire polygon. Many variants of this problems have already been studied. In this paper, we are interested in examining and visualizing some of algorithms for the distributed version of the AGP, where guards are autonomous and have limited communication abilities. For this purpose, we present a self-contained simulator that is able to read or generate non convex polygons and to simulate the movements of robotic guards inside the polygonal environment. In order to move inside the polygon, the guards explore a rooted tree that is generated by partitioning the given polygon. Furthermore, we introduce a new algorithm and compare it with two existing methods: Random Search (RS) and Depth-First Search (DFS). We compare the algorithms, in terms of computation time, by testing them on benchmark instances and randomly generated polygons. According to our experiments, each algorithm has a better performance on specific types of polygons and our algorithm outperforms the other methods.

3 - Network community structure detection and the Berge-Zhukovskii equilibrium
Rodica Ioana Lung, Noémi Gaskó, Mihai Suciu

The Berge-Zhukovskii (BZ) equilibrium is an alternate solution concept in non-cooperative game theory that formalizes cooperation in a non-cooperative setting. In this paper, this concept is used in the context of the problem of identifying the community structure in social networks by converting it into a game in which nodes are players that have to choose their community. The BZ of this game, if it exists, is a network partition that ensures for every node a payoff that would not decrease under any changes made by any of the other nodes. To approximate BZ equilibria for this game we use an extremal optimization algorithm endowed with a generative relation that guides the search towards game equilibria. Numerical experiments performed on synthetic and real-world benchmarks, with comparisons with other state-of-art methods, indicate the potential of using this equilibrium concept to approach the community structure detection problem.

■ TD-20

Tuesday, 14:30-16:00 - Building CW, ground floor, Room 022

Cutting and Packing 1

Stream: Cutting and Packing
Chair: *Gerhard Wäscher*

1 - A novel MIP formulation and a BRKGA based approach and for a two-dimensional cutting problem with defects
José Fernando Gonçalves, Gerhard Wäscher

This paper addresses a two-dimensional (2D) non-guillotine cutting problem, where a fixed set of small rectangles has to be cut from a larger stock rectangle with defects so as to maximize the value of the rectangles cut. We introduce a novel MIP formulation and a hybrid approach combining a placement procedure with a biased random-key genetic algorithm (BRKGA). The approaches are tested on a set of benchmark instances taken from the literature and compared. The experimental results validate the quality of the solutions and the effectiveness of the proposed BRKGA algorithm. Supported by Project "NORTE-01-0145-FEDER-000020" financed by the North Portugal Regional Operational Programme (NORTE 2020), under the PORTUGAL 2020 Partnership Agreement, and through the European Regional Development Fund (ERDF).

2 - Two-Dimensional Bin Packing Problem with Partial Conflicts
Salma Mezghani, Boukthir Haddar, Habib Chabchoub

In our work,We deal with a new version of 2DBP with partial conflicts (PC). The 2DBPPC consists in finding a minimum number of bins used to pack all the items without overlapping and taking into account the safety distance between items partially conflicting, placed in the same bin. Our problem formulation involves packing a set of rectangular items,each item is characterized by (wi,hi), the bins are identical and a conflict graph G= (I,E), where (i, j) E if items i and j are partially in conflict. We have already presented a new mathematical model for 2DBPPC. Our model is tested using Cplex 12.5 on a set of benchmark instances taken from the literature and compared. We have proposed a new heuristic Iterative Linear Programming based Heuristic (ILPH) to solve 2DBPPC. The ILPH is an algorithm conceived to solve 0-1 integer programming. It solves a series of linear programming relaxation in order to improve lower and upper bounds on the optimal value. Also, new valid constraints are added to speed the resolution of reduced problems.Through the results of exhaustive experiments on a set of offline 2DBPP benchmark problem instances, we conclude that the proposed algorithms gave good result

3 - Raster Penetration Map Applied to Irregular Packing Problems
A. Miguel Gomes

One of the most complex problems in the area of 2-dimensional cutting & packing are irregular packing problems, in which the geometry of items is often more complex. These problems are prominent in several industries, including, but not limited to, the textile, shipbuilding and leather factories. They consist of placing a set of items, whose geometry are often represented by simple polygons, into one or more containers such that there is no overlap between items such that the utility rate of the container is maximized. In this work, the irregular strip packing problem, in which the container has a variable length, is investigated. A raster heuristic is employed to limit the placement possibilities through the adoption of a rectangular grid, and a full search is performed using the raster penetration map to determine the new position of an item. Moreover, some techniques are employed to speed up the calculations involved. Tests were performed using benchmark cases, whose results were competitive, and using simple dotted board model cases. In the latter cases, some optimum solutions were already determined in the literature and, in such instances, the proposed solution was always capable of producing an optimum layout.

■ TD-21

Tuesday, 14:30-16:00 - Building CW, ground floor, Room 025

Data analysis and efficiency

Stream: Public Transportation
Chair: *Pravesh Biyani*

1 - Delay data analysis for railway scheduling
Josephine Reuer, Natalia Kliewer

The planning and operation of railway systems is a complex task itself. On top of that, passengers request reliable services and thus robustness of schedules becomes one of the central objectives of railway operators. Solution methods e.g. for robust timetabling, rolling stock scheduling or real time delay management usually require the analysis of historical delay data. Up to now, those analyses have often been performed on corridors or smaller subnetworks only and findings were used mainly in online delay management. In this research, we develop approaches to handle big amounts of data for large railway networks and conduct an analysis of running and dwell times as well as arrival and departure delays. Therefore, we analyze operating data from two years for the German railway network. Primarily, we focus on passenger intercity rail traffic in order to find systematic deviations from the schedule that could be used again for instance on the tactical planning level for the timetable construction. Plan deviations are examined on different levels of aggregation: First, we will look at the network as a whole. Second, we will study train lines and finally single trains. Furthermore, delays at large stations or on busy blocks may be analyzed using different dimensions, such as time of the day or type of train.

2 - Measuring production efficiency and service effectiveness of multi-mode metro-transit: A network DEA model
Chao-Chung Kang

Unlike the production and service process of manufacture industry, metro transit services have un-storable and multi-mode characteristics, while measuring metro-transit performance in terms of efficiency and effectiveness. The internal structures among sub-units are usually ignored by traditional data envelopment analysis (DEA) model although several studies have been contributed on investigating performance of rail or metro-transits using various methods. The purpose of this study is to propose a network data envelopment analysis (NDEA) model using the directional distance function (DDF) concept with considerations of network and parallel processes of multi-mode transit. This model allows to measure production efficiency, service effectiveness, and overall operational performance of metro-transit simultaneously. The empirical case is conducted to investigate performance of the Taipei Metro Transit System (TMTS) which provides two types of public transport services, high-capacity and medium-capacity, for passengers in Taipei metropolis area. The internal linkage and shared-inputs between activities of these two modes are also considered in this model except multiple input-output variables. The advantages of this model can be used to measure the production efficiency and service effectiveness of high-capac

3 - Efficient Update of the Traffic Graph
Pravesh Biyani, Sakshi Taneja

A city road transport network can be modelled as a graph where the vertices represents junctions or intersections and the set of edges represents road segments joining consecutive nodes. The temporal change in traffic (or the speed) in the edges of the graph is generally sparse in nature, specially for the short time intervals (e.g 15 minutes). The total weight (or speed) for any path in the graph can be obtained by calling a map function call (for example Google APIs). Given the set of edge weights (that is the state of graph) at time t=0, the problem is to devise a sensing strategy for the temporal update of the state of the graph such that as few as possible samples (or API calls) are needed. We apply the idea of compressive sensing on the city traffic graph. We use the Delhi city graph for our experiments. Through the traffic data that we collected in Delhi, we observed that less than 15% of the total edges had a speed change of more than 2 Kms per hour in any 15 minute interval throughout the day. For this case, we achieve a complete update by sensing only 35% of the total edges. Finding an efficient update of the city graph has many applications in public transport companies and other on-demand economy companies which transport goods from one point in a city to another and require a real time traffic information of the city.

4 - Modelling traffic jams caused by slow vehicles on secondary roads
Tom Maertens, Willem Melange, Sabine Wittevrongel, Joris Walraevens

According to a report of Inrix, international market leader in real-time traffic information, the average Belgian car driver has lost 51 hours in traffic jam in 2014. With that number, Belgium is at the top of the ranking. Not only the highways are caught by traffic jams, also the situation on secondary roads is extremely harsh. Traffic jams on highways, however, decrease drastically outside the rush hour, while the secondary roads suffer all day long, with a peak at noon. Traffic jams have many underlying causes, but in general one can say that traffic jam appears when the capacity of the road (network) is too small in comparison with the momentarily traffic volume. In our research, we focus on a special kind of traffic jam, i.e., the (driving) traffic jam behind a slow vehicle such as a tractor or exceptional freight transport. We model this kind of traffic jam and calculate the average time that a normal vehicle needs to pass through a piece of road where they may encounter one or more slow vehicles. We consider a road where both normal and slow vehicles arrive according to Poisson processes. When a normal vehicle encounters a slow vehicle, it has to adapt its speed during a certain period of time. This period of time is calculated by means of an M/M/1 queueing model describing a system with passing the slow vehicle as service and the traffic jam as queue.

■ TD-22

Tuesday, 14:30-16:00 - Building CW, ground floor, Room 027

Scheduling Models and New Applications 2

Stream: Combinatorial Optimization
Chair: *Eugene Levner*
Chair: *Frank Werner*

1 - Multi-Objective Fuzzy Approach to the Newsvendor Problem
Servet Hasgul, Ahmet Sabri Ogutlu

The newsvendor problem or single period problem is one of the most well-known problems in the literature on inventory management. The previous studies attempts to find order quantity within stochastic demand in a single period so as to maximize the expected profit or minimize the expected costs. However, decision makers may be more concerned with a probability level to achieve a specific target profit as another performance measure beside the expected profit. These two performance measures are conflicted to each other, and generally cannot be optimized simultaneously. In this study, a fuzzy multi-objective programming model is developed to find a good compromise solution to the newsvendor problem. An illustrative numerical example is presented to demonstrate the use of the proposed model under exponential demand. Moreover, a simulation study is performed to show the efficiency of the proposed approach.

2 - Agent-based Integrated Production Scheduling and Employee Timetabling in Robotic Assembly Lines
David Alcaide Lopez de Pablo, Eugene Levner, Vladimir Kats

The participation of assembly robots has improved the production capabilities in the manufacturing world. They make the assembly process faster, more efficient and precise than ever before. Robots save workers from tedious and dull conveyor work, and increase production and savings in the process. In robotic assembly systems, decisions related to job/robot scheduling are made to maximise the system productivity, whereas the decisions related to employee timetabling are made in order to maximise worker satisfaction and/or minimise labour costs. Such an integrated scheduling problem is an NP-hard combinatorial problem. In this paper we suggest an agent-based approach. We consider the production scheduling and the employee timetabling decisions, arising in practice of automatic assembly lines, simultaneously, and not sequentially as has been done in earlier studies. Each robot and each employee (operator) is considered and scheduled as a mobile agent. The precedence relations between operations, for every job, are given by a general directed acyclic graph. The objective is to coordinate the actions done by robotic and operator agents in prescribed time intervals so as to maximise the line performance, or, equivalently, to minimise the cycle time, under the condition that the labour costs are limited by given bounds. The problem generalizes several scheduling and timetabling problems with time-windows known in the literature.

3 - Mixed programming problems of optimally allocating and scheduling the openings of transport hubs and access roads to them in a geographic region
Gennady Fedin, Alexander Belenky, Alain Kornhauser

A problem of optimally allocating a set of new transport hubs in a geographic region in which a transportation network already functions and roads to new hubs are to be built in a certain period of time is formulated as a minimax problem in a finite-dimensional space. In this minimax problem, the goal function of vector arguments is minimized on a polyhedron, whereas the maximum function is that of two vector arguments each of which belongs to a subset of a polyhedron formed by its points with all integer components. The costs of a) building the hubs, b) building access roads to each new hub, c) transporting cargoes to and from each of the potential places for allocating the hubs, and d) maintaining the existing transportation infrastructure in the region are parameters determining the coefficients in the linear equations and inequalities, describing the systems of constraints and the goal function in this minimax problem. It is proved that solving this minimax problem (to determine both an optimal allocation and optimal capacities of the new transport hubs with access roads to them) is reducible to solving a mixed programming problem in which all the integer variables are Boolean. A problem of optimally scheduling a set of works associated with opening new and reconstructing already functioning transport hubs and access roads to them in the geographic region is also formulated as a mixed programming problem coupled with the above minimax problem.

■ TD-23

Tuesday, 14:30-16:00 - Building CW, ground floor, Room 028

Electric Car Sharing

Stream: Green Logistics
Chair: *Mario Ruthmair*

1 - An Event-based Simulation for Optimizing One-way Carsharing Systems
Martin Repoux, Burak Boyaci, Nikolas Geroliminis

In this paper we address issues related to non-floating one-way electric car-sharing systems. Such a mobility option aims at proposing a complementary and sustainable mode of transportation to city dwellers. In the type of system we investigate, electric shared vehicles can be picked-up and dropped-off only at specific locations. Starting and final stations can be different, giving the customer more flexibility than in systems with the same location for drop-off and pick-up. On top of other constraints, this operating choice creates imbalances in vehicle distribution that can be corrected and controlled through various rental and relocation strategies. Demand stochasticity over time also requires operation policies that provide an efficient dynamic management of the system. Relocation optimization algorithms are developed and various rental settings are investigated to make the system more sustainable from the operator's point of view and improve customer satisfaction. In order to evaluate their impact and efficiency, we embed them as different modules in an event-based simulator we code and use demand and system data from a real car-sharing system implemented in Nice, France.

2 - Optimizing One-way Electric Carsharing Operations Using Real-time Information

Burak Boyaci, Konstantinos G. Zografos

One-way systems provide flexibility for their users. However, operators prefer to implement round-trip systems since they are easy and less costly to implement. In one-way carsharing systems, users are usually allowed to reserve an available vehicle shortly (not more than 30 minutes) before the desirable pick-up time. Providing the flexibility of early reservations in one-way systems can increase the demand by attracting more customers and can lead to a better utilization of the available resources.

In this work, we combine different types of demand (with different levels of information) for a one-way non-floating electric carsharing system, and develop an optimization-simulation framework for optimizing its operation. We assume that the users can provide in advance information regarding pick-up and drop-off locations and times and they will update this information as necessary before they return the car. We incorporate the available information into a model aiming to optimize operational decisions regarding vehicle and personnel relocation. We compare the performance of the system with different levels of available information using the data of the carsharing system in Nice, France.

3 - Location and Routing Decisions in an Ad-hoc Electric Car Sharing System

Hatice Calik, Bernard Fortz

We focus on a one way electric car sharing system where we have a set of customers, each of which requests to travel from an origin point to a destination point at a certain time slot of the day by using the electric cars available in certain stations of a company. The customers are allowed to leave a car in a station different to the one where they have picked it up. However, due to the battery restriction of the cars, a direct routing between the starting and the ending station of some trips might be infeasible. In this case, routing the customer via some intermediary stations provides an effective solution to the problem. We consider this system under both deterministic and stochastic demand scenarios. If the customers are required to book in advance, the system is called pre-booked. If the demand is not known in advance, then it is called an ad-hoc system. The objective of the problem is to decide on the location of the stations, the proportion of the customer trips to be served and their routes (that is, the order of the stations to be visited by customers) in the most profitable way. The profit function considers the revenue obtained by serving the selected customers and fixed location or operating cost of the opened stations. We develop flow based and path based mathematical formulations for solving both pre-booked and ad-hoc variations of the problem and conduct computational experiments to evaluate the performance of our models.

■ TD-24

Tuesday, 14:30-16:00 - Building BM, 1st floor, Room 119

Production and Logistics Applications of Optimization Techniques

Stream: Project Management and Scheduling

Chair: *Mikhail Y. Kovalyov*
Chair: *Boris V. Sokolov*

1 - Single Machine Minmax Cost Problem under Precedence Constraints and Uncertainty

Yakov Shafransky, Nadia Brauner, Gerd Finke

We consider the classical problem of sequencing jobs on a single machine under precedence constraints to minimize the maximum cost under the additional condition that some job parameters are uncertain. The aim is to find the minmax regret solution for the problem. We introduce the notion of t-regularity for the set of cost functions and show that the infinite set of feasible scenarios can be reduced to n special scenarios if the cost functions are t-regular. Our algorithm for this case requires a cubic time to construct the minmax regret solution. We also introduce the notion of t-uniformity of the set of cost functions. If this set is both t-regular and t-uniform, then the time complexity of our algorithm is quadratic. Using these results we were able to reduce the complexity of some problems from the literature and solve some new problems with multiple uncertain parameters.

2 - A Special Case of the Asymmetric Travelling Salesman Problem Arising in the Process of Consolidation of Containers in the Rail-Rail and Port Terminals

Erwin Pesch, Maksim Barketau

We consider the following problem arising in the process of consolidation of containers in the rail-rail and port terminals. The set of n ordered pairs of points called vectors is given in metric space. First point of the pair is the start point of vector, second point of the pair is the end point of vector. The problem is to traverse all vectors in some order (all vectors are traversed from their start point to their end point and from their end point to the start point of the next vector) so that to minimize the traversal distance between vectors. The problem is a special case of the asymmetric travelling salesman problem. We propose a 3-approximation polynomial algorithm for the problem and show that this bound is tight. We further prove that there is no polynomial time approximation algorithm with the approximation guarantee less than 1+0.23/n unless P=NP.

3 - Vessel Body Assembly Planning as a Three-Stage Flow-Shop Scheduling Problem

Mikhail Y. Kovalyov, Alexander G. Grivachevsky, Vadim D. Grivachevsky, Boris V. Sokolov, Anatoly I. Sukhomlinov

The vessel body assembly consists of manufacturing and welding metal components. Each component passes three production stages in the same order: 1) cutting a billet from a metal sheet, 2) fabricating component from the billet, and 3) welding component with the framework and other components of the vessel body. Operations on different components do not intersect in time in each stage, and the three operations on the same component do not intersect in time. The order of welding operations is restricted by precedence constraints. The operation processing times are all known. The problem is to find a feasible schedule such that the makespan is minimized. This problem is a variation of the classic strongly NP-hard three-machine flowshop scheduling problem (Johnson 1954), in which operations in the third stage must satisfy precedence constraints (Gladky, Shafransky and Strusevich 2004). There exists an optimal schedule for the classic problem, called permutation schedule, in which components sequence is the same in each stage. It is not the case if precedence constraints are given in the third stage. However, in the real-life problem, it is required that the components sequence is the same in each stage. Thus, the real-life problem can be modeled by the three-stage permutation flow-shop scheduling problem, which is to find a permutation schedule such that the precedence constraints are satisfied and the makespan is minimized. We suggest a Genetic Algorithm to solve this problem.

■ TD-25

Tuesday, 14:30-16:00 - Building BM, ground floor, Room 19

Behavioural issues in multicriteria decision making

Stream: Behavioural Operational Research
Chair: *Jyrki Wallenius*
Chair: *Pekka Korhonen*

1 - Voting Advice Model
Jyrki Wallenius, Tommi Pajala, Pekka Korhonen, Pekka Malo, Ankur Sinha, Akram Dehnokhalaji

Various Voting Advice Applications (VAAs), that is online questionnaires to match voters with parties or candidates in different political elections, play a major role in many countries. Helsingin Sanomat, the largest newspaper in Finland, manages one of the most influential of such VAAs (in Finland). It has about one million users before major elections, representing roughly half of the people who vote. We worked closely with Helsingin Sanomat to develop the theory for a better VAA matching algorithm and to have it implemented by them in the metropolitan area election district for the April 2015 Parliamentary Elections, representing a unique mass application of our algorithm. We improved the old matching algorithm by including measures of prominence and political power. A large group of voters liked the suggestions provided by our algorithm.

2 - Judgments of importance revisited: What do they mean?
Tommi Pajala, Pekka Korhonen, Jyrki Wallenius

When faced with a multiple criteria decision making problem, decision makers seem to have no difficulty in making judgments on one criterion being more important than another. Even though linear models have been heavily used in choice prediction for decades, it has remained unclear is whether their weights are somehow connected to the judgments of importance that subjects can so easily make. A surprisingly common assumption is that a more important criterion will tend to have a larger weight, as if weights and importance were the same thing, or at least heavily correlated. In this paper we present experimental evidence that Goldstein's idea of connecting judgments of importance to impact is more meaningful than connecting them to weights. In the experiment subjects provided their judgments of importance, and made pairwise choices with apartments defined by four criteria. Additionally, we show that if value function weights were to be connected to judgments of importance, we would need to know the scale the decision maker has in her mind. In the absence of knowledge about the scale that subjects use internally, interpreting their judgments of importance in terms of weights may not be possible.

3 - Some thoughts of choosing criteria for decision problems
Abolfazl Keshvari, Pekka Korhonen, Jyrki Wallenius

We discuss various important aspects that should be taken into account in choosing criteria for a decision making problem. Such aspects are the dependence of criteria, the reduction of the number of criteria, the impact of wrong choices, and the importance versus weights of the criteria in a linear value function. Moreover, we discuss the connection between abstract criteria and concrete indicators.

4 - Logit, CES, and Rational Inattention
Andrei Matveenko

We reconsider the connection between the CES utility function and multinomial logit model. Such link was first explored by Anderson et al. (1987, 1988). Their analysis is based on the stochastic utility approach and they connect parameters of a random shock to consumer's gain with elasticity of substitution in the CES utility function. We base our anal- ysis on the model of rational inattention by Matejka and McKay (2015) and obtain a new interpretation for the elasticity of substitution and the coefficients of the CES utility function. Namely, assuming that consumers do not observe prices perfectly, we provide the correspondence between parameters of the CES function and the cost of information.

■ TD-26

Tuesday, 14:30-16:00 - Building BM, 1st floor, Room 109D

Advances in Credit Risk Modelling 2

Stream: Business Analytics and Intelligent Optimization
Chair: *Jonathan Crook*

1 - Prepayment and Default of Consumer Loans in Online Lending
Zhiyong Li

Internet finance provides a means of fast financing for borrowers based on their creditworthiness. Borrowers in needs of money can easily get access to credit via online lending such as Peer-to-Peer lending, however due to information asymmetry borrowers may undermine the agreement due to early repayment or default, which are two major concerns for the platform and lenders, since both affect the profitability of a loan. While default risk is frequently focused on in credit scoring literature, prepayment has received much less attention, despite a higher prepayment rate being observed in online lending when compared with default. This paper uses multivariate logistic regression to predict the probability of both the underlying prepayment and default risk. Real consumer lending data of 160,956 unsecured loans provides evidence that these two events have their own distinct patterns. The model, incorporating macroeconomic factors, also addresses the influence of economic conditions which cannot be ignored since the last financial crisis. The out-of-sample prediction results have shown that both prepayment and default can be accurately predicted. This paper provides insights for both the P2P platform and the investors who may need to pay attention to the risks of both default and prepayment in online lending.

2 - Modelling the P2P lender's investment decision
Christophe Mues, Lyn Thomas, Mee Chi So, Zhiyong Li

Since its advent in the UK and the US, peer-to-peer (P2P) lending has become a growing area of consumer and SME finance. On a P2P website, an electronic market is created which allows multiple lenders to fund a borrower's request for a loan. Several market mechanisms have been developed to implement P2P lending. We focus on a P2P market that has individual listings, is closed at funding and where the interest rate is set by the platform. We consider two simplified versions of the investment problem faced by a P2P lender. In the first, the only decision for the lender is how much to invest initially in the lending opportunity, given its characteristics, and this is done before and without the knowledge of what the other lenders will offer to invest. In a more complicated model, the lender makes two decisions. The first is how much, if anything, the initial investment should be. The second decision is made in the event that the other lenders have not offered a sufficient amount of money to match the required loan amount. In that case, the question for the lender is whether to increase their investment so that the loan is fully funded. In either of these cases, if the loan is not fully funded, all the arrangements are cancelled. For both cases, we use a Markov decision process to model the lender's decision. We will present computational results based on data obtained from a P2P platform provider.

3 - Analysis of the impact of behavioural and sector-specific variables in credit risk measurement for the agribusiness
Cristian Bravo, Raffaella Calabrese, Daniela Lazo

Entrepreneurs of the agricultural sector encompass a significant sector of many economies, and are critical to all countries that wish to be independent in terms of food production. The agribusiness is unique in its exposure to seasonality and weather risk, besides the well-known market risks, which in turns affects default rates. In addition, agriculture has long production cycles, which reflects in loans with seasonal terms. In this work we study the repayment behaviour in the agribusiness controlling by risk predictors, the size of the company, and different models. Although there are works regarding credit scoring in the agribusiness, there has not been any detailed study regarding which variables are available for the sector, and a formal comparison over the relative impact of the available subsets of variables that can be used design scorecards. The data used in this work comes from a company that provides credit to farmers for the supply of inputs, besides providing support services. The data consist of five years of daily operations, over 75,000 loans, and three different variable subsets: Agribusiness-related variables, behavioural variables, and socio-demographic variables. Our results show that, even though behavioural variables have the highest predictive power, the impact of a detailed evaluation of the agribusiness increases notably the predictive capability of the lender, but whether to use these variables is highly dependent on the extra cost they bring.

■ TD-27

Tuesday, 14:30-16:00 - Building BM, ground floor, Room 20

Challenges in Industry

Stream: Case Studies in OR
Chair: *Olli Bräysy*
Chair: *Tiziano Parriani*

1 - Flexible and cost-efficient vacation scheduling with a constraint programming model
Teemu Kinnunen, Antti Punkka

In many industries vacation scheduling is a fairly simple task as temporary workers are available, workload is approximately constant in time and new employees can be recruited to replace retired workers. However, some industries have characteristics that make vacation scheduling more difficult, for example due to unavailability of temporary personnel, long trainings that precede recruitments, fluctuating demand between and within seasons, and varying maximum (non-overtime) working hours between planning periods.

We discuss how operations research can be used to support cost-efficient scheduling of employees' vacations for one calendar year. This process is further complicated by several conditions set by collective bargaining and law, the need for unbiased and fair treatment of employees in various aspects, and the goal of acknowledging employees' wishes on their vacation schedule.

We develop a constraint programming model to solve the vacation scheduling problem and discuss how the model has been applied to schedule vacations of some 1000 employees in 25 depots in Finland. We also discuss the benefits and difficulties related to adopting the new model.

2 - Tactical wood sourcing at a large forestry company: optimization approach and project description
Eero Lehtonen, Anssi Käki, Kimmo Mikkonen

We present a planning project at a large forestry company that consumes some 10-20 million m3 of roundwood annually. Specifically, we focus on a tactical sourcing problem where monthly plans to procure wood are created with a rolling 12-month horizon. Majority of the wood is procured from a geographically limited area that is divided to some hundreds of sources and further supplied to around a hundred sinks. The underlying LP-optimization problem is a multi-commodity flow problem with various complexities, such as multiple transportation modes, varying harvesting yield with calendar dependency, inventories, byproduct streams and end product substitution. In addition to harvesting and transportation decisions, the model also handles B2B-trades, imports/exports, and purchases of new forest reserves. We present an overview of the optimization solution, and discuss our agile approach to its implementation and key takeaways.

3 - Waste Flow Optimization with an Application in the Italian Context
Tiziano Parriani, Claudio Gambella, Angelo Gordini, Adriano Guarnieri, Matteo Pozzi, Fabio Lombardi, Lorenzo Ravaglia, Fabrizio Salieri, Daniele Vigo

Waste management is a priority for urban and rural communities throughout the world. The amount of waste generated each year in industrialized and developing countries, along with the public concern for environmental preservation, is making such a problem one of the most relevant issues in modern societies. An important source of complexity in waste management is given by the typical need to treat waste flows in various kinds of processing facilities before reaching a disposal plant or an external market (e.g., for recyclables). Operations research helps the waste manager to decide how to ship the waste inside the network to minimize logistic costs and maximize possible revenue coming from energy produced or recyclables sold. We propose mixed integer linear formulations, and relative resolution methods, for problems arising in the context of waste logistic management, with an application on a real world case study. In response to the actual needs of an important Italian waste operator, we introduce modeling of some relevant features of these problems, such as digester facilities, transportation economies of scale and temporary storages of the waste. The model has been incorporated into a Decision Support System that helped the waste operator in obtaining remarkable cost savings in the network management.

■ TD-29

Tuesday, 14:30-16:00 - Building BM, ground floor, Room 7

Soft OR and Problem Structuring Methods 2

Stream: Soft OR and Problem Structuring Methods
Chair: *Doris Behrens*
Chair: *Jennifer Morgan*

1 - Building a Systems Dynamics Model of Unscheduled Care
Doris Behrens, Jennifer Morgan, John Frankish

The aim of this research is to develop a robust hospital and social care policy evaluation tool for health care managers in Wales to explore system impact. The tool is focused on understanding individual choices as characteristic for decisions in unscheduled care and results from comparing and merging three models (A, B and C) developed from three different sources: the received literature, expert judgment of medical professionals, health board managers, planers, etc. and patients using soft OR tools to elicit views and structure the problem. It is motivated by concerns, when considering the relationship between hospital and social care, the current view of the system boundary is too narrow and that there is a need to broaden this to capture the dynamic responsiveness of the system. A structured literature analysis identified the core system entities and the existence of relationships between them to create the first model (model A). Interactive-model-building workshops with experts created the second model (model B). Patient narratives will be used to build a model that integrates the patients' perspective (model C). Comparing and merging these three models will highlight commonality and contradiction and the presentation describes work to date.

2 - Systems' Vulnerability Mapping: A Method for Structuring Knowledge in Tail Dependence Elicitation
Christoph Werner

In decision and risk analysis problems, probabilistic modelling of uncertainties provides essential information for decision-makers. As uncertainties are typically not isolated, methods that model dependence quantitatively are being developed. Whenever relevant data for parameterisation is lacking and simplifying assumptions, such as independence, are not sensible, the dependence information should be elicited from experts. A structured approach to expert judgement is desirable as it is methodologically robust and addresses potential pitfalls, such as the prevalence of biases. In contrast to univariate uncertainties, guidance for eliciting dependence is sparse. In particular, little research is available on how to capture knowledge and structure experts' beliefs about dependence relationships prior to a quantitative elicitation. This is however essential given experts' low level of intuitiveness about joint distributions. Some attempts are knowledge maps and directed acyclic graphs of Bayesian (Belief) networks. Nevertheless, existing techniques are not addressing appropriately recent quantitative modelling topics of which tail dependence is of particular interest as it assesses the systemic impact of extreme events. Therefore, a scenario mapping technique that structures experts' beliefs about tail dependence is introduced. It has been developed from findings of Problem Structuring Methods (or "soft OR" methods), systems' thinking and qualitative risk analysis.

3 - Application of the Multimethodological Model "Planejamento Estratégico Situacional -Soft" in a City Hall in Brazil

Paloma Santos, Mischel Carmen N. Belderrain, Alberto Paucar-Caceres

The method "Planejamento Estratégico Situacional" (PES) proposed by Carlos Matus was conceived specifically to help public managers in their planning activities. The PES consists of four "moments": Explanatory, Normative, Strategic and Tactical-operational. Its practical implementation was strongly focused on the underlying concepts rather than using the four moments. Based on this premise, a multimethodological model considering PES, Soft Systems Methodology (SSM) and the Strategic Choice Approach (SCA) was developed. The present proposal aims to reduce the complexity of PES in order to ease the implementation of the four moments. The proposed model "Planejamento Estratégico Situacional-Soft (PES-Soft)" was applied in a city hall in Brazil. During the year 2015 two meetings were held with the stakeholders. The first meeting included the development of the first three moments (Explanatory, Normative and Strategic). The monitoring of the project planning, which corresponds to the tactical-operational moment, was dealt with in the second meeting. This paper aims to present the implementation of the strategic planning model PES-Soft, report the difficulties and present a critical analysis of the experience. The results obtained in this present exercise have shown that the application of the model is feasible.

■ TD-30

Tuesday, 14:30-16:00 - Building BM, 1st floor, Room 110

Healthcare Services Research and Policy 2

Stream: Operational Research for Health and Social Care
Chair: *Hassan Baalbaki*

1 - Human Mortality and Fertility Modeling with a Fuzzy Approach Based on Singular Value Decomposition Technique

Duygun Fatih Demirel, Melek Basak

Modeling and forecasting human mortality and fertility are significant research topics in several disciplines because these demographic rates are fundamental in financial planning and social policy decisions. Among various techniques, Lee Carter (LC) model is one of the most popular stochastic method in human mortality and fertility modeling. The original LC method for mortality modeling was fuzzified to eliminate the assumptions related with homoscedasticity and the ambiguity on the size of the error term variances by Koissi and Shapiro. The fuzzified LC model utilizes ordinary least squares (OLS) technique, which prevents the model to capture the possible fluctuations in data. In this study, a modified version of fuzzy LC model utilizing singular value decomposition (SVD) technique for modeling human mortality and fertility is proposed to overcome the above mentioned issue. The proposed method is composed of two phases: Phase I - the fuzzification of observed crisp demographic rates, and Phase II - estimation phase. Phase I makes use of fuzzy regression technique based on minimum fuzziness criterion and linear programming, while Phase II includes solving an unconstrained nonlinear optimization model. The proposed method is applied to mortality and fertility data of Finland for illustration purposes. Numerical outputs show that proposed method gives statistically better fits for both demographic rates compared to the existing method.

2 - Management of Patient response time in an Ophthalmology clinic

Narasimhan Ravichandran, Harshal Lowalekar

We propose and study a model to manage the response time of patients who visit an ophthalmology clinic in a metro city in India. The service consists of multiple stages beginning from preliminary examination to final recommendation and prescription. In every stage there are multiple resources (critical/non-critical). The patient arrival is stochastic. By using simulation and a queuing network model, we recommend strategic option to manage the patient response time.

3 - Randomization and Optimization Procedures for Clinical Trials

Hassan Baalbaki

Clinical trials are essential to assess the effectiveness of new drugs and treatments. Last year alone, more than 23 thousand registered trials were conducted around the globe. In order to eliminate any potential bias, in the selection process and the patients' assignment into different treatment groups, randomization procedures and blinding techniques are commonly used to prevent such cases and to ensure the quality of the final outcomes. However, every individual is different, having unique set of baseline characteristics that could impact the final outcome of the study. In small and medium sized trials, we could clearly distinguish some imbalances between the covariates of different treatment groups, and thus impacting the precision of the final outcome of the trial. In our work, we consider a randomization procedure of the patients' based on a selection by batch then, the assignment problem is modeled as mixed integer linear programming problem, and solved using open source tools and libraries.

■ TD-31

Tuesday, 14:30-16:00 - Building BM, 1st floor, Room 111

Fleet and Asset Management in the Humanitarian Sector

Stream: Humanitarian Operations
Chair: *Luk Van Wassenhove*
Chair: *Nathan Kunz*

1 - Vehicle leasing in the humanitarian sector: The impact of planning and execution on satisfaction

Luk Van Wassenhove, Nathan Kunz

International humanitarian organizations rely on heavy-duty 4x4 vehicles to reach beneficiaries in remote areas with poor road infrastructures. Recognizing the importance of proper fleet management, several organizations have introduced internal leasing programs (ILPs). ILPs procure vehicles centrally and lease them to field offices for a monthly fee. This model has significantly reduced vehicle procurement costs and improved cash flows management in different organizations. Despite these benefits, field offices still resist the implementation of ILPs. We conduct a multiple case study of eight field offices of the UN World Food Program to identify the challenges and benefits of ILPs from the perspective of field offices, and we find significant differences in satisfaction levels. We find that field offices with limited fleet management capabilities and difficulties in planning their vehicle needs are dissatisfied with ILPs. We recommend ILPs to tailor their services to the differing needs of field offices, which will increase their satisfaction.

Increased satisfaction will improve the acceptance of the ILP model, and more international humanitarian organizations will benefit from its numerous advantages. Our paper provides researchers with a better understanding of the ILP model, and they can build upon the constructs we have developed when analyzing fleet management in the humanitarian sector.

2 - Fleet management for humanitarian development programs under budget uncertainty

Milad Keshvari Fard, Felix Papier, Mahyar Eftekhar

Motivated by the fleet management of an international humanitarian organization, we develop a stochastic dynamic program to model the managerial dynamics of a fleet of vehicles used for serving humanitarian missions with differences in their criticality. We develop an efficient heuristic policy that considers the interaction of purchasing and operating decisions in a context of uncertain financial budget. We use data from real humanitarian missions to test the efficiency of our heuristic and we find that it leads to near-minimal social costs for the people that receive humanitarian aid, thereby outperforming existing policies from research on humanitarian and commercial fleet management. Furthermore, we derive several managerial insights for fleet managers in humanitarian organizations, such as the importance of keeping a safety budget to ensure serving critical missions in future periods, or the non-optimality of serving as many humanitarian missions as the budget would allow.

3 - Fleet size prediction in humanitarian operations

Othman Boufaied, Luk Van Wassenhove, Nathan Kunz

Vehicles used in humanitarian operations are important assets that generate significant costs. Relief organizations often struggle to determine the right number of vehicles for each country of operation. We develop a multiple regression model based on empirical data from the Office of the UN High Commissioner for Refugees (UNHCR). We use a stepwise regression method to identify which contextual and organizational variables provide a good estimate of the recommended fleet size for each operation. We find that three variables explain 90% of the variance of fleet size in a given country: staff size, number of partners working with UNHCR, and that country's state fragility index. We validate the model both statistically and through extensive discussions with practitioners. Our model is currently used by the UNHCR and has already provided the organization with valuable indications about the right-sizing of vehicle fleet in many countries. The model is used to monitor fleet size at a global level and to quickly identify oversized or undersized fleets in the countries of operation. It can also be used as a planning tool to determine the number of vehicles each country of operation should procure for the year ahead. Finally it can serve as a basis for discussion between parties involved in vehicle procurement, i.e., headquarters and country offices. The model can be generalized for organizations comparable to the UNHCR. It can also be adapted to other types of organizations.

4 - A bi-objective robust optimisation model for relief distribution under social concerns

Douglas Alem, Alistair Clark, Alfredo Moreno

In this study, we consider a dynamic relief distribution problem under demand uncertainty. Distribution among nodes is optimally defined by the flow of emergency aid along the available routes and by determining a suitable fleet size, i.e., types and quantities of each vehicle necessary to carry relief commodities. Uncertainty is modelled using polyhedral uncertainty sets, thus yielding a tractable robust counterpart from the worst-case perspective in the robust optimisation sense. Social concerns are included to avoid shortages of emergency aid in more vulnerable areas when overall resources are not sufficient to meet the victims' needs in all affected areas. A bi-objective modelling paradigm is used to balance social concerns and logistics costs simultaneously. Preliminary results illustrate the importance of accounting for social concerns in order to achieve better fairness in distribution relief.

■ TD-33

Tuesday, 14:30-16:00 - Building BM, 1st floor, Room 113

Theoretical Scheduling

Stream: Scheduling, Sequencing, and Applications
Chair: *Frits Spieksma*

1 - Online and semi-online scheduling of two job types on a set of multipurpose machines

Dvir Shabtay, Shlomo Karhi Karhi

We study the online scheduling problem of minimizing the makespan on a set of m multipurpose machines, where there are two different job types and each job type can only be processed on a unique subset of machines. The literature shows that the TLS algorithm is optimal for the special cases where either m = 2. We show that the TLS algorithm is optimal also for the special cases where the job processing times are either job type or machine set dependent. For both cases, the optimality of the TLS algorithm is proven by showing that its competitive ratio matches the lower bound for any processing set and processing time parameters.

2 - Synchronous flow shop problems with additional resources and setup times

Stefan Waldherr, Sigrid Knust

Synchronous flow shops are a variant of a non-preemptive permutation flow shop. Jobs have to be moved from one machine to the next by an unpaced synchronous transportation system which implies that the processing is organized in synchronized cycles. In each cycle the current jobs start at the same time on their corresponding machines and are moved to the next machine simultaneously once all jobs have finished processing. The time of a cycle is thus determined by the maximum processing times of the jobs. Motivated by a practical application, each job additionally requires a resources (workpiece carrier) during its whole processing. After a job is completed, the corresponding resource may immediately be used by the next job starting on the first machine. If the resource is not feasible for the starting job, it must be changed. These setup times in general do not occur between jobs that directly succeed each other in the production sequence. The goal is to find a permutation of the jobs as well as a feasible assignment of resources to the jobs such that the production time (sum of times of the cycles and sum of setup times) is minimized. We discuss the complexity of the problem and propose two decomposition approaches dealing with the two subproblems of job scheduling and resource assignment hierarchically. Both decomposition approaches are evaluated and compared using artificially generated test sets as well as real-world data.

3 - On the complexity of scheduling locks in sequence

Ward Passchyn, Frits Spieksma

We discuss a problem inspired by the practical setting of scheduling a series of locks arranged in a sequence: a setting that occurs along many inland waterways. This problem can be considered as the scheduling of a series of batching machines where each job belongs to one of two job families. In our problem setting, ships traverse a waterway from a known arrival position to a known destination position. The ships arrive at a specified moment in time and travel at a known and fixed speed. Each of the locks is characterized by a lockage duration (i.e. processing time) and a capacity (i.e. maximum batch size).

We investigate the computational complexity of a number of problem variants. In particular, we show that minimizing the total waiting time for ships travelling through these locks is strongly NP-hard. This holds even when (i) there are only two locks, (ii) both locks have identical lockage duration and capacity, and (iii) all ships traverse the waterway in the same direction.

We further show that, when all ships travel at a fixed and identical speed, the problem remains strongly NP-hard when ships travel the canal in two directions. To show that two-directional travel contributes fundamentally to the hardness of our problem in this setting, we also provide a polynomial-time procedure for the setting where all ships travel in the same direction.

■ TD-34

Tuesday, 14:30-16:00 - Building BM, 1st floor, Room 116

Novel Problem Formulations and Solution Approaches for Resource-Constrained Project Scheduling

Stream: Supply Chain Scheduling and Logistics
Chair: *Esther Mohr*

1 - The Proactive and Reactive Resource-Constrained Project Scheduling Problem
Morteza Davari, Erik Demeulemeester

Uncertainty has become an inevitable aspect of project scheduling. We study the resource-constrained project scheduling problem (RCPSP) with duration uncertainty. One of the most studied approaches to deal with uncertainty is that of proactive and reactive scheduling. In this paper, we formulate an integrated proactive and reactive scheduling problem with a general combined cost function which includes a baseline schedule cost as well as costs of a series of reactions. We propose three dynamic programming based models (Models 1-3) that solve the problem until optimality over different classes of policies. We compare our models with each other and with a combination of a traditional proactive solution (STC) and a reactive solution (RP_SGS). Computational results show that Model 2 outperforms the traditional solution only when reaction costs are greater than zero. Moreover, Model 3 clearly outperforms Model 1 and Model 2 in all settings and the traditional solution in most of the settings.

2 - Resource-Constrained Project Scheduling with Overtime
Andre Schnabel, Carolin Kellenbrink

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

We present different exact and heuristic solution methods for solving this NP-hard problem. These include utilizing a MILP solver, custom genetic algorithms, a problem specific branch and bound procedure, and various approaches based on LocalSolver, which is a general-purpose local-search solver that allows arbitrary algorithmic computations as model elements. In order to explore the solution space efficiently, we introduce different solution representations and corresponding direct and indirect decoding procedures. These encodings are the central component of the genetic algorithms and the local-search based approaches.

We evaluate the effectiveness of the proposed heuristic and exact methods in an extensive comparative study. In particular, this study focuses on the influence of different direct and indirect solution encodings on the performance and the solution progression over time.

3 - A Project Scheduling Problem with Nonrenewable Resources
Cansu Altintas, Meral Azizoglu

In this study, we consider a project scheduling problem with a single nonrenewable resource. We assume that the resource is released in prespecified times at prespecified quantities. The activities can be processed at different modes where a mode is defined by a processing time and a resource requirement amount. Our problem is to select the modes and timings of the activities so as to minimize the project completion time. We give an efficient mathematical formulation and discuss some approaches for its solution.

■ TD-35

Tuesday, 14:30-16:00 - Building BM, ground floor, Room 17

Mathematical Models for Biology

Stream: Computational Biology, Bioinformatics and Medicine
Chair: *Giovanni Felici*

1 - Mathematical Modeling of Atherogenesis with Particular Emphasis on Aging, Inflammation and Statins Treatment
Piotr Formanowicz, Dorota Formanowicz, Bartłomiej Perek, Jacek Krawczyk

The pathophysiology of the formation of atherosclerotic plaque is a multi-factorial phenomenon and somewhat incomprehensible. A scheme, which represents a simplification to facilitate understanding of the emergence of this disorder, involves four main steps, i.e., endothelial cell injury; lipoprotein deposition and their oxidation; inflammation and smooth muscle cell cap formation. The plaques-deposition process is dynamic, i.e., the current state's plaques-width depends on the previous state. It can also be controlled or even partially reverted. To capture the basic features of this process we have proposed a mathematical model in non-linear differential equations, including in this model these factors that seem to be most useful for the diagnosis and cardiovascular risk prediction. Our study has been carried out on the basis of data obtained both from our clinical studies, available large clinical trials and expert knowledge. It should be underlined here, that the proposed mathematical model does not describe a particular patient's disease history (parameters are calibrated, rather than estimated). Therefore our numerical outcomes are more indicative than conclusive of what will happen to a particular patient with atherosclerosis. We hope that our model will help to better understand the disease development allowing for therapy and prognosticate patient's survival.

2 - Optimum Blend of Fractal Methods Applied on Dermoscopic Images for the Diagnosis of Melanoma
Burak Cavdaroglu

The most vital step in the treatment of melanoma is early and effective diagnosis. The most common practice for melanoma diagnosis is visual examination of dermoscopic images and manual drawing of their lesion borders for future reference. In most cases, it is not easy for dermatologists to detect and grade border irregularities by just examination. Even with the help of dermoscopy 70% of melanoma claims are still false-negative since the risk aversive attitude of dermatologists prevents them from making impetuous positive-diagnosis and possible surgical biopsy. This situation provides a motivation for computer assisted diagnosis techniques to help dermatologists standardize and speed up the diagnosis process. These techniques utilize fractal methods, each of which basically assign a fractal dimension to a dermoscopic image and measure the lesion border irregularities based on the value of this fractal dimension. Our aim is to determine which fractal method(s) are more successful on detecting malignant lesions. We develop four mixed integer programming models, and test these models on a dataset of 100 patients. First, we determine the optimum blend (usage rate) of fractal methods for each model using a "training sample". Second, we identify the model with the highest success rate (true diagnosis) by testing each model and its optimum blend with a "testing sample". Our experiments show that the best model and its optimum blend results in an average success rate of 73%.

3 - A Combinatorial Model for Protein Descriptors' Structural Alignment
Maciej Antczak, Marta Kasprzak, Piotr Lukasiak, Jacek Blazewicz

One of the most challenging problem in molecular computational biology, namely structural alignment of two proteins, can be solved through an application of a protein descriptor concept. Descriptors are local substructures, treated as building blocks, that can be observed in many homological proteins. A segmentation of the original problem of structure alignment into a set of subproblems consisting in structural alignment of descriptors allows to find an original solution more efficiently. Here, we propose a new combinatorial model and new polynomial-time algorithms dedicated to structural alignment of descriptor pairs. Apart from a simplification coming from combinatorial modelling, on both conceptual and complexity level, we obtain high quality results in terms of obtained 3D alignment quality as well as processing efficiency.

4 - Optimum Solution of the Closest String Problem via Rank Distance
Mara Servilio, Giovanni Felici, Claudio Arbib, Paolo Ventura

The Closest String Problem (CSP) calls for nding an n-dimensional string that minimizes, for a given metric, its maximum distance from a given target set of m strings of the same dimension. Under some metrics, such as the Hamming distance, integer linear programming (ILP) proved to be able to nd optimal solutions to relatively large CSPs, thus providing a basis for successful employment in math-heuristics. In computational biology, however, Hamming distance seems to be outperformed by more complex metrics that take into account insertions and deletions — the most established one being the Levenshtein distance, also referred to as edit distance. With edit distance, however, it does not appear easy to formulate the CSP as ILP. Recent research has demonstrated that another metric, called the rank distance, can provide interesting results from both computational and experimental standpoints when applied to genomic sequences. An advantage of the rank distance is that, in this case, the CSP can easily be formulated as an integer program — precisely as a multi-weighted matching problem. In this way, optimal solutions can be found for moderate string sizes; otherwise, dual gap provides useful information on how far feasible solutions are from optimality. In this work we extend an existing ILP formulation of the CSP under rank distance, and use it in a computational experience on biological data in order to evaluate its viability.

■ TD-36

Tuesday, 14:30-16:00 - Building BM, ground floor, Room 18

Information and Intelligent Systems 3

Stream: Information and Intelligent Systems
Chair: *Ipek Deveci Kocakoç*

1 - Localization of Prostate in T2W MRI scans
Justinas Jucevičius, Povilas Treigys, Jolita Bernatavičien, Ruta Briediene, Ieva Naruseviciute

World Cancer Research Fund International states that prostate cancer is the second most frequent tumour amongst men and fourth most common among both sexes in the same year worldwide. Biopsy is the main way that can unambiguously detect prostate cancer if performed on the right location. However, only 70-80% of clinical cancer cases are detected by biopsy. Nowadays multi parametric magnetic resonance imaging (mpMRI) is used to determine the location to perform biopsy on. Usually localization is done by hand, but it takes a lot of time and is inaccurate. This causes the need of software to aid automated prostate and abnormal prostate areas location computation in standardized manner. Standardization allow radiologists and urologist to collaborate efficiently while examining patients. However, the problem of automated prostate MRI image segmentation is burdened by the fact that most researches cannot compare effectiveness of different algorithms due to either troublesome implementation without the help of the original author or algorithm being closed source. What further aggravates the problem is that MRI signal intensity is not standardized and image appearance is for a large part determined by acquisition protocol, field strength, coil profile and scanner type. According to Prostate MR Image Segmentation (PROMISE12) challenge results, authors provides insights on T2W scans automated prostate segmentation problem by comparing the best automatic segmentation algorithms.

2 - Comparison of Naive Bayes and Random Forest Classifiers on Product-Review Data
Tomas Pranckevicius, V. Marcinkevicius

Today, a largely scalable computing environment provides the possibility of carrying out various data-intensive natural language processing and machine-learning tasks. One of these is text classification into predefined categories, with issues involving text classification recently investigated by many data scientists. The authors of this paper investigate Naive Bayes and Random Forest classifiers implemented in Apache Spark, the in-memory intensive computing platform. The focus of the paper is on comparing classifiers by evaluating classification accuracy based on the size of training data sets and number of n-grams. In experiments, product-review data from Amazon are analysed.

3 - An Empirical Comparison of Some Artificial Neural Networks Techniques for Forecasting Short-Term Electricity Demand: A case of Turkey
Ipek Deveci Kocakoç, Serkan Aras

There is a strong relationship between economic growth and demand for electricity. Among OECD countries, Turkey has the most rapid increase in electricity consumption for the last decade. As a developing country, it is expected that Turkey will need more electricity in future. In addition to sustaining its growing position, it is also vital for the needs of people to be able to live a modern life and for human welfare. Hence, forecasting electricity needs helps government and private organizations in reaching their aims. The aim of this study is to forecast short-term electricity demand for Turkey using five different artificial neural networks, namely, Multilayer Perceptron with early stopping (MLP) , Bayesian Regularization Backpropagation (BRB), Radial Basis Function Neural Networks (RBFNN), NeuroEvolution of Augmenting Topologies (NEAT) and Least Squares Support Vector Machines (LSSVM). Also, the well-known forecast combination techniques are employed to evaluate their performances. The results show that combining forecasts leads to better predictions than single models.

■ TD-38

Tuesday, 14:30-16:00 - Building BM, 1st floor, Room 109M

Scheduling with Resource Constraints I

Stream: Scheduling with Resource Constraints
Chair: *Amelie Eilken*

1 - Integration of Vehicle Maintenance Scheduling and Single Dead-End Track Parking
Murat Elhüseyni, Ali Tamer Unal

We introduce an integrated maintenance scheduling problem that incorporates hangar specific parking structure into vehicle maintenance scheduling which includes passenger service satisfaction. It is proven that even the simplest version of this problem, only hangar parking scheduling, is NP-Hard. We propose a MIP model to solve the integrated problem. New optimality conditions are presented for the integrated problem. We make use of these conditions to derive some strategies to facilitate solution of the MIP model. Besides, we develop a heuristic to find an efficient starting solution for the MIP formulation. Our preliminary computational experiment results demonstrate that those strategies and the heuristic yield a significant reduction in computational time.

2 - Optimization Algorithms for a Car Re-Sequencing Problem in Automotive Paint Shops
Sungwon Hong, Jinil Han, Kyungsik Lee

We consider the car re-sequencing problem in automotive paint shops, where a set of cars conveyed from the upstream shop to one of the multiple conveyors is retrieved sequentially before painting operation. The aim of the problem is to find car retrieval schedules which minimize the sequence-dependent setup costs incurred when two consecutive cars do not share the same color. We present two exact solution approaches including the dynamic programming algorithm and the branch-and-cut algorithm to find optimal solutions. Computational results on the instances from the literature are also presented.

3 - Solving Methods for Several Max-Plus Linear Equations Based on Mixed-Integer Programming
Hiroyuki Goto, Yoichi Shimakawa

This research focuses on solving several common equations in max-plus algebra under the framework of mixed integer programming (MIP). Max-plus algebra is an algebraic system in which the max and plus operations are defined as addition and multiplication, respectively. The target equations can be used for modeling and analysis of discrete event systems with structures of parallel processing, synchronization, no-concurrency, and so on. Typical systems of this kind include manufacturing systems, transportation systems, project management, etc. The state transitions of such systems can be represented only with max-plus linear equations. However, it is impossible to construct a method to adjust the states of a system to a desirable one. We thus develop a framework to adjust control inputs or system parameters by converting the equations into constraint satisfaction problems in MIP. In addition to several basic equations, two key equations are extensively focused on. One is a relaxed system of linear equations in max-plus algebra, which can be used for calculating the latest schedule for given due dates. The other one is a relaxed recursive system of linear equations. It is essentially reduced to a longest paths problem for all pair nodes, and can be used for calculating the earliest schedule for given start times. By converting these equations to constraint satisfaction problems and not optimization ones, an adjusting method for internal parameters can be constructed.

4 - Scheduling of Automated Yard Cranes at Container Terminals
Amelie Eilken

The block storage yard at a container terminal serves as an intermediate buffer between the seaside and the hinterland. In today's ports, the storage yard often becomes a critical bottleneck in minimizing the time in port of incoming vessels, which is one of the major objectives in operational planning. One optimization problem that arises in block yard management is the scheduling of yard cranes subject to time windows with the objective to minimize the maximal lateness. This planning task usually comprises the assignment of jobs to cranes, the sequencing of jobs per crane and the scheduling of job executions. We consider a very common yard configuration, a block storage system with two identical automated gantry cranes, called twin cranes. Since the cranes in this system cannot pass one another, each crane exclusively serves either the landside or the seaside of the terminal and so the jobs are assigned accordingly. We introduce a polynomial-time algorithm for the scheduling of the cranes. As the sequencing part of the planning task is already NP-complete, this problem is solved heuristically. We use a branch and bound procedure that includes the introduced scheduling algorithm as an evaluation subroutine. A computational study is presented to test the performance of this approach against a mathematical program solved by CPLEX.

■ TD-39

Tuesday, 14:30-16:00 - Building WE, 1st floor, Room 107

Big Data Analytics & Decision Making

Stream: Decision Support Systems
Chair: *Isabelle Linden*
Chair: *Boris Delibasic*

1 - Ski injury risk segmentation based on massive skier transportation data
Boris Delibasic, Milija Suknović

Skiers use ski lift gates on ski resorts to enter ski lifts. Ski lift gates track personalized entrances of all transportation of the entire skier population based on RFID ski tickets. We aim towards extracting patterns of ski injury based on this massive data. Univariate data analysis as well logistic regression are used as baseline models for identifying attributes and models which best discriminate the injured and non-injured population. We show how the CHAID decision tree algorithm can be used for building univariate and multivariate decision models for risk segmentation of the skier population.The goal of this research is to build models which could be used in decision support systems for injury prevention.

2 - Does text analytics fit text analytics needs?
Isabelle Linden, Anne Wallemacq

In the Big Data trends, text analytics holds a significant position: from emails to pdf documents going through tweets or posts on the social web, a wide variety of supports are available as natural language texts in numeric formats.

The first part of this work draws a state-of-the art overview of text analytics applications and methods: information retrieval text mining, web mining, OLAP and textual data. We pay a particular attention to the models underlying these techniques. Most of them manipulate representations of the texts which tend to reduce complex and multiple sense to univocality.

Text data have the specificity of being mainly produced by humans to be consumed by humans. If they don't have the computing power of machines, Humans have high analytical competencies: the ability to deal with polysemy, implicit aspects, evocation, ambiguity, to catch the context, humour, etc. The second part of the work discuss the limitations of existing tools and models regarding the actual richness of texts as they are analysed by Human scientists.

3 - Early Rapid Prognostic System for Sepsis
Shuaiyu Yao, Jian-Bo Yang, Dong-Ling Xu

Sepsis is a kind of clinical syndrome about infection and inflammation and one of the most serious diseases in the world. Sepsis is confirmed by SIRS and infection. As it takes a few days to decide whether it is Sepsis by blood culture and in this period, healthcare practitioners generally provide early and persistent delivery of potent antibiotics against probable pathogens for patients with SIRS which inevitably leads to adverse effects, it is imperative to develop methods providing accurate and reliable information for diagnostic decisions within the early hours after the presence of suspicious Sepsis symptoms. This research is aimed to design a decision support system with decision approaches for Sepsis diagnosis between clinical suspicion and Sepsis confirmation. In this research, the first stage is data preparation in which the data are cleaned, integrated, and transformed for further analysis. The second stage is modeling. The model is trained and validated on cross-validation. The alternative approaches for modeling are evidential reasoning, SVM, logistic regression, etc. The most appropriate approach is selected among these alternatives for the system. The final stage is the software development for the system. Contributions are expected in providing accurate and reliable information to support rapid early Sepsis diagnosis so that targeted antibiotic therapy could be provided to eschew adverse effects of potent antibiotics to improve patients' survival prospects.

■ TD-40

Tuesday, 14:30-16:00 - Building WE, 1st floor, Room 108

Supply Chain Games

Stream: Game Theory and Operations Management
Chair: *Yael Perlman*

1 - Cooperative line balancing games in parallel M/M/1 lines and loss systems
Shoshana Anily, Moshe Haviv

We consider line balancing of parallel lines in transportation and production systems. We consider two types of systems: (i) Each line is preceded by an infinitely large buffer so that all incoming traffic is eventually served. (ii) Systems with no buffers. Unbalanced lines cause bottlenecks and loss of customers that result in high operating costs. We consider balancing lines by unobservable routing and strategic outsourcing, or by capacity sharing with reduction of excess capacity. The ultimate goal is minimizing the long-run average cost. We define cooperative games where the players are either parallel M/M/1 lines, or parallel M/M/1/1 lines. We consider two policies: (i) unobservable routing of the incoming units to the lines with possibly outsourcing some demand, and (ii) capacity sharing with possibly excess capacity reduction. In M/M/1 systems the objective is to minimize the total congestion cost integrated with either outsourcing costs or with savings due to capacity reduction. For M/M/1/1 systems the cost structure is the same except that the cost of units that are lost due to busy lines replaces the congestion cost. Each problem is solved to optimality, and is presented as a cooperative game. The proposed games are shown to be reducible to market games, implying that they are totally balanced. A core cost allocation based on competitive equilibrium prices is specified for each game.

2 - Duopoly pricing game with exogenous focal point
Sylwester Bejger

In the study a theoretical model of strategic pricing behavior of the players in specific market has been constructed. Central question of the research was: what type of game may generate observable price levels at equilibrium? The model is focused on the wholesale fuel market in Poland, as that market possess a set of distinct economic characteristics. Those characteristics lead to specification of the main ingredients of the game model: price as a primary strategic variable; no threats of significant entry into the market in the sample period; capacities as exogenous parameters; single period of a game, defined as a one day; single period's (stage) game is defined as a non-zero sum, complete information, finite game with simultaneous moves in pure action spaces. Moreover the model have a built-in adjustment to focal price, which resembles the Import Parity Pricing mechanism relevant to the market. This is substantial part of the model as most of the game theory models of duopolistic (oligopolistic) competition assume some price level which is "focal" or "collusive", but this price rarely becomes public information. On the contrary, in our case, such a "focal" price is exogenous for the players and is roughly established. The model assumed repetition of a stage game in an infinite horizon. The equilibrium of the constructed supergame lead to interesting conclusions, explaining strategic pricing behavior in the market.

3 - Sourcing Decisions for a Retailer Under Supply Disruption and Competition
Milan Kumar, Preetam Basu, Balram Avittathur

We have analysed a retailer that has to decide sourcing configuration under the threat of disruption when competing against a more reliable supply chain. We compare the three decision of choosing between single sourcing from foreign supplier(SF) or domestic supplier(SD) (where former offers at lower price but is vulnerable to disruption and latter is expensive but is reliable) and dual sourcing(D). We explore the importance of pricing as a decision variable when demand is price dependent and how sourcing configuration is affected by it. We calculate the expected profit function in all the three cases and find the critical probability where one dominates the others. We find that the SF and D are dominant strategies for certain range of probabilities and SD is never a dominant strategy.

4 - Mergers and acquisitions between risk averse parties
Yael Perlman, Tatyana Chernonog, Tal Avinadav

This paper evaluates different types of mergers and acquisitions (M&A) in a supply chain of virtual products involving risk-averse parties. Specifically, we distinguish among mergers, forward acquisitions and backward acquisitions, and compare these arrangements to a decentralized supply chain (i.e., before M&A). We examine the expected utility gained by each party under each type of M&A, and evaluate the effect of each type of M&A on the consumer in terms of price and quality of the product.

■ TD-41

Tuesday, 14:30-16:00 - Building WE, 2nd floor, Room 209

OR in Forestry

Stream: OR in Agriculture, Forestry and Fisheries
Chair: *Concepcion Maroto*

1 - AHP to prioritise sustainable forestry indicators adapted to ecosystem services under Mediterranean conditions
Pablo Valls-Donderis, María C. Vallés, Francisco Galiana

Sustainable forest management (SFM) considers the social and environmental implications of forestry, and the many products that forests provide. Its principles vary depending on the type of forest. Criteria and indicators (C&I) serve to know what to look at in a particular situation.

In this research, a set of C&I for SFM is identified for Mediterranean conditions. This set is adapted to an ecosystem services classification. Afterwards, the indicators are verified with experts by means of an AHP questionnaire. A variation of the method is applied in order to shorten the questionnaire, since there are many indicators to compare.

Results show that AHP proves to be a proper method to verify and reduce a list of indicators. AHP is suitable for indicators and for experts because it requires conscious valuations and indicators are within the grasp of experts' knowledge.

2 - Automatic programming system for forestry harvesting teams based in optimization and column generation
Tomás Pacheco Riedel, Pablo González-Brevis

Finding an optimal sequence for the harvest planning teams in the forest industry, is a really complex task, due to the high number of combinations that exist to allocate usually more than 40 teams, 100 harvest units in a planning horizon of 4-5 months. In this talk we will show an automatic system for the planification of harvesting teams using different optimization models and methods that simplify this complex process. In this project an integer linear programming model with binary decision variables associated with the location of harvesting teams at every time period, opening and closing operations in a specific unit of harvest and harvesting teams trips occurring between the units that are available unharvested is proposed as a base model for the other methods presented in this project. Due to the high complexity posed by this problem, two methods that simplify the task of assigning harvesting teams to harvesting units are studied: a model that generates and selects harvesting patterns and a model based in Dantzig-Wolfe decomposition principle and column generation. In this project, we have developed a relational database and a web platform to create flexible instances allowing us to compare and analyze the proposed solution strategies. The results show that increasing the number of units and harvesting teams, can generate time differences among the proposed strategies of up to 600%.

3 - Wildfire fuel management: optimisation of prescribed burning.
Dmytro Matsypura, Oleg Prokopyev

Wildfires are part of the Australian landscape. They have been around for an estimated 60 million years and they are part of a regular cycle in Australian climate. Each year, such fires impact extensive areas presenting a real and continuing problem that can have a major impact on people, wildlife and the environment. On the one hand, wildfires can cause property damage and loss of human life. On the other hand, certain native flora in Australia have evolved to rely on bushfires as a means of reproduction, and fire events are an interwoven and an essential part of the ecology of the continent. Since eliminating wildfires completely is not an option, we would like to reduce the severity of their effect. This can be achieved through fuel management, which usually consists of mechanical thinning and prescribed burning of the landscape. We propose a general methodology to address the problem of wildfire fuel management subject to landscape connectivity and exponential fuel regeneration. In this work we draw inspiration from the literature on critical element detection in graphs. We develop a number of mixed integer programming formulations that are based on various landscape connectivity metrics. We present extensive computational experiments that reveal interesting insights and demonstrate advantages and limitations of the proposed framework.

■ TD-42

Tuesday, 14:30-16:00 - Building WE, 1st floor, Room 120

Decabornizing electric systems (Part II: Demand and behavior)

Stream: Long Term Planning in Energy, Environment and Climate
Chair: *Edi Assoumou*

1 - A Bottom-up and Partial Decomposition Model for Long-term Forecasting
Fernando Luiz Cyrino Oliveira, Bruno Bastos, Gheisa Esteves, Reinaldo Souza, Rodrigo Calili, Paula Maçaira, Felipe Silva, Wesley Fagundes, Danilo Carmo, Vanessa Oliveira, Plutarcho Lourenco

Annual and hourly long-term electricity demand forecasting are essential for planning the electricity sector, since demand has impacts on the requirements for investments in generation and dispatch for power plants. In this context, this paper combines a bottom-up and a partial decomposition model to provide long-term annual and hourly electricity demand projections for Brazil until 2050 on regional level. The bottom-up model generates electricity demand projections based on technology-specific and macroeconomic data. The model is divided into three sub modules: households, industry and tertiary sector. Each sub module treats the demand in a disaggregated manner, detailed by end-use. The results are obtained by region, sector, year, application and technology. The partial decomposition model uses bottom-up annual projections to get the electricity demand hourly curves. From the disaggregated results relevant and non-relevant applications are established and specific load curves are created for each one of them. The study main innovation relies on the combination of a botton-up model, which can address technological energy policies issues with a partial decomposition model, enabling the decision maker to visualize its impact on the electricity prices.

2 - A semivectorial bilevel programming approach to model the interaction between electricity retailers and consumers
Maria João Alves, Carlos Henggeler Antunes, Pedro Carrasqueira

Presently residential electricity consumers are, in general, charged at a flat or dual time-of-use tariff along the day. Therefore, they lack the incentives to engage in different consumption patterns namely using the flexibility they generally have in the operation of some end-use loads. Dynamic tariffs, i.e. energy prices varying in short periods of time, are expected to become an applicable pricing scheme in smart grids. In this setting, energy management systems can play an important role to help end-users optimizing the usage of appliances to minimize energy costs without compromising comfort. A bilevel programming model is developed to study the interaction between electricity retailers and consumers. The retailer (upper level decision maker) establishes dynamic electricity prices to maximize profits. The consumer (lower level decision maker) responds by selecting, under that price setting, a nondominated solution balancing his objectives of minimizing the electricity bill (cost dimension) and the dissatisfaction associated with the corresponding load scheduling in face of his preferences and requirements (comfort dimension). The lower level optimization problem is formulated as a bi-objective mixed-integer linear programming (MILP) problem. A hybrid approach consisting of an evolutionary algorithm for the upper level problem and an exact MILP solver to solve scalarization problems at the lower level is proposed. An illustrative case is analyzed and discussed.

3 - Optimal design of tariff structures with discontinuities
Kai Helge Becker, Alex Bahnisch

Electricity retailers typically offer a set of different electricity tariffs to their customers. The individual tariffs that make up the tariff structure of an electricity retailer are often characterized by different price components, i.e. the total price to be paid by a customer can depend on several variables, such as the peak energy demand or the total energy consumption over a period of time. To determine a particular customer's tariff within the tariff structure offered, electricity retailers may use certain thresholds regarding the customer's peak demand or energy consumption, i.e. a customer may be forced into a different tariff when its demand or consumption exceeds, or remains under, a relevant threshold. This can lead to a situation in which small changes in the energy demand or consumption of a customer may lead to a large difference in the electricity price that the customer has to pay. A customer friendly approach therefore would be to design the tariff structure such that discontinuities between tariffs are minimized. The paper presents a linearized optimization model with stochastic components to address this problem for a case in the Australian electricity market. We also discuss the relevance of our approach for pricing decisions in other industries.

■ TD-43

Tuesday, 14:30-16:00 - Building WE, ground floor, Room 18

DEA and Performance Measurement 2

Stream: DEA and Performance Measurement
Chair: *Chris Tofallis*

1 - Robust Performance evaluation of Belgian R&D firms with missing data
Pegah Khoshnevis, Peter Teirlinck, Adel Hatamimarbini

In this study, our aim is to evaluate the performance of Belgian R&D firms using data envelopment analysis (DEA). We use anonymized firm-level data from the OECD business R&D survey conducted recently for Belgium. This survey entails information with regard to the R&D activities of a repertory of (quasi-) permanent R&D active firms in Belgium for the years 2008 and 2009. While the whole population contains 7185 observations, only 428 firms provide all required information. This problem can be regarded as a big data evaluation but the missing data in the data set that are relatively large occur and we inevitably refuse to take into account the bulk of R&D firms. Obviously, the existing missing data distort inferences as well as dropping many firms from performance evaluation. In addition, in the presence of uncertainty in data definition and collection, the best-practice frontier estimated by DEA may be misplaced, particularly when analyzing massive observations. Therefore, we propose a three-step framework to gauge the multi-dimensional performance of R&D firms in Belgium. Firstly, we cope with missing data to avoid removing the observations. Secondly, we detect the outliers and omit them from the dataset. Finally, we apply the DEA models to evaluate the performance of Belgian R&D firms.

2 - Selecting the Most Efficient Set of Projects using DEA
Mahnaz Mirbolouki

One of the important decisions that any organization would have to make is project selection. Every project includes an initial plan to run, but not every plan can be implemented as a project. In situations with lacks of resources or funds, all different plans must first be able to assess profitability in an accurate way, and then, select a combination of the proposals to carry out as projects. The main purpose of this paper is to select the most efficient bundle of plans in a way that none of the projects could be implemented by the remaining resources. Here, efficiency would be measured by a new common set of weight data envelopment analysis model with a new innovation that considers integer variables.

3 - Performance measurement with DEA, Process Mining and Business process simulation
Michael Leyer, Silke Hüttel

Business processes link resources, organisational units, activities and process instances (e.g. customer orders) throughout a company. Evaluating the performance of business processes is important for understanding the root causes of performance step by step. There are three prominent methodologies for assessing performance of processes from different angles. This paper presents a novel methodology that combines these three on a process level, namely Data Envelopment Analysis (DEA), Process Mining and Business Process Simulation (BPS). The core unit of analysis are process instances. DEA is used to measure the efficiency of a process (Process instances equal DMUs) and identifying the production function by being able to compare several in- and outputs. If inefficiencies are detected, process mining is applied for identifying the process model and finding the root causes of inefficiency in activities. To overcome identified inefficiencies BPS is applied to analyse potential changes in the process leading to a better efficiency. The simulation results can then be assessed with DEA and compared to initial values. The combination of DEA, Process Mining and BPS is a promising approach for analysing process efficiency. We demonstrate the capabilities of our approach at the example of livestock breeding.

4 - A formula for efficiency based on DEA scores
Chris Tofallis

We show how to generate a formula which expresses efficiency scores in terms of input and output values. The formula is a ratio of linear expressions, as frequently used in efficiency analysis, although other functional forms can be used. The parameters in the formula are estimated using the Automatic-Democratic Method, i.e. the DEA scores are regressed on the underlying data. This provides a compact efficiency formula which avoids the often unrealistic input and output weights arising in DEA, and the consequent lack of discrimination. It also avoids the problem of efficiency scores not reflecting slacks due to units not being naturally enveloped. Regression ensures the scores are as close as possible to the DEA scores, which are viewed as optimistic upper bounds.

■ TD-47

Tuesday, 14:30-16:00 - Building WE, 1st floor, Room 115

Robust Optimization in Transportation and Energy

Stream: Robust Optimization
Chair: *Chungmok Lee*

1 - Benders-and-Price Approach for Electric Vehicle Charging Location Problem under Uncertainty
Chungmok Lee

One of critical problems in operating electric vehicles is the limited travel range without recharging. To enable a long range travel, multiple charging stations should be available in the routes of electric vehicles. Due to the limited budget, the locations for the charging stations should be determined so that the maximum amount of traffic of the electric vehicles will be covered. Moreover, the travel range of the electric vehicles can vary significantly depending on the condition of travel, which yields a nonlinear mixed integer programming problem. In this talk, we propose a Benders-and-Price approach to efficiently handle the travel range uncertainty. The computational experiments show that the proposed approach is able to solve real-life-size problems.

2 - Design of customer center network for warranty services
Minjae Park, Chungmok Lee

In this paper, a warranty customer center network is designed to consider different types of warranty services for customers and to match a closed loop supply chain network with specific challenges for counter movement management like recovery, repair and replacement service. We present a nonlinear mixed integer programming model for the design of the warranty customer center network of a company. This study optimizes a design of warranty customer center of failed products and inventory locations of products as well as the forward flow of new products. We consider different recovery processes of products by performing the repair service and the replacement service using repair time limit which results in nonlinearities in the model. If a failed product is delivered to the warranty customer center, then a repair service is provided first. If its repair time exceeds the repair time limit, instead of continuing to repair a replacement service is provided for the customer's satisfaction. The real application is implemented using the proposed approach and numerical examples are discussed to exemplify the applicability of the methodologies derived in this paper.

3 - Modeling systems of municipal waste management in municipalities of Lower Silesian Voivodship
Dagmara Pisiewicz

The paper concerns the problem of functioning of municipal waste management systems implemented after the entry into force of the Act of 1 July 2011. amending the law on maintaining cleanliness and order municipalities. In the article discusses the changes in the existing municipal waste management which were necessary to implement from the perspective of the new responsibilities of municipalities The paper discusses the assumptions used at the Voivodeship Waste Management Plan Lower Silesian Voivodship for in 2012 and an attempt to assess the assumptions adopted from perspective logistics, economic, and inclusion the principles of sustainable development. Is the proposed decision model that could serve as a tool for optimal organization of municipal waste management systems. Then analyzed the possibility of implementing the proposed solution using the methods of linear programming. Finally, the paper presents the results of research and applications of the proposed optimization model with respect to future research in the discussed issue.

■ TD-48

Tuesday, 14:30-16:00 - Building WE, 1st floor, Room 116

OR and Water Management

Stream: Energy/Environment and Climate
Chair: *Gerhard-Wilhelm Weber*
Chair: *Gamze Nalçacı*

1 - Optimization of Leakage in Water Distribution Networks Using Pressure Reducing Valve
Ezgi Köker, A. Burcu Altan-Sakarya

Excessive water loss from drinking water distribution network is a serious problem in many countries all over the world including Turkey where total water losses is around 45% of the distributed water. Water loss not only cause a critical amount of energy and economic losses but also results in water quality and sustainability problems. Thus it is crucial to determine, reduce and manage water loss. The most effective means of reducing water loss in distribution systems is proven by former studies to be the control of excessive pressures in the network. In this study, an optimization method is developed to minimize leakage in a water distribution system by pressure reducing valves (PRV) usage. The aim is to optimize tolerance, which is the difference between existing and predefined minimum allowable nodal head, while considering pressure head limitations and PRV settings. The leakage is expressed as a function of pressure, due to the strong correlation between them. In addition to that, chance constraint is applied to cover uncertainties in the system which are resulting from the change of roughness height of pipes with time. Network hydraulics and optimization model are solved by simultaneously using EPANET and GAMS, respectively.

2 - Convex Relaxation for Water Distribution Systems

Gratien Bonvin, Sophie Demassey

In developed countries, water distribution systems can typically account for 4% of all electricity consumption, and nearly all the electricity purchased is used for pumping. Due to increase concerns about energy efficiency but also to opportunities arising from water networks storage abilities, new interests concerning the pump scheduling problem have been observed.

However, the optimal control of a water distribution system remains a difficult task because the mathematical formulation gathers both discrete decisions such as switching pumps on and off, and non-convex constraints for the description of pressure-related physical laws.

In this paper, we present both theoretical and experimental evidence that relaxing the non-convex constraints to their associated convex hull can lead to near-feasible solutions. Applications to different networks and comparison with existing methods are presented in order to highlight the relevance of our solution.

3 - Soft Classification of Satellite Data for Snow Mapping by using Multivariate Adaptive Regression Splines

Semih Kuter, Zuhal Akyurek, Gerhard-Wilhelm Weber

Measurement of the areal extent of snow cover with high accuracy plays an important role in hydrological and climate modeling. Remotely-sensed data acquired by earth-observing satellites offer great advantages for timely monitoring of snow cover. However, the main obstacle is the trade-off between the temporal and spatial resolution of the satellite imageries. Soft or sub-pixel classification of low or moderate resolution satellite images is a preferred technique to overcome this problem. In this presentation, we represent fractional snow cover (FSC) mapping from Moderate Resolution Imaging Spectroradiometer (MODIS) data in Alps by using Multivariate Adaptive Regression Splines (MARS). The MARS model is trained in order to estimate FSC using MODIS surface reflectance data for the first seven reflective solar bands, Normalized Difference Snow Index and Normalized Difference Vegetation Index as predictor variables. FSC cover maps obtained by binary classification of higher spatial resolution Landsat ETM+ images are used for MARS model training and validation. The results of MARS FSC maps are also compared with the standard MODIS FSC product, and the results are given in terms of RMSE and coefficient of determination values.

4 - Probabilistic forecasts for short-term wind power generation using Singular Spectrum Analysis and Conditional Density Kernel

Reinaldo Souza, Soraida Aguilar, José Pessanha, Fernando Luiz Cyrino Oliveira, Luiz Fernando Lorey

Short probabilistic forecasting is becoming one of the most used approaches to forecast wind power generation, and for this purpose, different strategies have been employed. This work combines non-parametric techniques that lead to a conditional density of the wind power generation. The methodology uses singular spectrum analysis (SSA) to forecast the wind speed and conditional kernel density (CKD) to estimate the conditional density of the wind energy based on hourly dataset of wind speed and wind power of a Brazilian wind farm. With this estimation and given the wind speed forecasts one obtains the wind power output for a 24-hour-ahead leadtime. These forecasts are compared with others that use different approaches to generate the wind speed forecasts.

■ TD-51

Tuesday, 14:30-16:00 - Building PA, Room D

Algorithmic Nonsmooth Optimization 2

Stream: Nonsmooth Optimization
Chair: *Andreas Griewank*
Chair: *Andrea Walther*

1 - Calculating Convex and Nonconvex Subdifferentials by the Quasidifferential and Set Operations

Robert Baier

First we will collect known facts on the quasidifferential which is introduced by Demyanov/Rubinov as a tool similar to subdifferentials to formulate e.g. necessary and sufficient optimality conditions and descent directions.

It is based on the embedding of convex compact sets into pairs of sets with an equivalence relation and is defined for quasidifferentiable functions, i.e. if the directional derivative is a difference of two support functions of convex sets. Due to the embedding into a vector space the quasidifferential satisfies good calculus rules: there are exact formulas for the sum, difference, maximum or minimum of two quasidifferentiable functions (without extra regularity assumptions).

With the help of the geometric or the Demyanov difference of two convex sets, the Dini subdifferential and superdifferential as well as the small subdifferential and a subset of Clarke's generalized gradients can be recovered for quasidifferentiable, locally Lipschitz functions.

In the second part directed subdifferentiable functions are considered for which the function and certain restrictions to recursively defined orthogonal hyperplanes are uniformly directionally differentiable. This class contains quasidifferentiable, amenable, lower-Ck and locally Lipschitz, definable functions on o-minimal structures.

Some advantages and nonconvex visualizations of the corresponding directed subdifferential are compared to convex/nonconvex subdifferentials for simple examples.

2 - Extended supporting hyperplane algorithm for nonsmooth MINLP

Ville-Pekka Eronen, Jan Kronqvist, Napsu Karmitsa, Tapio Westerlund, Marko M. Mäkelä

In this talk a generalization of the Extended Supporting Hyperplane (ESH) algorithm to solve nonsmooth mixed-integer nonlinear programming problems is presented. In the generalization, the subgradients of Clarke subdifferential is used instead of gradients. The algorithm is shown to converge to a global minimum if the objective function is linear and constraint functions are locally Lipschitz continuous and $fcirc$-pseudoconvex. Finally, we make some comparisons between the generalized ESH and extended cutting plane method.

3 - The MFS method: a subdivision scheme for obtaining all the global optimal solutions of continuous optimization problems

Albert Ferrer, Juan José Mesas, Luis Sainz

When a deterministic global optimization algorithm, such as the Extended Cutting Angle Method (ECAM) is used for solving Lipschitz programs, the algorithm always converges to the same solution for the global optimum irrespective of the starting point. This is a very usual fact of the deterministic global optimization algorithms. While this could be good enough in many situations, it is not convenient in many other cases in which there may be different solutions for the global optimum and the realistic solution depends on the physical (or engineering) interpretation of these solutions. To overcome this limitation, this article provides the Mesas-Ferrer-Sainz method (MFS) for subdividing the domain of definition of a given optimization problem in such a way that it is possible to find all its global optimal solutions, especially when the set of global optimal solutions is finite. The main characteristic of MFS is its generality so it can be applied to any deterministic global optimization algorithm for solving continuous optimization problems. As an example of application, the MFS method will be used for the resolution of an electrical engineering problem: The Load Flow in an Electrical Network.

■ TD-52

Tuesday, 14:30-16:00 - Building PA, Room C

Vector and Set-Valued Optimization III

Stream: Vector and Set-Valued Optimization
Chair: *Marius Durea*

1 - Minimal Time Function with Respect to a Set of Directions

Marian Dumitru Pantiruc

In order to study new directional regularity properties, we introduce a new type of minimal time function with respect to a set of directions. Several properties such as semicontinuity, convexity and Lipschitz behavior, as well as subdifferential calculus are explored. A new Ekeland Variational Principle using this new minimal time function is provided. This study opens some new possibilities to define and to explore directional behavior of single and set-valued mappings, which act as objectives for various optimization problems.

2 - A New Type of Directional Regularity for Multifunctions with Applications to Optimization

Radu Strugariu

The concepts of linear openness, metric regularity and Aubin property of mappings were intensively studied in the last three decades, due to their importance as qualification conditions in mathematical programming with single and set-valued objectives. In this talk, we discuss a new type of directional regularity for mappings, constructed by the use of a minimal time function studied in a previous work. The corresponding directional triplet of regularities naturally appears, as shown by several examples. We investigate necessary and sufficient conditions for the new directional regularity properties, formulated in terms of generalized differentiation objects of Fréchet type. Finally, applications to necessary and sufficient optimality conditions for Pareto minima of sets and multifunctions are provided, making use by the regularity concepts analyzed before. In all the results we present, the directional character of both hypotheses and conclusions is emphasized.

3 - Optimality Conditions for Sharp and Robust Efficiencies in Vector Optimization with Variable Ordering Structure

Elena-Andreea Florea

In the last years, the vector optimization field received a new impetus with the introduction of variable ordering structures. In some of the main references on the subject, the variable ordering structure is seen as a set-valued map from the output space of the objective mapping to itself. A different perspective takes the ordering mapping acting between the same spaces as the objective mapping, and this is motivated by natural requirements. In this talk we follow this approach, and our objective in this context is twofold. On one hand, we introduce two new notions of minimum, namely the sharp and robust efficiencies, and we study their relations with the other notions and the classical efficiency concepts in vector optimization. On the other hand, we propose necessary optimality conditions for the new concepts, using Fréchet and Mordukhovich calculus, coupled with the Gerstewitz's (Tammer's) scalarizing functional and openness results for set-valued maps. The investigation for the latter objective allows us to motivate the presence of the two notions of efficiency we study, since these are united by the methods we use.

4 - Penalization Techniques and Optimality Conditions in Vector Optimization

Marius Durea

The penalization techniques play an important role in the investigation of optimization problems with constraints. The main idea on which these procedures rely is to transform a (local) minimum point of a constrained problem into a (local) minimum point of an unconstrained problem, by adding to the objective mapping a penalty term which somehow contains the constraints of the initial problem. We discuss several techniques to penalize vector optimization problems and we show their versatility for getting various necessary optimality conditions in different settings. For the latter purpose, we make use of several optimality conditions for unconstrained problems available in the literature and of generalized differentiation tools. We observe that in order to get appropriate optimality conditions, in many cases one has to derive new specific calculus rules of generalized differentiation, as well as to investigate new interesting Lipschitz-like properties for single and set-valued maps. Among the features we would like to discuss in this presentation are the directional nature of some of the questions we study and the use of sub-differentiation objects in order to get optimality conditions for maximization problems.

■ TD-53

Tuesday, 14:30-16:00 - Building PA, Room A

Packing, Cutting and Zoning with Metaheuristics

Stream: Metaheuristics
Chair: *Andreas Reinholz*

1 - An Iterated Local Search Algorithm for the Generalized Quadratic Multiple Knapsack Problem

Mustafa Avci, Seyda Topaloglu

The Quadratic multiple knapsack problem (QMKP) is a variant of the classical knapsack problem where multiple knapsacks are considered and the objective is to maximize a quadratic objective function subject to capacity constraints. The generalized quadratic multiple knapsack problem (G-QMKP) extends the QMKP by considering the setups, assignment conditions and the knapsack preferences of the items. In this study, an iterated local search algorithm in which the variable neighborhood descent algorithm is combined with an adaptive perturbation mechanism is proposed to solve the G-QMKP. The proposed approach is tested on G-QMKP benchmark instances derived from the literature. The results indicate that the developed approach can produce efficient and effective solutions for the G-QMKP.

2 - The Plant Propagation Algorithm for Discrete Optimisation: The Case of the Knapsack Problem

Birsen Irem Selamoglu, Abdellah Salhi

The Plant Propagation algorithm (PPA) has been demonstrated to work well on both unconstrained and constrained continuous optimization problems. PPA emulates the strategy that plants deploy to survive by colonising new places which have good conditions for growth. Plants, like animals, survive by overcoming adverse conditions. The strawberry plant, for instance, has a survival and expansion strategy which is to send short runners to exploit the local area if the latter has good conditions, and to send long runners to explore new and more remote areas, i.e. to run away from a not so favourable current area. Recently, PPA has been extended to solve discrete optimization problems such as the well-known Travelling Salesman Problem (TSP). The main issue is how to the implement the idea of short and long runners when searching for Hamiltonian cycles in complete graphs. In this paper, we investigate its use to solve another discrete optimization problem, namely the Knapsack Problem. The aim is to maximise the total value of a knapsack by picking up items without exceeding the capacity constraint of the knapsack. The performance of the algorithm on a standard list of test problems is compared to that of the Genetic Algorithm, Simulated Annealing, Particle Swarm Optimization and more recent algorithms such as the Firefly Algorithm. Computational results are included.

3 - Multiobjective Tabu Search for the Zoning Problem
Beatriz Bernabe, Rogelio González Velázquez, José Martín Estrada, Mario Bustillo, Gerardo Martinez

This document describes a Tabu Search algorithm embedded in a multiobjective framework capable of finding solutions for the zoning problem by allowing the optimization of multiple objectives. Compactness, meaning proximity of objects in the same cluster (territorial units for the zoning problem) represents one of those objectives to be optimized; homogeneity meaning a balance in the distribution of several variables that each object in the problem possesses and are selected as input for the algorithm represents the other objective to be optimized, both are being minimized. Zoning is a technique that belongs to the area of urban studies. The main idea with this technique, the most popular in urbanization, is to produce a partition of homogeneous regions according to some criteria. In our case each variable matches a criteria and each basic geo-statistics area possesses a collection of values each representing the value for some variable. These variables could be demographic, for instance, people who are older than twenty years old, people younger than ten years old, etc. A basic geo-statistical area (BGA) is the manner in which we will refer to a basic or primitive region to be clustered. Any BGA consists of a pair (position, variables_values) where position marks the location of the area in space (usually two coordinates) and variables_values represent a list of values for every variable in the problem.

4 - Applications of the Biased Random Key Genetic Algorithm to the Field Technician Scheduling Problem
Debora Ronconi, Ricardo Damm

This work addresses a technician scheduling problem in which a set of tasks, at different locations and with time windows restrictions, should be assigned to technicians taking their skills and working hours into account. The objective is to maximize the sum of priority values associated with the tasks that can be scheduled in a given day. Due to the complexity of the problem, several heuristics that explore particular characteristics of the problem were developed. In special, we proposed three versions of the metaheuristic BRKGA associated with a diversification strategy of the elite group. Numerical experiments were conducted with instances with up to 166 technicians and 999 tasks. In order to measure the quality of the heuristic solutions a comparison with proposed upper bounds was performed. The results showed that the presented heuristics are able to obtain noteworthy quality solutions.

■ TD-54

Tuesday, 14:30-16:00 - Building PA, Room B

Numerical methods in optimal control and optimization

Stream: Convex Optimization
Chair: *Luis Briceño-Arias*

1 - On the convergence of discrete optimal controls
Francisco José Silva Alvarez

In this talk we survey some classical and new results regarding the discretization of stochastic or deterministic optimal control problems. We focus our attention on Semi-Lagrangian schemes recalling first some classical convergence result for the value function which can be proved analytically or by using probabilistic arguments. Next we discuss the more delicate issue of the convergence of the optimizers as well as the connections with Mean Field Games theory.

2 - Construction of Proximal Distances over Symmetric Cones
Julio López, Erik Alex Papa Quiroz

This work is devoted to the study of proximal distances defined over symmetric cones. Specifically, our aim is to provide two ways for build them. For this, we consider two classes of real-valued functions. Then, we show that its corresponding spectral function is a proximal distance. In addition, we present several examples and some properties of this distance. These properties are useful for the analyze of convergence of proximal algorithms associated with a proximal distance.

3 - Projected Chambolle-Pock splitting for solving monotone inclusions
Luis Briceño-Arias

In this talk a modification of Chambolle-Pock splitting for solving primal-dual optimization problems is presented. In the case when the primal solution is known to be in some convex closed set, the proposed primal-dual method performs an additional projection step which guarantees that the primal sequence belongs in that set. This feature is desired, for instance, in optimization problems with linear constraints, in which the solution must be feasible and, hence, an algorithm whose primal iterates satisfy the constraints is useful. In this case, the flexibility of the method allows to consider different sets to perform the projection allowing, for example, to choose some of the linear constraints in order to obtain a projection easy to compute. In some cases this can help to improve the performance of the algorithm with respect to the original method. Finally, a generalization to composite primal-dual monotone inclusions is provided together with some numerical examples.

Tuesday, 17:30-18:30

■ TE-57

Tuesday, 17:30-18:30 - Poznan Internat. Fair, Earth Hall

Central Plenary Robert Aumann

Stream: Plenary, Keynote and Tutorial Sessions
Chair: *Roman Slowinski*
Chair: *Daniele Vigo*

1 - Why Optimize? An Evolutionary Perspective
Robert J. Aumann

By the doctrine of "Survival of the Fittest", evolutionary pressures indirectly lead to optimal functioning of vital processes like nourishment and reproduction. Conscious, purposeful optimization does so directly, indeed more efficiently. We suggest that the poorly understood phenomenon of consciousness has evolved for precisely that reason – to enable efficient optimization of life processes.

Wednesday, 8:30-10:00

■ WA-01

Wednesday, 8:30-10:00 - Building CW, AULA MAGNA

Keynote Marc Pirlot

Stream: Plenary, Keynote and Tutorial Sessions
Chair: *Salvatore Greco*

1 - Preference Elicitation and Learning in a Multiple Criteria Decision Analysis Perspective: Specificities and Fertilization Through Inter-disciplinary Dialogue
Marc Pirlot

Capturing, modelling and predicting preferences has become an important issue in many different disciplines, among which we may cite psychology, decision analysis, machine learning, artificial intelligence, information retrieval, social choice theory. Preferences also play a major role in applications such as marketing and electronic commerce.

Although they work with the same notion, the different communities have specific issues to deal with and they use their own methods and standards. In recent years, several workshops were organized with the aim of bringing together people working in preference related domains, yet coming from various research horizons. Let us mention for instance, the Dagstuhl Seminar 14101 on Preference Learning and the DA2PL (From Decision Analysis To Preference Learning) Workshops, the next one scheduled November 2016 in Paderborn, Germany.

In this talk, we shall first sketch the way different communities look at preference learning and contrast them with the peculiarities of Multiple Criteria Decision Analysis. We then mainly focus on the inter-relations with the Machine Learning community, aiming to identify what are the issues we have in common and what can be learned from them in a Decision Analysis perspective. We illustrate the commonalities and discrepancies between both approaches by presenting some recent research works. The last part of the talk will propose and describe four research avenues which we see as structuring the recent and forthcoming efforts regarding preference elicitation and learning in the field of multiple criteria decision analysis. In these four trends, the interactions with disciplines such as Optimization, Artificial Intelligence and Machine Learning are likely to become increasingly important.

■ WA-02

Wednesday, 8:30-10:00 - Building CW, 1st floor, Room 7

Algorithms and Applications

Stream: Algorithms and Computational Optimization
Chair: *Ali Hamidoglu*

1 - Maximizing total job value on a single machine with job selection
Eun-Seok Kim

We study a single machine scheduling problem of maximizing total job value with job selection. The value of each job is given as a non-increasing step function of its completion time.

We examine some properties for an optimal solution, and based on these properties we develop a branch-and-bound algorithm and a heuristic algorithm for the problem. Finally, we perform computational experiments showing that the developed algorithms provide efficient and effective solutions.

2 - An Evolutionary Framework for Implementing Dual Local Search with Application in Routing
Mona Hamid, Jamal Ouenniche

Combinatorial optimization problems have been at the origin of the design of many optimal and heuristic solution frameworks such as branch-and-bound algorithms, branch-and-cut algorithms, classical local search methods, metaheuristics, and hyperheuristics. In this paper, we propose a genetic algorithm-based framework to optimize the parameters of a generic and parametrised dual local search algorithm. We empirically assess the performance of the proposed framework using instances from the TSPLIB. Empirical results suggest that the proposed framework delivers outstanding performance.

3 - A simulation optimization approach for emergency department layout design problem
Taho Yang, Teng Kuan Wang

The overcrowding problem in hospital emergency department (ED) is an important issue worldwide. To ensure that emergency patients receive care on time most countries use triage scoring to prioritize their ED patients. The triage process based on the emergency severity index system and the current layout design give rise to the phenomenon of sequential batch processing. Most of the patient care is delayed during the process. This study is based on value stream mapping for the design and analysis of the ED. The study investigates cellular manufacturing design, which addresses the decisions of continuous steps in a cell simultaneously and considers the optimal staff assignment to convert from batch processing to continuous processing. The staffing assignment problem is solved by the proposed simulation optimization approach. A practical case is adopted for illustration of the effectiveness of the proposed methodology and the empirical results are promising. The patients' average waiting time was reduced from 78 minutes to 38 minutes, a 51% improvement, and the service level was increased from 54.86% to 88.55%, a 61% improvement. Moreover, the suggested layout design can reduce the staffing level—the number of nurses nine to six.

■ WA-03

Wednesday, 8:30-10:00 - Building CW, 1st floor, Room 13

Preference Learning 5

Stream: Preference Learning
Chair: *Robert Busa-Fekete*

1 - Preferences and Counterfactuals: Learning from logged implicit feedback
Adith Swaminathan, Thorsten Joachims

Recent works have shown how to effectively use data collected from an operational interactive system (e.g. recommenders, ad placement and search engines) to evaluate new systems in a robust, unbiased manner. They open up a wide area of research on new evaluation and learning techniques for ranking, recommendation and other preference learning problems. We will describe a new learning principle–Counterfactual Risk Minimization (CRM), and an efficient algorithm–POEM (Policy Optimizer for Exponential Models), for offline learning from logged online feedback. We model the problem as a batch variant of contextual bandits (Batch Learning from Bandit Feedback). We first address the counterfactual nature of the learning problem through propensity scoring. Next, we account for the non-uniform variance of the propensity-scored empirical risk estimator. This produces the CRM learning principle. Finally, we employ a Majorization-Minimization strategy to regularize this variance. This yields a flexible stochastic gradient algorithm that learns stochastic linear rules for structured output prediction. We conclude with experiments on several multi-label classification problems and a real-world information retrieval task, and point out future research directions.

2 - Controlling the distance to a Kemeny consensus without computing it
Anna Korba

Due to its numerous applications, rank aggregation has become a problem of major interest across many fields of the computer science literature. In the vast majority of situations, Kemeny consensus(es) are considered as the ideal solutions. It is however well known that their computation is NP-hard. Many contributions have thus established various results to apprehend this complexity. In this paper we introduce a practical method to predict, for a ranking and a dataset, how close the Kemeny consensus(es) are to this ranking. A major strength of this method is its generality: it does not require any assumption on the dataset nor the ranking. Furthermore, it relies on a new geometric interpretation of Kemeny aggregation that, we believe, could lead to many other results.

3 - Online Rank Elicitation on Weighted Tournaments
Robert Busa-Fekete, Adil Paul, Eyke Hüllermeier

We study the problem of online rank elicitation, in which a learner is allowed to query (stochastic) pairwise comparisons between a finite set of alternatives. Each comparison corresponds to sampling from a Bernoulli distribution that specifies the probability of one alternative beating another one in a pairwise duel. Using this information, the learner seeks to quickly yet reliably predict a ground-truth ranking of all alternatives, which we assume to be given by the solution to the weighted feedback arc set problem on tournaments (WFAS-T) with the underlying weights given by the parameters of the Bernoulli distributions. Since the WFAS-T problem is in general NP-hard, our learning algorithm relies on some recent approximation results. We also consider some interesting special cases in which the learner is able to estimate the exact solution, for example where the weights of the tournament graph satisfy the Bradley-Terry assumption.

■ WA-04
Wednesday, 8:30-10:00 - Building CW, ground floor, Room 6

Green Sourcing and Inventory Management

Stream: Environmental Sustainability in Supply Chains
Chair: *Lena Silbermayr*

1 - Inventory pooling with environmental constraints using copulas
Lena Silbermayr, Werner Jammernegg, Peter Kischka

Pooling is a best practice in inventory management for economic objectives. In this paper we investigate whether pooling stays advantageous if in addition to the economic performance also environmental sustainability is considered, i.e. whether pooling can resolve the often claimed trade-off between economic and environmental performance. Within the newsvendor framework we consider three pooling models - centralization, pooling via transshipments, and centralization including inventory allocation to the retailers for a fixed list policy - that include environmental constraints covering all manufacturing and logistics operations. For all models we present conditions such that the concavity of the profit is preserved. Using copulas to model the joint distribution of (positive) dependent demands we extend Corbett and Rajaram's (2006) result and prove that for our pooling models the profit decreases with increasing demand dependence. Further we prove that, if the environmental constraint is binding, inventory and emissions decrease with increasing demand dependence. Additionally, we numerically show the impact of the copula on inventory pooling and also characterize when the trade-off between economic and environmental performance of pooling can be resolved.

2 - Sustainable dual sourcing of strategic raw materials by integrating recycled materials
Patricia Rogetzer, Lena Silbermayr, Werner Jammernegg

Recycling makes it possible to integrate raw materials out of steadily increasing waste streams back into production processes and at the same time contributes to a reduced dependency on imports. Considering such an alternative supply option can increase the economic, environmental and social sustainability of supply chains. Moreover, it enables resources being used more efficiently. Currently, a lot of research is done in the area of establishing technical possibilities for efficient recycling of strategically important raw materials for the electronics industry. Though, quantities resulting from recycling processes are still uncertain and therefore, demand cannot be met by this secondary source alone and the primary mining source is still needed. Nevertheless, having a second supply source in place enables manufacturers to reduce supply risks and increase sustainability in comparison to single sourcing.

In this paper, we investigate a dual sourcing strategy where strategic materials can be procured from a primary raw materials supplier and from a secondary recycling source, hence taking into account new and recycled materials simultaneously. Considering uncertain prices for recycled materials, uncertain recycling quantities and uncertain demand as well as their potential dependencies we develop a single period inventory model. We derive the order quantities for recycled and primary materials, the related costs and evaluate the effectiveness of a dual sourcing strategy.

3 - Reasons for the incorporation of standards: A literature review concerning theories of the firm
Felix Tuczek, Tina Wakolbinger

The emergence and diffusion of standards have received considerable attention. Competing theories concerning the reasons for adopting standards can be found in the literature. The objective of this literature review is to gain a holistic overview of theoretical considerations for the adoption of standards and their effects. We apply the Snowballing approach for gathering papers. Then, we derive a taxonomy for the aims pursued by the adoption of standards. Finally, we elucidate recommendations for future research based on the research gaps detected. Our research indicates that researchers should emphasize the combination of different theoretical lenses and integrate ecological, environmental and social standards in a single study.

■ WA-05
Wednesday, 8:30-10:00 - Building CW, 1st floor, Room 8

Applications of Multiobjective Optimization

Stream: Multiobjective Optimization
Chair: *Karthik Sindhya*

1 - Selecting Cost-Efficient Safety Actions in High-Risk Installations by Combining Portfolio Decision Analysis with Bayesian Belief Networks
Alessandro Mancuso, Michele Compare, Ahti Salo, Enrico Zio

We develop a method of Portfolio Decision Analysis to support the selection of cost-efficient portfolios of safety actions in high-risk installations. Towards this aim, the sequences of events which may lead to accidents are modelled as Bayesian Belief Networks (BBN) whose nodes represent these events and whose arcs indicate causal dependencies between the events. In the resulting BBN model, the alternative safety actions modify the probability distributions and thus affect the probability of the accident. Finally, we develop a computationally efficient enumeration algorithm to identify which portfolios of safety actions lower the risk of accidents most at any given cost level. This permits a holistic approach to risk management: instead of identifying through what-if analyses what would be the best single action to respond to deviation events, we are able to determine which portfolio of actions is optimal in view of all such deviations. The method is illustrated with a case study concerning the airlock system failure in a CANDU Nuclear Power Plant.

2 - Multiobjective Environmentally Sustainable Network Design using Pareto Optimization
Yi Wang, Wai Yuen Szeto

To control the environmental deterioration and enhance the environmental sustainability of transportation systems are pressing subjects for governments and transportation authorities nowadays. To this end, a more realistic and systematic modeling, evaluation, and design framework with environmental sustainability is particularly urged. In this paper, a bi-level transportation network design problem with multiple environmental considerations is investigated. To explicitly reflect various requirements of environmental sustainability from planners, total emissions costs and total excessive cost are minimized along with total system travel time while performing optimal capacity expansion. To leave space for additional information on decision-making for planners and provide more generalized description of solution optimality, Pareto optimization approach is adopted. The study proposed a multi-objective variant of a new meta-heuristic named Chemical Reaction Optimization (CRO) as the optimization tool to solve the formulated network design problem. Well-constructed Pareto sets have been successfully acquired for each scenario tested using Sioux Falls network. The result shows that there are different conflicting relations between pairwise objectives under different demand situations and the newly proposed multi-objective metaheuristic succeeds to produce approximations of Pareto front with comparable quality to NSGA-II with less runtime for the considered road network.

3 - Concurrent Real-Time Optimization of Detecting Unexpected Tasks in Embedded Systems Design Process
Adam Górski, Maciej Ogorzałek

Unexpected tasks can appear when embedded system is designed, and any resource cannot be added to the system. What is worth to underline we understand unexpected tasks not as faults but as an extension of possibilities of designing systems. Unexpected tasks are able to solve some problems encountered during the work of embedded systems. When system meets unexpected situation, the designer must provide a list of possible problems. It is possible that solutions of some problems will not solve the situation. Each problem can have many solutions. Each solution of one problem consists of many different tasks. The tasks are described by two parameters: time and cost of its execution on every resource. It is easy to observe that optimization can be made in at least two phases. The first phase is the choice of problems to solve. The second phase is the choice of solution for selected problems. The results from each phase has a great impact on results of the second one. Therefore it should be done concurrently in real time. In this work we propose a genetic algorithm to described situation. The algorithm will allow to compare the results for different problems and to escape from local minima of optimizing parameters.

4 - Effects of the product value in intermodal freight transportation planning: A tri-objective Pareto front analysis integrating in-transit inventory
Andreas Rudi, Patrick Breun, Frank Schultmann

Intermodal freight transportation is expected to play a significant role in mitigating air emissions. Whereas ecological objectives request low-emission transport services at the expense of longer transit times, economic objectives demand fast low-cost transportation. Although this characteristic tradeoff in intermodal transportation is mainly described by the negative correlation of costs and emissions as for road and rail haulage, the time criterion is crucial especially for high-value products. The higher the value of a product the greater affected are the overall costs by rising in-transit costs amplifying the objective to reduce transit times. It is aim of this talk to present a tri-objective model formulation, which analyzes the effects of the product value onto the design of intermodal networks while minimizing transport emissions, costs and time. The underlying capacitated multi-commodity network flow model integrates transport and transshipment processes and enables the modal shift of full truck loads at capacitated terminals. By applying the augmented ϵ-constraint method, a set of tri-objective Pareto fronts is generated based on varying product values and validated within a case study. Methodological contribution of this approach is offered to the research on multi-objective optimization in sustainable transportation planning and to industrial practitioners for the assessment of emission abatement potentials in freight transportation with regard to valuable goods.

■ WA-06

Wednesday, 8:30-10:00 - Building CW, ground floor, Room 2

MCDA and Environmental Management 2

Stream: Multiple Criteria Decision Aiding
Chair: *Antonio Boggia*
Chair: *Luisa Paolotti*
Chair: *Lucia Rocchi*

1 - Resilience assessment in urban systems: a proposal for the Metropolitan Area of Naples (Italy)
Silvia Iodice, Pasquale De Toro

The concept of resilience describes the capacity of a system to maintain or to recover its functionality after a disruption or disturbance, in order to make people who work and live in cities able to survive to the stresses and shocks they have to face. The City Resilient Framework elaborated by Arup International Development identifies four different categories, 12 key goals and 52 indicators in order to evaluate the resilience of a city. Considering that every city is a unique ecosystem with its proper singularities, the aim of the paper is to apply this model to the Metropolitan Area of Naples (Italy), in order to provide a classification of the territory according to the resilience it may offer and to identify the factors that contribute to its capacity of recover. Four different perspective have been considered: leadership and strategy, health and wellbeing, infrastructure and ecosystems, economy and society. According to this reference framework, a system of indicators has been developed with the aim of identifying their territorial distribution, providing a division of the Metropolitan Area in different zones with variable levels of resistance to risks and vulnerabilities. The evaluation has been carried out through an integration between Geographic Information System and Multi-Criteria Decision Analysis.

2 - Integration of Geo-Design and Multi-Criteria Decision Aiding for Cultural Landscape Evaluation
Raffaele Attardi, Maria Cerreta, Maria Luigia Manzi

The paper introduces the multi-methodological decision-making process implemented in the 'Green Lucania project' of University of Naples Federico II. We test the integration of Multi-Criteria Decision Analysis and Geo-Design approach in order to develop and evaluate alternative scenarios for the valorization of cultural landscape; the proposed methodology is developed and implemented in the municipality of Pisticci (Basilicata region, Italy). Geo-Design is an iterative design method that uses stakeholders' input, geospatial modelling, impacts simulations, and real-time feedback to facilitate holistic design and smart decisions. Combining the information capacity of GIS with decision-making inside the design processes through interactive and informative planning and design tools, Geo-Design covers a variety of scales, bridging the gap between regional and local context. Indeed, Geo-Design can be considered a powerful tool for the integration and implementation of the typical environmental evaluation process (conceptualization, modelling, implementation, ex-post evaluation and monitoring) into a wider design framework, where the evaluation acts simultaneously alongside the proper creative design. The combination of Geo-Design and Multi-Criteria Analysis tools enables the development and evaluation of place-based scenarios for landscape valorization, taking into account a wide set of multidimensional values and local community different points of views.

■ WA-08

Wednesday, 8:30-10:00 - Building CW, 1st floor, Room 9

Customer Based Services and Knowledge in Organizations

Stream: Customer Based Services and Knowledge in Organizations
Chair: *A. D. Amar*

1 - A Fuzzy Optimization Method to Select Marketing Strategies for New Products Based on Similar Cases
Yao Zhang

Successful new product launches are significant for company survival in intense competition environments. Companies generally divide customers into different marketing segments to increase profits due to the growing focus on customer relationship management (CRM). For new product launches, developing marketing strategies towards customers in different segments is a critical issue faced by companies. To address this issue, this paper proposes a fuzzy optimization method to select marketing strategies for new products based on similar cases. In the proposed method, a case database and a target case are constructed that consist of relevant data about historical products and a new product, respectively. Then, historical similar cases are retrieved based on similarities and adapted according to the current situation. Next, triangular fuzzy numbers are used to describe customers' responses to the marketing strategies. Finally, a fuzzy integer linear model is constructed. By solving this model, marketing strategies for the new product towards customers in different segments can be obtained. A case study is provided to illustrate the potential for the practical application of the proposed methodology and several managerial implications are also noted.

2 - The Economics of Innovation
A. D. Amar, Kamali Archukan

To consider the economics of innovation, we start with a clear distinction between the development of ideas into new actionable knowledge, and the commercialization of this newly developed knowledge into new or improved products, services or processes. While both could be extremely expensive, as well as time consuming, because of their risk dimensions, their economics could be very different. When the firms innovate, they have to go through some multiple rigorous processes before arriving at a final outcome, as well as the decision of its marketing. The entire process could take a tremendous amount of time. Seeking out investors to invest in the project has to be thought out thoroughly because such incorporations involve forgoing equity in the company that could have strategic consequences. Multiple evaluation techniques have to be considered and tested out before deciding which projects should be pursued amongst the simultaneous, multiple innovative ideas banked into the firm's "idea vault" that are competing for the firm's resources. These economic evaluation techniques have to be executed in a timely manner because speed is of the essence in exploiting technological discoveries in a constantly emerging and competitive global marketplace.

■ WA-09

Wednesday, 8:30-10:00 - Building CW, 1st floor, Room 12

Applications in Management Science

Stream: Emerging Applications in Portfolio Selection and Management Science
Chair: *Armin Fügenschuh*

1 - Multicriteria Evaluation of Pipe Organ Construction Projects
Tadeusz Trzaskalik, Malgorzata Trzaskalik-Wyrwa, Ireneusz Wyrwa

The construction of a pipe organ is a heterogeneous problem. Each interior, for which the instrument is planned, has its individual architectural and acoustic characteristics. The design of the instrument must be matched to the interior and therefore it will be individual and usually unique. Each investor commissioning a pipe organ also has his/her individual taste, preferences, and budget. These most important factors make the construction of a pipe organ a sum of the various relationships and a result of the willingness to compromise between objective factors and preferences of people. This paper presents the issue as a multiobjective task, in which we consider various criteria, such as size, volume, palette of timbres, etc., and show how the various options are presented to the investor. Will the best designers' solution be accepted by the investor and his/her budget? We should handle the various criteria so as to satisfy the investor without compromising the quality of the instrument.

2 - A Comparison of Parametric Modeling Approaches for Multi-response Design Parameter Optimization Problems
Gülten Gökayaz, Gülser Köksal

Product and process designers need to find most preferable settings of design parameters to simultaneously achieve multiple quality objectives based on some performance measures such as means and variances of quality characteristics or responses. In the optimization studies, typically empirical models of such performance measures are utilized. These models are usually developed using response surface methodology (RSM), based on data collected through statistically designed experiments, and using Ordinary Least Squares (OLS) regression method. One of the underlying assumptions of OLS is that the error terms have a constant variance at different design variable settings. However, the design parameter optimization problems are formulated and solved assuming that there exists a solution where the variance is minimal. Furthermore, OLS ignores the correlation between the responses since it fits the models individually. It is not known if alternative parametric modeling methods such as Weighted Least Squares, Generalized Least Squares, Multivariate Regression, and Seemingly Unrelated Regression perform better in solving these problems. In this study, accuracy of these RSM methods in estimating the performance measures of the responses are compared using joint confidence and prediction regions at given settings of the design parameters. Since these regions are not analytically available, they are approximated by means of a bootstrap method. Results of this comparison are presented.

3 - A Goal Programming Approach to Analyze Sustainable Development Goals of India
Armin Fügenschuh, Irfan Ali, Mohammad Asim Nomani, Aquil Ahmed

Energy policy, environmental planning and economic development play a key role in sustainable development. Sustainable development requires suitable and strategic policies satisfying multiple and conflicting objectives. The goal programming is a well known approach in multi-criteria decision making for its practical applications. In this paper a goal programming approach is presented to analyze environmental, energy and sustainability goals of India by the year 2030 with reference to the key economic sectors of India. The presented model analyzes the improvement opportunities, requirement of efforts and implementation of the sustainable development plans. Numerical illustration is also provided for validation and application of the proposed model.

■ WA-10

Wednesday, 8:30-10:00 - Building CW, ground floor, Room 1

AHP/ANP in urban planning and management of energy transition

Stream: Analytic Hierarchy Process / Analytic Network Process

Chair: *Patrizia Lombardi*
Chair: *Valentina Ferretti*

1 - Selection of Social Housing initiatives through Analytical Hierarchy Process and Choquet integral combined within Non Addititive Robust Ordinal Regression
Francesca Abastante, Salvatore Corrente, Salvatore Greco, Alessio Ishizaka, Isabella Lami

This research aims to test the application of an innovative multicriteria decision analysis (MCDA) framework to an urban problem. The Choquet integral is a well-known MCDA methodology taking into account interactions between criteria but it shows two main problems: 1) the need to determine a capacity that assigns a weight not only to single criteria but also to subsets of criteria; 2) the need to express on the same scale evaluations on different criteria. To handle the first problem we adopt the Non Additive Robust Ordinal Regression (NAROR) (Corrente et al., 2015) that considers simultaneously all the capacities compatible with the indirect preference information provided by the Decision Maker (DM). With respect to the second problem, we apply the Analytic Hierarchy Process (AHP). The proposed methodology is here applied to a current topic concerning the choice of allocation of the financial resources in Social Housing (SH) initiatives in Turin (Italy). The case study concerns the simulation of a decision process involving real actors aiming at selecting refurbishment interventions for properties envisaging a housing supply destined to "weak" segments of the population. The aim of the paper is to evaluate if and how the framework proposed could be useful in a similar decision problem, in particular because of the presence of a certain number of interacting criteria and a high number of alternatives that can be handled by the model.

2 - Multicriteria Analysis toward sustainable spatial planning. The case of the Smart Susa Valley project
Dafne Regis, Marta Bottero, Angioletta Voghera

The present contribution focuses on the topic of spatial planning and design, meant as a framework of strategies, tools and methods for implementing territorial transformations, defining innovative perspectives of socio-economic development and promoting new urban sustainability's practices. In this context, programmatic, multi-functional, cross-sectoral and inter-scalar spatial planning and design approaches have to deal with complex issues that involve public decisions. This complexity requires a high integration of planning and design activities with evaluation techniques. In the work we present an application of the Analytic Network Process (ANP) technique to rank alternative actions related to the Smart Susa Valley (SSV) territorial project. SSV is an institutional project which focuses on territorial regeneration toward new smart, inclusive and sustainable scenarios. The project is financed by the international fund for the compensations related to the realization of the Turin-Lion high speed railway. In particular, the ANP model has been organized in different networks and subnetworks in order to consider the complexity of the SSV project, which is structured according to axes of intervention, measures and actions. The evaluation process has been supported by a combination of various participatory methods (interviews, questionnaires, focus groups) that allowed to include in the ANP model the opinions of the different stakeholders involved in the decision problem.

3 - Consensus based siting of wind power (ConSite Wind)
Frank Hanssen, Roel May

Norway's campaign for expanded wind energy production cause increased pressure on Norwegian wilderness areas. Emerging construction projects demand improved planning and decision support tools. The Norwegian Institute for Nature Research (NINA) is developing a Spatial Multi-Criteria Decision Analysis tool (SMCDA) for siting of onshore wind-power named ConSite Wind (Consensus Based Siting). ConSite Wind aims to secure stakeholder participation, conflict reduction, re-examination and improved decision making. The tool is structured into the operational steps of a classical SMCDA: Problem structuring (dialogue meetings), value functions (fuzzy logic normalization), weight assessment (AHP), aggregation (WLC/OWA) and sensitivity analysis. All criteria maps are normalized into conflict maps according to the stakeholders/experts degree of acceptance ranging from 0 (low conflict) to 1 (high conflict). Siting options in low-medium conflict areas is finally outlined and evaluated according to the areas overall suitability. ConSite Wind has great inter-disciplinary synergies and addresses the societal demands for transparency and democracy in public decision making. This was emphasized by the EU Commission DGE Environment at the Geospatial World Forum in Rotterdam in 2013. ConSite Wind is currently implemented in conflict zoning and siting of wind-power plants in Lithuania.

4 - The Analytic Network process for the resilient scenarios in Trentino, Italy
Ombretta Caldarice, Grazia Brunetta, Patrizia Lombardi

Trentino is an Italian cross-border region characterised by internationally renowned landscape values and a lively tourist and retail demand. Recently, Trentino planning policies are been retaught thanks to Territorial integrated evaluation (Tie), a scientific methodology that builds innovative technical knowledge and orients the regional planning policies linking the territorial development with the environmental sustainability. In this perspective, Tie has designed one development scenario for each Trentino Valley Community (VC) looking simultaneously at retail, tourism, territorial infrastructures, environment and landscape. In order to define the strategic feasibility of the territorial development scenarios, Tie was reinforced and augmented by a multi-criteria Analytic Network Process (ANP) model. The ANP model is developed both at the VC and municipal level and shows indicators' priorities to the relative control criterion for a better definition of Tie territorial development scenarios. Starting from this framework, the paper aims to illustrate the ANP model and its application in a specific Trentino area (Val d'Adige VC and its pole, Trento) describing the ANP approach restructured for the Tie methodology. Finally, the paper discusses the ANP model's potential as an instrument that can support the policy makers in participative processes and in designing territorial development policies.

■ WA-11

Wednesday, 8:30-10:00 - Building CW, 1st floor, Room 127

Imprecise probability

Stream: Probabilistic Models
Chair: *Barbara Vantaggi*

1 - Probabilistic merging and revision via efficient L1-distance minimization
Andrea Capotorti

The risk of dealing with incoherent probability assessments is significantly present when the numerical evaluation comes from different sources of information and/or structural constraints limit the possible states. We propose an effective procedure which corrects an incoherent probability assessment on a finite domain by exploiting a geometric property of L1-distance (known also as Manhattan distance) and linear mixed integer programming. We profit from the polytope structures of both sets of coherent probability assessments and of L1 "balls" and from a translation of both objective function and coherence requirements in linear constraints involving integer and real variables. This represents a computational advantage compared to other distances that imply implementation of non linear (quadratic, logarithmic, etc.) optimizations tools. Our minimization applied to partial probability assessments does not produce, in general, a unique solution but rather a whole set of candidates that can be interpreted as an imprecise probability model. This could represent an alternative way, with respect to the historical ones, of legitimating the adoption of imprecise probabilities. Our methodology can be easily applied to the merging of separate assessments whose direct juxtaposition is incoherent, and to the revision of beliefs, where new evaluations must be taken as grated even inconsistent with the previous. An example shows the steps of the various procedures.

2 - On the median in imprecise ordinal problems
Sebastien Destercke

When having to make a prediction under probabilistic uncertainty in ordinal problems, the median offers a number of interesting properties compared to other statistics such as the expected value. In particular, it does not depend on a particular metric defined over the elements, but still takes account of the ordinal nature of the data. It can also be shown to be the minimizer of the L1 loss function. In this paper, we show that similar results can be obtained when the uncertainty is described not by a single probability distributions, but by a convex set of those. In particular, we relate the lower and upper medians to the L1 loss function via the notion of lower and upper expectations (and extend these results to general quantiles). We also show that, using a different decision rule, the lower and upper median can be retrieved when assuming the cost to be strictly monotonic and symmetric, and nothing more. Finally, we run some tests to show the interest of using Median based predictions with convex sets of probabilities in ordinal regression problems.

3 - LQ optimal control for partially specified input noise
Alexander Erreygers, Gert de Cooman, Jasper De Bock, Arthur Van Camp

We consider the problem of controlling a discrete-time scalar linear system subject to stochastic input noise, using a state-feedback control policy whose performance is measured by means of a quadratic cost.

If the stochastic model for the noise is specified exactly, a control policy is said to be optimal if it minimises the expected value of the cost. For independent noise, such an optimal control policy is known to be unique, and consists of a combination of state feedback and noise feedforward.

Our first contribution consists in showing that this result remains true for dependent noise. However, in this generalised case, computing the optimal control policy is intractable.

Next, our main contribution consists in additionally dropping the assumption that the stochastic model for the noise is specified exactly. Basically, we impose local bounds on the expectation of the noise, and consider the set of all (possibly dependent) stochastic models that are compatible with these bounds. In this context, we call a control policy optimal if it minimises the expected value of the cost for at least one of these compatible noise models. We show that any such optimal control policy consists of the same state feedback term and a possibly different noise feedforward term, and we derive backwards recursive expressions that provide tight bounds on these noise feedforward terms. These bounds are easy to compute, and the recursive expressions turn out to be very familiar.

4 - Credal Likelihood: an Imprecise Probability Approach to Model Unobserved Heterogeneity
Thomas Augustin

From econometrics and the social sciences to biometrics and epidemiology, a frequent problem in applied regression analysis is unobserved heterogeneity (frailty), i.e. the situation where the underlying probability distributions depend not only on covariates but also on unobservable additional individual characteristics (like personal attitudes or hidden genetic dispositions). Most traditional methods to cope with this problem require to assume and specify a precise probability distribution for the corresponding latent variable, in order to be able to integrate out its effects. We suggest an alternative approach that is based on the idea of imprecise sampling models where likelihood contributions depend on individual parameters, varying in an interval. Based on this, we directly fit an optimal credal set to the data. In our presentation we introduce the basic concepts of this credal maximum likelihood approach, discuss practical calculation of the resulting estimators as well as some of their general properties, and compare our results with the traditional approach in different situations. The talk will conclude with some reflections on the general role imprecise sampling models can play in statistics when we use them actively as a powerful modelling tool.

■ WA-12
Wednesday, 8:30-10:00 - Building CW, ground floor, Room 029

New Trends in Combinatorial Optimization

Stream: Combinatorial Optimization
Chair: *Mutsunori Yagiura*
Chair: *Hirotaka Ono*
Chair: *Yuichi Takano*

1 - Minimax Regret 1-Median Problem in Dynamic Path Networks
Yuya Higashikawa, Siu-Wing Cheng, Naoki Katoh, Shun Saburi

We consider the minimax regret 1-median problem in dynamic path networks. In our model, we are given a dynamic path network consisting of an undirected path with positive edge lengths, uniform positive edge capacity, and nonnegative vertex supplies. Here, each vertex supply is unknown but only an interval of supply is known. A particular assignment of supply to each vertex is called a scenario. Given a scenario s and a sink location x in a dynamic path network, let us consider the evacuation time to x of a unit supply given on a vertex by s. The cost of x under s is defined as the sum of evacuation times to x for all supplies given by s, and the median under s is defined as a sink location which minimizes this cost. The regret for x under s is defined as the cost of x under s minus the cost of the median under s. Then, the problem is to find a sink location such that the maximum regret for all possible scenarios is minimized. We propose an O(n3) time algorithm for the minimax regret 1-median problem in dynamic path networks with uniform capacity, where n is the number of vertices in the network.

2 - Consistent Neighborhood Search for Bin Packing
Michel Vasquez, Mirsad Buljubasic

We present a consistent neighborhood search approach to solving the one-dimensional bin packing problem (BPP). The goal of this local search is to derive a feasible solution with a given number of bins, m, starting from m = UB-1, where UB is an upper bound obtained by using a variation of the classical First Fit heuristic. To this end, the local search was performed on a partial solution with m-2 bins, i.e. a solution containing a subset of items packed into m-2 bins without capacity violations and a set of non-assigned items, with the objective of minimizing the total weight of non-assigned items and, ultimately, packing all the non-assigned items into two bins. A partial solution was constructed by deleting bins from the last complete solution. Local moves include rearranging the items assigned to a single bin along with non-assigned items, i.e. removing and adding items to the bin. A tabu search was performed with moves featuring a limited number of items to be added/dropped, plus a hill climbing/descent procedure with general (unlimited) add/drop moves, in order to minimize a given objective function. Promising results were obtained for a very wide range of benchmark instances; solutions were obtained that equalled or improved the best known found by heuristic methods for all the instances considered, successfully outperforming published results for the particular class of instances hard28, which appears to cause the greatest degree of difficulty for BPP algorithms.

3 - The dependency of optimal road repair schedules on routing strategies
Shungo Koichi

We propose two mathematical programming models to deal with a scheduling problem on the renovation of several roads that need to be repaired by certain dates. Our idea behind the formulation of the models is that, if one optimizes sets of roads simultaneously under repair, then the influence on traffic can be minimized. One of the differences between the two models is routing strategies. The first model supposes that drivers choose their own shortest routes independently of traffic volumes, which allows us to formulate the model as a 0-1 integer programming. Moreover, an additional simple assumption linearizes the

0-1 integer programming model. The second model adopts the so-called user equilibrium flow, which requires more computational cost but makes the second model more realistic than the first model. We compare the results for the two models to show the dependency of optimal road repair schedules on routing strategies. By introducing n-away pairs of roads, we grasp the features of the two models.

4 - Feature Subset Selection for Logistic Regression via Mixed Integer Optimization
Yuichi Takano, Toshiki Sato, Ryuhei Miyashiro, Akiko Yoshise

This talk concerns a method of selecting a subset of features for a logistic regression model. Information criteria, such as the Akaike information criterion and Bayesian information criterion, are employed as a goodness-of-fit measure. The purpose of our work is to establish a computational framework for selecting a subset of features with an optimality guarantee. For this purpose, we devise mixed integer optimization formulations for feature subset selection in logistic regression. Specifically, we pose the problem as a mixed integer linear optimization problem, which can be solved with standard mixed integer optimization software, by making a piecewise linear approximation of the logistic loss function. The computational results demonstrate that when the number of candidate features was less than 40, our method successfully provided a feature subset that was sufficiently close to an optimal one in a reasonable amount of time. Furthermore, even if there were more candidate features, our method often found a better subset of features than the stepwise methods did in terms of information criteria.

■ WA-13

Wednesday, 8:30-10:00 - Building CW, ground floor, Room 3

VeRoLog: Inventory routing

Stream: Vehicle Routing and Logistics Optimization
Chair: *Olivier Peton*

1 - Inventory Routing Problem
Chanicha Moryadee

The inventory routing problem (IRP) integrates two components of supply chain management: inventory management and vehicle routing. These two issues have been traditionally dealt with the problems in the area of logistics separately, but their integration can have a greater impact on overall system performance. This research studies the IRP that deals with direct deliveries from the supplier with and without transhipments (Inventory Routing Problem with Transhipment, IRPT) between customers in conjunction with multi-customer routes in order to increase the flexibility of the system. The research is structured around two main aspects: development of the optimisation models for IRPT and IRP for deterministic and stochastic demand, and development of heuristic, meta-heuristic and sim-heuristics approaches to solve the problem. The advantage of using heuristics, meta-heuristics and sim-heuristics is that they can solve large problems faster. Specifically, Clark and Wright Saving and randomised Clark and Wright Saving algorithms are adopted to solve deterministic and stochastic IRPT and IRP problems respectively. The algorithms are coded in Java language with eclipse software and all the tests are run on a computer with the specification of Core i5, 2.30 GHz processor and 4 GB of RAM. In the experiments, we consider the average over the five instances for each combination and compared both algorithms. This is the first time that CWS and Randomised CWS algorithms are used to solve

2 - Inventory routing problem in rolling horizon planning approach
Jacek Kaleta

In this paper, the solution approach for the inventory-routing problem in rolling horizon planning environment is presented. The combination of decisions concerning inventory management and vehicle routing yields a complex combinatorial optimization problem called Inventory Routing Problem (IRP). It arises when both inventory and routing decisions must be made simultaneously. The main targets of the paper are identification and evaluation of expected savings due to replacement of classical VRP by IRP approach (in terms of business standpoint: replacement of classical ordering system by the solution based on VMI concept).Potential advantages of VMI approach implementation for consolidated deliveries are identified. Identification and evaluation of potential savings due to replacement of classical VRP by IRP approach are the main targets of the paper. Distribution plans based on classical VRP algorithms are compared with IRP-approach-based plans for different periods of rolling horizon planning environment. One of the focus is on creating a solution methodology appropriate for real-life instances which is critical for company resources planning and fleet utilization. Computational experiments demonstrating the effectiveness of proposed approach are presented.

3 - Optimization of biomethane collection
Olivier Peton

We optimize the collection of biomethane at a set of biogas farms that convert agricultural waste to biogas. We consider a relatively small set of farms spread over a radius of approximately 100km. The biomethane is brought to a unique collection and processing facility where it is injected into a national gas network.

The goal is to plan the collection of biomethane at the farms, while minimizing the routing costs and satisfying maximal inventory constraints. Since there is one inventory at each farm, the problem can be formulated as an inventory routing problem. Due to the relatively small number of collection points, we formulate the problem as a set partitioning model that relies on a predetermined set of feasible routes. This formulation is solved with the Cplex solver.

We present numerical results corresponding to a real-life case study in western France, compare various transporation scenarios, and suggest future research directions.

4 - The Joint Replenishment Problem with Approximated Routing Costs
Annelieke Baller, Said Dabia, Wout Dullaert

In the Inventory Routing Problem (IRP) the amount and timing of deliveries to individual customers is determined to minimize inventory holding and transportation costs. Given the complexity of the IRP, existing solution approaches are limited to solving small to medium-sized instances. We propose an alternative approach reminiscent of the Joint Replenishment Problem to minimize inventory holding and transportation costs in large scale distribution problems. Rather than servicing customers in an explicit route, subsets of customers are created and their routing cost is approximated. To determine replenishment quantities at the level of individual customers and delivery moments at the level of subsets of customers, a branch-and-price framework is used. The master problem selects for each day at most one customer subset to be delivered by one or several vehicles to minimize costs. The customers subsets are determined by a pricing problem for which we are examining alternative approaches using routing cost approximations. The inventory routing problem under consideration is inspired by a real life case in replenishing ATMs. The branch-and-price framework is therefore tested on both artificial problem instances and real-life data.

■ WA-14

Wednesday, 8:30-10:00 - Building CW, 1st floor, Room 125

Optimization in Liner Shipping

Stream: Maritime Transportation
Chair: *Dario Pacino*

1 - An algorithm for optimizing the container vessel stowage slot planning
Ramon Alvarez-Valdes, Dario Pacino, Francisco Parreño

The stowage planning problem, in which a plan is developed for the position of the containers in a ship, is, according to the state-of-the-art, most efficiently solved in two phases. In the first phase, Master Planning, groups of containers are assigned to locations in the ship. In the second phase, Slot Planning, the exact position of each container is determined. In this paper, we address the slot planning phase, in which the containers assigned to a container ship location have to be stowed, satisfying many conditions related to the way in which containers have to be stacked, the weight distribution, and the specific conditions regulating the containers with dangerous products. The main objective is to pack as many containers as possible, all the assigned containers if they feasibly fit into the location, and the secondary objective is to minimize the number of unproductive moves of containers that have to be removed just to get access to other containers below them. In order to study the structure of the problem, we have developed an integer linear model. In order to efficiently solve problems of realistic size, we have developed a GRASP algorithm which includes two constructive methods, several randomization strategies, and several improvement moves. The algorithms have been tested on both a set of real-world and custom generated instances. The results show that the GRASP algorithm obtains good results in a wide range of problems.

2 - Will liner ships make fewer port calls per route?
Judith Mulder, Rommert Dekker

Traditional liner shipping route networks consists of many port calls per route. However, container ship sizes have increased substantially over the past few years. These large container ships benefit from economies of scale at sea, but might suffer diseconomies of scale in ports. Therefore, we investigate whether larger container ships will lead to fewer port calls per route. We propose a mathematical approach to obtain networks with fewer port calls per route. Liner shipping route networks are generated by distinguishing between hub routes and regional routes. Hub routes are used to connect a small number of hubs, while regional routes connect all other ports with its nearest hub. An iterative approach is used to generate networks, which are evaluated using a mixed integer program in which the joint ship allocation and cargo routing problem is solved. A case study is performed with different combinations of seven potential hub ports. In the case study, three capacity scenarios are considered: low, base and high capacity. Our networks generate profits that are more than 20% higher compared with the best known networks in literature.

3 - A Matheuristic for Block Stowage Planning with Crane Intensity
Dario Pacino, Roberto Roberti

The ever growing size of todays liner ships, has turned on the interest of liner shippers towards stowage plans that are easier to produce and can have a better turnaround time at port. In this talk we will introduce two new planning concept used by the industry: block stowage and crane intensity. We proposed a compact formulation of the problem and show that seemingly simplifications of the problem hide some combinatorial complexity that is not very well suited for compact model. We then proposed a set of benchmark instances and a matheuristic approach to solve them. Future work and new challenges will then finally be presented

■ WA-15
Wednesday, 8:30-10:00 - Building CW, 1st floor, Room 126

Multi-objective supply chains

Stream: Supply Chain Management
Chair: *Cagri Sel*

1 - Fuzzy multi-objective supplier selection considering risk and a strategic plan
Magdalena Ronge, Dobrila Petrovic

The paper concerns a selection of suppliers in a large real-world manufacturing supply network. The suppliers are selected considering three objectives including minimization of the total cost and risk and maximization of the strategic plan achievement. Two decision variables are introduced to handle risky suppliers - safety time for suppliers with consistent delivery problems and safety stock for critical products supplied by suppliers with a high non-conformance rate. The risk is modelled using two parameters: the product risk (related to the product complexity and the authority of the relevant supplier) and the supplier risk (related to the quality and delivery performance indicators). The achievement of the strategic plan considers categorisation of the suppliers into four categories: E-exit suppliers with bad scores, M-maintain suppliers with good scores difficult to replace, G-grow suppliers with increasing importance and N-new strategically important suppliers. Uncertain contributions of the four supplier categories to the achievement of the strategic plan are described by imprecise terms such as low, medium, high or very high and are modelled using fuzzy numbers. Depending on user preferences, each objective can be assigned different importance. The fuzzy multi-objective optimisation model is transformed into a corresponding crisp optimisation model with a single objective to maximise satisfaction degree of attaining the optimal value of each objective.

2 - Stochastic optimization of the collaborative manufacturing and service chains: the catering industry
Cagri Sel, Mehmet PinarbaŞi, Mehmet Soysal, Mustafa Cimen

Supply chain management revolves around the flow of good, i.e., the movement and storage of raw materials, work-in-process inventory, and finished goods to point of consumption. Though often related to products, supply chain management can have service origins. The purpose of this study is to design a catering supply chain that builds on the complementary strengths of the production and service characteristics. The production characteristics include planning of mass production, lot-sizing, and scheduling required to deliver the food, while the service ones are the operations associated with the assembly line systems that serve foods. Demand uncertainty influences customer service level negatively in the catering sector. If production is in excess of demand, food waste occurs and if the quantity is produced in short of demand, this leads to shortage. To address this problem, we develop a stochastic programming model accounting for the key performance indicators of total waste and total shortage. The consideration of the aforementioned indicators enables to assess the sustainability performance of the catering supply chain. The numerical study we present is based on a catering organization of a University cafeteria in Turkey. The added value of the proposed decision support model has been shown through the analyses on the base case. Therefore, the model can aid decision making process in production and distribution planning in the catering industry.

3 - Performance evaluation of a merge supply network with multiple unreliable random suppliers and a distribution centre via matrix analytic methods
Michael Vidalis, Alexandros Diamantidis, Michael Geranios, Stelios Koukoumialos

This paper examines the confluence of supplier's availability and lead-time uncertainty on a two echelon discrete flow push convergent supply network system. The first echelon consists of a distribution centre with identical parallel servers exponentially distributed and a shared buffer of finite capacity. The second echelon includes multiple non-identical merging unreliable suppliers that feed a distribution centre. Each supplier has different service, breakdown and repair rates, all exponentially distributed. The supply network is modelled as a continuous time Markov process with discrete states. Matrix analytic methods is used to explore the structure of the transition matrices of these specific systems. Next a computational algorithm is developed to generate stationary distribution for different values of the system characteristics. The effect of certain system characteristics, such as the parameters of each supplier, the capacity of the buffer and the distribution centre and the number of suppliers, on specific performance measures of the system, like the output rate (throughput), the work in process (WIP) of the system and the distribution centre is explored through numerical experiments. The proposed algorithm is used as an optimization tool to figure out which is the best configuration of the system in order to achieve the maximization of the system performance measures

■ WA-16

Wednesday, 8:30-10:00 - Building CW, 1st floor, Room 128

Ambulance Fleet Management 1

Stream: Healthcare Logistics
Chair: *Amir Rastpour*

1 - Locating Emergency Vehicles with an Approximate Queueing Model and a Meta-heuristic Solution Approach
M. Altan Akdogan, Z. Pelin Bayindir, Cem Iyigün

In this study, the problem of optimal location decision of Emergency Service (ES) vehicles such as ambulances, fire trucks and patrols as a server-to-customer service is discussed. Hypercube queueing model (HQM) are employed to achieve performance measures that are significant to the location decision of ES vehicles. As an extension of this model, Spatial Queueing Model (SQM) is introduced for spatial networks. This study proposes a generalization of SQM for complete networks. Districting of the demand regions with respect to the travel times is used to approximate the service and the interarrival times in Approximate Queueing Model. Service times for the calls are differentiated for every demand call regarding the location of the responding vehicle and the demand call. The approximations in SQM is questioned in terms of quality regarding the districting levels, and results are reported against various network parameters such as traffic intensity or distribution of demand regions over the area. The number of servers located in a single location is taken unrestricted. The effect of allowing multiple servers in a location is reported. A genetic algorithm is proposed to solve the model for which no closed-form expression exists and its performance is reported.

2 - The Importance of Forecasting in Ambulance Deployment Models: Sensitivity Analysis
Hubert Setzler, Hari Rajagopalan, Cem Saydam, Sanjaya Mayadunne

Demand for ambulances is known to fluctuate spatially and temporally by day of the week, and time of day. EMS managers have the option of redeploying their fleet to compensate. To help EMS managers with their redeployment there has been a number of models in literature which try to optimize the locations and the redeployments to maximize coverage. These redeployment models are dependent on the forecast of calls, and while there is literature for forecasts for emergency medical response for an entire year or for an entire city, the input needed for redeployment models usually requires data at a finer granularity in space and time. There are few forecasting models which try to predict ambulance calls at different temporal and spatial granularities. We shall study at how robust ambulance redeployment models are to forecasting errors. We will produce forecasts of varying error and input them into a redeployment model. We will then take the locations prescribed by the redeployment model and validate the coverage using a simulation which uses the actual data instead of the forecast. The difference between the coverage predicted by the redeployment model and the simulation will tell us how sensitive the redeployment model is to forecasting error. These results would be important to the EMS research community.If the redeployment models are not very sensitive then it may not be worth the time and effort researching into forecasting methods which only provide marginal improvements.

3 - From Theoretical Models to Practical Use in the Ambulance Dispatch Center
Martin van Buuren

High standard ambulance care is considered a human right in today's society. At times of increasing demand, the merging of dispatch centers and budget cuts, logistical decisions become far more complex for the medically schooled centralists. That makes it harder to hold on to these common standards. As applied mathematicians we can help ambulance service providers to maintain a good coverage by handing decision support tools that can be used at the dispatch center. We discuss practical issues of relocation models when they are brought into use at a real ambulance dispatch center, and how we can adapt existing models such that they better reflect the daily practice. This interactive presentation includes state-of-the-art mathematical (re)formulations, our experiences at the dispatch center, and counter-intuitive examples that illustrate how decision support tools contribute at this very moment.

■ WA-17

Wednesday, 8:30-10:00 - Building CW, ground floor, Room 0210

Retail Marketing

Stream: Demand and Supply Management in Retail and Consumer Goods
Chair: *Winfried Steiner*

1 - Market value of fair trade labels
Daniel Guhl, Friederike Paetz

In many product categories (e.g., coffee, chocolate) fair trade (FT) labels are common as a credible sign that products adhere to the guidelines of FT organizations. It seems like entering the FT market becomes more attractive for firms as the consumption of FT products rose considerably during the last decade. Furthermore, a large body of literature documents a positive willingness-to-pay (WTP) of consumers for FT products (avg. premium of almost 17% according to a recent metastudy). These papers, however, do not take competitors' reactions (i.e., the supply side of the market) and the costs of a FT label into account, and hence, the results may be misleading. The economic valuation of a FT label should better be defined as the change in the equilibrium profits. We study the German orange juice market in which none of the top-brands currently has a FT label. We estimate a mixed logit demand system using data from a choice experiment and price equilibria for several counterfactual scenarios are calculated using a fixed-point approach. In case of Bertrand competition on the manufacturer level and a retailer using fixed markups, the increase of the equilibrium price for the leading brand Hohes C when introducing a new FT-product as a product line extension, is certainly lower compared to the WTP for the FT label (0.29 Euro vs. 0.43 Euro). However, profits are still higher for Hohes C and, therefore, introducing the FT label would be advisable from an economic point of view.

2 - Maximizing expected category profits of retailers: The roles of nonlinearity and heterogeneity in price effects
Winfried Steiner, Anett Weber, Stefan Lang

Category management requires sales response models that are able to simultaneously estimate marketing mix effects for all brands of a product category. We therefore develop a general heterogeneity seemingly unrelated regression (SUR) model accommodating correlations between sales across brands. This model contains a latent class SUR model, the well-known hierarchical Bayesian SUR model and the homogeneous SUR model as special cases. We further propose a hierarchical Bayesian semiparametric SUR model based on Bayesian P-splines which comprises a homogeneous semiparametric SUR model as nested version. The results of an empirical application with store-level scanner data indicate that the flexible SUR approaches of modeling price response clearly outperform the various parametric (homogeneous and heterogeneous) SUR approaches not only with respect to predictive validity but also with respect to total expected profits. Since both flexible SUR models perform nearly equally well with respect to expected category profits a uniform pricing strategy which is much less complex to implement than micromarketing can be recommended.

3 - Discovering Profitable Pricing Rules In The Retail Industry
Luis Aburto

Traditional approaches for pricing decisions in the retail industry involve the use of transactional data to estimate a demand system as a function of all prices available in the category. Conditional on the demand system, store managers can decide the price levels to all products in the assortment to maximize sales or profit over the complete product category. There are several challenges in this process. To capture cross-elasticities, demand systems tend to be highly parameterized and possible endogeneity of prices might lead to parameters with signs different than expected. Additionally, when solving for optimal prices, first order conditions frequently suggest extreme solutions which are beyond of what managers consider reasonable. In this work we describe a data-driven methodology to help managers to identify business rules that are likely to lead to better performance. To do so, we extend association rules techniques to search in historical transactional data those combinations of prices that tend to be present when the overall performance of the category is better. Business rules identified through our methodology are easy to implement and can help managers not only to make more profitable pricing decisions but also to make more consistent decisions.

■ WA-18

Wednesday, 8:30-10:00 - Building CW, ground floor, Room 023

Computing and OR - Emerging Applications 1

Stream: Computing
Chair: *Yavuz Yilmaz*
Chair: *Gerhard-Wilhelm Weber*
Chair: *Omer Melih Gul*

1 - A Surrogate Based Multiple Discipline Feasible Bi-Level Integrated System by Using Neural Network
Somayeh Khosravi, Alireza Fakharzadeh

A new algorithm to solve multidisciplinary design optimization is introduced, which is called multi discipline feasible- bi-level integrated system synthesis (MDF-BLISS) in this paper. The MDF-BLISS algorithm can be classified in multistage-multilevel structural for multidisciplinary design optimization (MDO). MDF-BLISS is organized based on multi-discipline feasible and bi-level integrated system synthesis-2000 procedures. Efficiency of the proposed algorithm is demonstrated by solving two MDO benchmark tests.

2 - Achieving Asymptotically Optimal Throughput in Centralized Mobile Robot Networks without Dispatching Feedback
Omer Melih Gul, Aydan M. Erkmen

Recent years have witnessed an increasing focus on scheduling problems in centralized wireless mobile networks such as robot networks. Generally a centralized controller decides upon the robot dispatches which are the nodes of a network according to the knowledge of the robot to be able to communicate or not whenever scheduled to do so. On the other hand, the scheduling scheme with no direct knowledge of buffer states of nodes, or data arrival (DA) processes is recently investigated by assuming unit size buffer. In this work, we investigate the missing link in these problems which is considering heterogeneous robots with different dynamics and the maximization of the throughput sum of robots for infinite capacity buffer case. In our problem we consider a robot network which consists of M heterogeneous robot nodes having different dynamics and a data fusion center (DFC) that schedules K nodes in each time slot. DFC has no direct knowledge of buffer states of nodes, or DA processes; it only knows outcomes of transmission attempts. The objective is to find a simple policy whereby DFC can collect the maximum throughput in the error-free communication system. Although the problem can be modeled as the famous restless bandit problem, we model it under average reward criteria by only assuming that DA processes are mean ergodic. We propose UROP (Uniforming Random Ordered Policy) and prove that it is near optimal over a finite horizon and asymptotically optimal over infinite horizon.

3 - Optimization Under Privacy Preservation: Possibilities and Trade-offs
Rowan Hoogervorst, Yingqian Zhang, Sicco Verwer, Zekeriya Erkin

We investigate the trade-off between privacy and solution quality that occurs when a privacy preserving database is used as input data to a bin-packing problem. To minimize this trade-off we firstly suggest different methods of privacy preservation to minimize the extent to which data is perturbed, under the privacy criteria of k-anonymity and differential privacy. Here we investigate the effects of using different global recoding techniques for k-anonymity and suggest the loss metric as a utility metric to guide anonymization for optimization performance. Secondly, we suggest optimization methods that minimize the extent to which the data perturbation affects the feasibility and objective value of the found solution. Here we utilize the frameworks of robust and stochastic optimization to enforce chance constraints for the case of k-anonymity, while we propose a heuristic based on the Next-Fit bin-packing heuristic to minimize the effect of perturbation in the case of interactive differential privacy. In an empirical evaluation of the proposed methods, we find that for the case of k-anonymity the combination of K-Optimize and stochastic programming provides overall the best solution quality. This while we find for differential privacy that enforcing feasibility comes at great cost in terms of the number of bins used, where our suggested heuristic performs best at ensuring feasibility.

■ WA-19

Wednesday, 8:30-10:00 - Building CW, ground floor, Room 021

Graphs and Networks

Stream: Graph Searching
Chair: *Nancy Clarke*

1 - Some special case of de Bruijn objects
Rafał Witkowski

A k-ary De Bruijn sequence B(n,k) of order n, is a sequence of a given alphabet A with size k for which every subsequence of length n in A appears as a sequence of consecutive characters exactly once. De Bruijn matrix is an array of symbols from an alphabet A of size k that contains every m-by-n matrix exactly once. Our goal is to maximize the size of the matrix. We will define a rotation resistant De Bruijn matrix as a matrix where k = 4 and each symbol can be rotated: 1 -> 2; 2->3; 3->4; 4->1. We will try to give an answer as to how big such a matrix can be. We will consider, if there exist upper bounds for the size of a regular de Bruijn matrix. This problem finds an application in digital pen&paper technology, that will be presented during the lecture.

2 - On the cubical dimension of certain binary trees
Kamal Kabyl, Abdelhafid Berrachedi

The hypercube is a structure whose topology is used in different fields such as computer science, combinatorics, code theory, etc. Thus, the study of spanning of graphs in the hypercube has received much interest these later years. In fact many efforts have been devoted to find sufficient conditions under which a graph G is a subgraph of the hypercube. The problem consists of giving the smallest dimension of a hypercube in which a given graph is embeddable. We then talk about optimal hypercube and cubical dimension of the graph. In this paper we give a cubical dimension of several families of binary trees. Furthermore, we prove that several balanced binary trees satisfy the conjecture of Havel, which states that every balanced binary tree with 2 to the power n vertices is embeddable in the hypercube of dimension n.

3 - Counting Independent Sets on Polygonal Array Graphs
Guillermo De Ita, Raymundo Marcia-Romero, Pedro Bello-López

We present a novel linear-time algorithm for counting independent sets on two basic graph patterns: simple cycles and tres, and we show how to extend this initial method for processing more complex graph topologies, efficiently. For example, we consider polygonal array graphs that are graphical representations of chemical molecular compounds. We show how our method processes poligonal trees based on a 2-treewidth decomposition of the input graph. We have designed a 2-treewidth decomposition for any polygonal tree graph TP, where all common edge between two consecutive polygon will appear exactly in two consecutive nodes of the treewidth. This structure for the treewidth allows the efficient application of macros for solving counting problems on TP. Our method explotes the use of macros for performing repetitive operations appearing on the basic common patterns (polygons) that form TP. A pair of macros is associated to each basic graphic pattern in this decomposition, allowing us to represent and to perform a series of repetitive operations while the same pattern graph is found. This results in a linear-time algorithm for counting its number of independet sets. Our algorithm can be adapted to solve other intrinsic properties on polygonal tree graphs, impacting directly on the time complexity of the algorithms for solving those problems.

■ WA-20

Wednesday, 8:30-10:00 - Building CW, ground floor, Room 022

Cutting and Packing 2

Stream: Cutting and Packing
Chair: *David Pisinger*

1 - Integrating load-balancing into multi-dimensional packing problems
Alessio Trivella, David Pisinger

The bin-packing problem is one of the most investigated and applicable combinatorial optimization problems and consists in packing objects of different sizes into the minimum number of bins. In this work we consider its multi-dimensional version with the practical extension of load balancing, i.e. to find the packing requiring the minimum number of bins while ensuring that the average center of mass of the loaded bins falls as close as possible to an ideal point, for instance the center of the bin or the center of its base. This problem is much more difficult than the classical bin-packing problem, and hence is more challenging. We formally describe the problem using mixed-integer linear programming models and present a multi-level local search heuristic able to deal with large instances. The algorithm takes advantage of a representation of feasible packings in terms of particular classes of interval graphs, and iteratively improves the load balancing of a bin-packing solution using different search levels, which involve the transitive orientations of the graphs and dynamical search techniques for recombining n-tuples of weekly balanced bins. Computational experiments are very promising, making the approach applicable in a set of real-life logistic problems.

2 - Balance and weight limit constraints for the Container Loading Problem on road transport
António Ramos, Elsa Silva

The Container Loading Problem is a real-world driven, hard combinatorial optimization problem, which arises in the context of the transportation industry, and has a high economical, safety and environmental impact. The problem has been extensively studied in the literature, but still fails in meeting a number of needs of the transportation industry, as the existing algorithms do not adequately address practical relevant constraints. One of the reasons that contribute to the discrepancy between research and practice lies in is the fact that practical relevant constraints that are hardly suitable to be generalized through all the transport modes are addressed as if they were. An example is the balance constraint, a physical practical relevant constraint that is not likely to be modelled the same way for air, water or land transport modes whether for the physical characteristics of the transport modes as for the specific regulations that they are subjected to. The balance and weight limit are frequently addressed separately, even though they are intimately related. The balance constraint is usually enforced by guaranteeing the centre of gravity of the cargo being located within a given gap of the centre of gravity of the container. In this work we address the interrelation between the balance and weight limit constraints for road transportation, present a more realistic model of these constraints and incorporate them into a Multi Population Biased Random Key Genetic Algorithm.

3 - Realistic problem instances for Container Loading Problems
Elsa Silva, António Ramos

The optimization of the spatial arrangement of cargo inside transportation vehicles or containers, to maximize the CTU space usage, is identified in the literature as the Container Loading Problem (CLP), which belongs to the class of Cutting and Packing (C&P) problems. Generally in CLP a set of boxes must be packed inside a CTU, such that boxes do not overlap and lie entirely within the CTU, while maximizing the space utilization. Despite the significant amount of research that has been conducted on this problem, outputs have fallen short of being widely used by transportation companies, due to the inadequate way practical-relevant constraints have been dealt with.

The design of algorithms that simultaneously consider issues relevant to container loading in practice is a pressing issue. In order to allow the evaluation of the new algorithms, problem generators and/or challenging test problems for the CLP are also required. This need was already identified in the state-of-the-art-review for constraints on CLP presented by Bortfeldt and Wäscher (2013), and in fact, there are no problem instances in the literature considering all the characteristics which are required to test most of the practical-relevant constraints on CLP. In this work we will try to outline a problem generator which can be able to generate problems instances that characterize realistic constraints.

■ WA-21

Wednesday, 8:30-10:00 - Building CW, ground floor, Room 025

System design

Stream: Public Transportation
Chair: *Leo Kroon*

1 - Mixed integer programming approaches for synchronizing night urban bus services
Cristian Cortes, Cristiam Gil, Antonio Gschwender, César Núñez, Pablo A. Rey

In the context of the public transport system operating in Santiago-Chile, called Transantiago, operators define "planned" timetables for their services complying with Authorities, which regulates frequencies and capacities ranges. Instead of following these timetables, in actual operation the dispatching of trips is decided on real time according to the available fleet together with other conditions. This approach works well enough during the daily operation when demand and frequencies are high. However, during the operation at night, when demand is low and there are a reduced number of services operating with lower frequencies, this type of policy may result in longer waiting times (at initial and transfer stops) and a bad service quality for passengers.

To address these inefficiencies, Transantiago has defined a set of night services that would operate according to fixed and coordinated timetables. These timetables consider the possibility of holding vehicles in special "transfer stops" in order to improve the synchronization of different lines.

In this work, we propose a mixed integer programming model for defining the specific timetables and the duration of the holding periods. We analyze its performance for solving the problem under a set of possible objective functions.

2 - Multimodal City-Courier Network Topological Design
Tsung-Sheng Chang, Shuo-yen Wang

To help city couriers effectively reduce cost, service time and greenhouse gas emissions, this research tackles the problem of topological optimization of a city-courier's service network. The core competence of city-couriers lies in providing quick service. However, the use of fast transportation modes may cause large emissions of greenhouse gas. Hence, the city-courier seeks to use multiple transportation modes to balance the trade-off between cost, service time and greenhouse gas emissions. The considered transportation modes in this research include metro, motorcycle and walking. The raised research issue is thus how to seamlessly integrate these modes into a service network. This research first mathematically models the problem, which involves multiple objectives and time periods. Then, this research proposes a matheuristic approach to solve such a complex problem. Finally, the proposed method is applied to a real-life case.

3 - Network design problem for electrical bus
Yousef Maknoon, Shadi Sharif Azadeh, Michel Bierlaire

Electrical bus is an economical and environmental alternative to the existing public transportation. Despite its advantages, these buses have limited driving range which forces them to use charging stations during their daily tasks. The main obstacle of using such buses for public transportation is to make them compatible with the existing network structure. In this presentation, we present the results of our study on the problem at strategic level and as well as our optimization approach to minimize the total installation cost taking into account network requirements. We then apply our approach to the series of case studies.

4 - Time-oriented model as a support for solving the Park and Ride problem
Piotr Sapiecha, B. Prokop, Jan Wojciech Owsinski, Krzysztof Sęp

The study aims to explore the possibilities of applying graph theory in the Park & Ride problem. We propose a model, in which the vertices of the graph represent individual stops, and the edges correspond to average travel times with the public transport network. The number of edges is then constrained by a maximum allowed travel time parameter. Our approach is based on computing a minimum dominating set (MDS) of such a grapg in order to identify the strategic locations in the network. Finding MDS of an arbitrary graph is well-known to be an NP problem. We use three methods to solve the MDS problem (greedy approach, mixed LP, and tabu search metaheuristic). The locations of stops, contained in the resulting set, can be seen as fitting candidates for Park & Ride facilities, and can provide support in the decision making process. All computations were performed on the Warsaw's public transport dataset and were compared to the city's existing Park & Ride system. The greedy and tabu search algorithms were implemented using Python with MunPy, and Sage Math MDS algorithm was used for mixed LP. To calculate over 16 million average travel times between 4073 stops in Warsaw we used Open Trip Planner.

■ WA-22

Wednesday, 8:30-10:00 - Building CW, ground floor, Room 027

New Developments in Heuristic Search for Combinatorial Optimization Problems

Stream: Combinatorial Optimization
Chair: *Manuel Laguna*

1 - Statistical analysis of randomization in adaptive large neighborhood search
Lars Magnus Hvattum, Ahmad Hemmati

Randomization is common in many metaheuristics, and is typically a main ingredient when considering adaptive large neighborhood search (ALNS). We consider a standard implementation of ALNS for maritime pickup and delivery problems, identify seven randomized components in that implementation, and propose and analyze simple non-randomized alternatives to those components. The results reveal that for one out of seven components, the randomized alternative performs slightly better. The deterministic alternatives perform better for one component, while the randomized and deterministic alternatives have similar performance for the remaining five components. There seems to be a larger variance in the results obtained with only randomized components, compared to the results with only deterministic components, even though the average results are similar. Much of the randomization typically found in implementations of ALNS therefore seems redundant.

2 - A multi-pheromone Ant Colony System algorithm for aid distribution
Gregorio Tirado, José María Ferrer, M. T. Ortuno

In this work we consider a last mile distribution problem in a post-disaster situation where the vehicles used for the transportation of humanitarian aid must travel together forming convoys for security reasons. Multiple optimization criteria are considered, such as the duration or the cost of the operation, the equity of the distribution, the priority of certain nodes and the security and reliability of the itineraries. We develop an adaptation of the Ant Colony Optimization metaheuristic to solve this problem, providing the detailed itinerary of each vehicle. The proposed algorithm is based on an Ant Colony System (ACS) algorithm, in which pheromones are updated in two ways to enhance the elements that are part of the best solutions obtained throughout the process and to diversify the construction of solutions. In order to build a complete solution for the problem, which comprises several components, the construction of each solution is performed by the coordinated action of several classes of ants that leave different types of pheromones during their trips. Some results performed on a realistic case study are presented to evaluate the performance of the proposed algorithm.

3 - Models and Solution Methods for the Uncapacitated r-Allocation p-Hub Center Problem
Manuel Laguna, Angel Corberan, Rafael Marti, Juanjo Peiró

Hub networks are commonly used in telecommunications and logistics to connect origins to destinations in situations where a direct connection between each origin-destination (o-d) pair is impractical or too costly. Hubs serve as switching points to consolidate and route traffic in order to realize economies of scale. The main decisions associated with hub-network problems include 1) determining the number of hubs (p), 2) selecting the p nodes in the network that will serve as hubs, 3) allocating non-hub nodes (terminals) to up to r hubs, and 4) routing the pairwise o-d traffic. Hub location problems include all four decisions while hub allocation problems assume that the value of p is given. In the hub median problem the objective is to minimize total cost while in the hub center problem the objective is to minimize the maximum cost between origin-destination pairs. We study the uncapacitated r-allocation p-hub center problem.

■ WA-23

Wednesday, 8:30-10:00 - Building CW, ground floor, Room 028

Electric Vehicle Routing

Stream: Green Logistics
Chair: *Mario Ruthmair*

1 - Stochastic Macroscopic Energy Consumption Model for Electric Vehicle Routing
Bartlomiej Ohde, Grzegorz Slaski, Michal Maciejewski

Due to the limited range of electric vehicles (EV), accurate models of energy consumption are necessary for ensuring optimal operation of EV fleets. Because detailed microscopic models require speed profiles of high resolution, their use is limited to small optimization problems (combined with traffic microsimulation) or post-processing of registered floating car data (FCD). In real-life problems, however, when a limited amount of statistical data is available (e.g., average speed over time at each link in a road network), only macroscopic consumption models can be used for estimating the vehicles' state of charge over time and incorporating that information into the optimization model.

We propose a macroscopic model for EV energy consumption that takes the average speed driven on an urban link (typically, dozens to hundreds of meters long) and calculates the average consumed energy and its standard deviation. The model is made up of components that have physical interpretation, such as inertial force, rolling resistance and aerodynamic drag. The model was calibrated for the Nissan Leaf with FCD recorded in the Poznan agglomeration.

The model was added into the open-source MATSim simulation platform and tested on various simulation scenarios of dispatching and recharging electric taxis in Poznan.

2 - Cyclic Giant Tour Decoding for the Electric Vehicle Routing Problem with Time Windows
Christopher Bacher, Günther Raidl

The scope of our work is the development of efficient route-first-cluster-second decoders for the Electric Vehicle Routing Problem with Time Windows (EVRPTW). Such a decoder has to fulfill two purposes: Splitting a permutation of all customer nodes into several feasible routes and inserting recharging stations into the giant tour.

We contribute the following to the field: First, a giant tour decoder is provided for the EVRPTW. Second, the presented approach relies on Dynamic Programming (DP) for all steps of the procedure. In contrast the adapted Split-algorithm by Montoya et al. (2015) for the related Green Vehicle Routing Problem (G-VRP) recomputes the optimal insertion of recharging stations for each evaluated split. Further the pervasive use of DP allows us to efficiently treat giant tours as cycles, determining the optimal starting position of the first vehicle automatically while avoiding costly recomputations. As the decoder is intended for future use in heuristic approaches the DP also facilitates partial (re-)evaluation. Lastly, as a result of our work, we will provide an open source DP framework for declaratively specifying DPs. The framework borrows the tree grammar analogy of Algebraic Dynamic Programming (Giegerich et al., 2002) and features separation of search tree traversal and evaluation, dominance conditions, search space constraints, and partial invalidation and recomputation.

3 - Developing an Infrastructure Concept for Electric Vehicle Charging Stations Based on Real-world Data
Alexander Döge, Ferdinand Kiermaier

Efficient electromobility requires a well-developed infrastructure with appropriate charging stations. In most cities the infrastructure is inadequately developed; charging stations are either missing at all or are poorly distributed over the city. The latter also applies to Munich and is the reason why the city wants to invest in the expansion of the charging station infrastructure. We develop a novel heuristic to tackle this problem with the objective to cover the highest possible demand while keeping the investment cost at a reasonable level. The demand is modeled using real-world traffic data collected by one of the largest taxi companies in Europe. By tracking about 16,000 daily taxi journeys, we are able to implicitly consider different driving patterns and time dependent traffic. The numeric results reveal that our approach significantly improves the previous solution in terms of both the coverage and the investment cost.

4 - Models for Electric Vehicle Routing Problems with Load-dependent Energy Consumption
Mario Ruthmair, Luís Gouveia, Daniel Rebelo dos Santos

We study a generalization of the classical vehicle routing problem: Instead of vehicles with a conventional combustion engine we consider electric vehicles which usually have a strictly limited range. Given is a graph with a depot and a set of clients. Each client has a strictly positive demand. A network arc is defined by its travel cost, the energy consumed by an empty vehicle, and the additional energy when carrying a single load unit. Based on these values the total consumed energy on this arc depending on the current vehicle's load can be derived. These energy values can be negative if the vehicle is able to recover energy on a downward slope. The fleet is homogeneous with fixed load and SOC limits. We also consider special variants with a single vehicle and/or with strictly positive energy values. The objective is to find a set of routes with minimal total costs such that each route starts and ends at the depot, each client is visited exactly once, the total demand of all clients on a route must not exceed the load capacity, and the SOC stays within its limits. We present flow-based and load-discretized mixed integer linear programming formulations and corresponding branch-and-cut methods to solve them.

■ WA-24

Wednesday, 8:30-10:00 - Building BM, 1st floor, Room 119

Project Scheduling 2

Stream: Project Management and Scheduling
Chair: *Piotr Jedrzejowicz*
Chair: *Dariusz Barbucha*

1 - SGS-Based Cooperative Approximation Algorithm for Solving RCPSP
Ewa Ratajczak-Ropel, Piotr Jedrzejowicz

In this paper the cooperative approximation algorithm based on different Schedule Generation Schemes (SGS) for solving the Resource-Constrained Project Scheduling Problem (RCPSP) is proposed and experimentally validated. The RCPSP belongs to the NP-hard problem class. The current approaches to solve these problems produce either approximate solutions or can only be applied for solving instances of the limited size. Hence, searching for more effective algorithms and solutions to the problems is still a lively field of research. One of the promising directions of such research is to take advantage of the parallel and distributed computation solutions, which are features of the contemporary multiagent systems. In the proposed approach a team of software agents has been implemented using multiagent system to solve the problem. The team is the set of objects including multiple optimization agents and the common memory which through interactions produce solutions of optimization problems. The proposed team produces solutions to the RCPSP instances using the SGS-based optimization agents. Each SGS-based agent uses different SGS and local search procedure to produce solutions to the RCPSP. To validate the proposed approach computational experiment has been carried out.

2 - Cooperative Search Approach to the Dynamic Vehicle Routing Problems
Dariusz Barbucha

The main contribution of the paper is to propose a new cooperative search approach to the Dynamic Vehicle Routing Problems (VRPs). Static versions of the VRPs include a set of customers which have to be served by a set of vehicles in order to minimize the total number of vehicles and the total travel distance. Several constraints reflecting vehicle's capacity and customers requirements have to be also fulfilled. The dynamic versions of VRPs assume that some information depends on time, for example new requests may occur while the system is already running. With new request, the current solution has to be reconfigured to better serve the updated set of requests. Typical approaches to the VRPs include two phases: routing, where requests are assigned to available vehicles, and scheduling, where requests assigned to vehicles are scheduled. The proposed approach assumes the existence of a set of optimizing agents managed by a coordinator. Each agent is an implementation of a method dedicated to solve a problem. The main role of the coordinator is to combine these agents into an effective problem-solving strategy. The strength of the proposed approach stems from the cooperation between agents which exchange important pieces of information and thus producing synergy effect. Such information includes different statistics which may help to guide a process of solving the problem. Proposed approach has been evaluated using different dynamic scenarios and using several measures.

3 - Tools to Visualize Patterns and Structure in Team Communication Data
Sara McComb, Deanna Kennedy

Team communication may appear chaotic as it is occurring, but research suggests that it may be structured. While communication structures may change over time, they may be similar for teams with comparable performance. This research demonstrates various techniques for examining communication structures. Communication data from 60 laboratory teams was recorded, transcribed, and coded by topic (e.g., approach, rules, goals) and exchange type (e.g., information, suggestion, summary). Team performance was assessed by the time required to complete the personnel scheduling task they were assigned and the cost associated with their final schedule. Log-linear modeling was employed to examine message-to-message transitions between topics and exchange types. This analysis indicated that sequential structures exist in the data that are not attributable to chance. Thus recurrence plots illustrating high-level conversation progression across time and dendograms representing hierarchical clustering of topics and exchanges at specific time periods were constructed. These visualization tools depict differences in the communication structures of high and low performing teams and the way structural patterns change over time. In sum, results show that teams achieving the best time and cost performance hold streamlined conversations where fewer topics and exchanges are repeated. Rules and approach discussions are mixed early in taskwork and become more compartmentalized as the task progresses.

■ WA-25

Wednesday, 8:30-10:00 - Building BM, ground floor, Room 19

Behavioural issues in environmental decision support

Stream: Behavioural Operational Research
Chair: *Judit Lienert*

1 - How to make ambiguity an enabling factor in group decision: hints from drought risk management
Raffaele Giordano, Irene Pluchinotta

Drought affects many countries in the Mediterranean area, impacting the economic development of the communities and resulting in conflicts among water uses and users. Developing effective drought management strategies is of utmost importance. Evidences demonstrate that most of the existing policies failed to achieve their objectives. This work aims at demonstrating that conflicts emerge due to the neglecting of ambiguity in risk perception. Policies for drought risk management are largely based on technical knowledge. Different actors perceive drought risk differently, according to her/his previous experiences which, in turn, affect her/his mental frame. Differences in problem framing influence their decisions and behaviors to cope with drought. Ambiguity in problem framing and understanding is unavoidable in multi-actors decision-making processes but it may have diverse implications. On the one hand, it can enhance the co-production of knowledge offering opportunities for innovative solutions. On the other hand, it could lead to polarization of viewpoints, impeding the policy implementation. This work aims at supporting the group decision process for drought risk management by increasing the stakeholders' awareness about the impact of ambiguity on decisions effectiveness. To this aim a Causal Loop Diagram has been developed to analyse the trade-off mechanisms leading to policy resistance. The case of the Apulia region (southern Italy) has been used to test the methodology.

2 - Objectives hierarchy related biases in environmental MCDA applications - a meta-analysis
Mika Marttunen, Valerie Belton, Judit Lienert

Procedural and behavioural biases have recently received little attention in MCDA research. Our literature review shows that most bias research was done 15-30 years ago. The main objective of this study is to investigate whether prior findings regarding such biases, which were mostly based on laboratory experiments, can be found in real-world applications. We analysed 61 environmental MCDA cases. We examined the objectives hierarchies, weight elicitation procedures and 234 weight profiles. Our main research questions were: (i) how do hierarchy size and structure affect the objectives' weights? (ii) how are weights distributed across economic, social and environmental objectives? and (iii) is there support for the equalizing bias? Our findings are mostly in line with earlier research and demonstrate that the hierarchy structure and content greatly influence weight profiles. For example, hierarchical weighting is prone to the asymmetry bias, which can occur when a hierarchy has branches at the same level that differ in the number of sub-objectives. We found no evidence for the equalizing bias. This type of meta-analysis, which analyses objectives' weights of a large number of cases, has to date not been conducted in the MCDA field. Our practical recommendations highlight issues which deserve more attention when developing objectives hierarchies and eliciting weights.

3 - Serious games in environmental MCDA: enhancing preference construction and citizen involvement
Alice H. Aubert, Judit Lienert

Many call for participatory approaches in environmental modelling, which supports decision making (DM). We transfer this call to environmental MCDA on wastewater management. In Switzerland, many water infrastructures are ageing and major investments are needed. Deciding on these public investments, which requires transparency, is typically well-addressed with MCDA. We assume that involving citizens, in addition to decision makers and stakeholders, is beneficial. Our research questions focus on (i) how to elicit reliable preferences from citizens usually not involved in DM process; and (ii) how to get many of those reliable preferences? Serious games (SG) are an option to communicate about and with a (simplified) model of the decision issue. The player experiments with the model, triggering learning. He takes actions or makes decisions in the SG that leads to feedbacks: reward or penalization. Then, he evaluates his action: confirms or adapts his mental representation of the issue, i.e. further understands the model. At the end of the SG, he has learnt, i.e. has in mind an image of the model. We hypothesize that asking for the player's preferences at various steps of the SG will help us to understand how people make decisions, in particular, with regards to the construction of preferences. The talk will present the underlying hypotheses we aim to test in our study (first focusing on weight elicitation) and the experimental plan being applied.

4 - Messy Environmental Decisions - A Summary of BOR Challenges and Research Ideas
Judit Lienert, Fridolin Haag

A behavioral perspective to environmental and policy decision-making is largely lacking. Environmental decisions are often long-term, irreversible, publicly financed, "messy", they affect many people and include different types of uncertainty. Behavioral issues may be the cause of difficulties in later MCDA, or typical characteristics can have behavioral consequences. For example, the objective "good ecological state" is characterized by numerous ecological indicators. Properly representing them can result in too-large objectives hierarchies, technical attributes, and redundant objectives. Stakeholders can have difficulties to formulate preferences, and these are not well represented by additive aggregation. MCDA preference models should also capture different interests and include time aspects, e.g. preferences that endure beyond a single situation. We will summarize behavioral aspects important for environmental decisions and discuss some of our ideas: (i) stronger focus on problem structuring methods; (ii) reducing large objectives hierarchies; (iii) developing more-direct attributes for ecological objectives; (iv) dealing with elicitation biases and (v) uncertainty (e.g. scenarios); (vi) including timing aspects (preference stability, adaptive management); and (vii) including public preferences (online elicitation, serious games). These ideas exemplify different types of behavioral issues. We hope to spark a lively discussion about suitable research approaches.

■ WA-26

Wednesday, 8:30-10:00 - Building BM, 1st floor, Room 109D

Analytics on network data

Stream: Business Analytics and Intelligent Optimization
Chair: *Dries Benoit*
Chair: *Wouter Verbeke*
Chair: *Kristof Coussement*

1 - Using social network knowledge to enhance customer churn prediction
Wai Kit Tsang, Dries Benoit

Customer churn prediction plays a crucial role in Customer Relationship Management (CRM). Early detection whether a customer will leave the company or not, can prevent potential damage to the customer base. Basic churn models do not fully take advantage of the connectivity between customers and mostly consider a limited form of network information. A suitable approach to fully exploit the interrelatedness between customers is provided by probabilistic graphical models that can model the probability to churn by making use of graph structures and probability theory. By analyzing network information in a framework of probabilistic graphical models, knowledge about the connectivity among customers can be exploited to enhance churn prediction.

2 - Identifying influencers in a social network: the value of real referral data
Iris Roelens, Philippe Baecke, Dries Benoit

Individuals influence each other through social interactions and marketers aim to leverage this phenomenon to attract new customers. It still remains a challenge to identify those customers in a social network that have the most influence on others. A common approach to the influence maximization problem is to simulate influence cascades through the network based on the existence of links using diffusion models. Our study contributes to the literature by evaluating these principles using real-life referral behaviour. A new ranking metric, Referral Rank, is introduced that builds on the game theoretic concept of Shapley value for assigning each individual a value that reflects its likelihood of referring new customers. We also explore whether these methods can be further improved by looking beyond the one-hop neighbourhood of influencers. Experiments on real-life telecommunication and referral data show that using traditional simulation based methods can lead to suboptimal decisions as the results overestimate actual referral cascades. We also find that looking at the influence of the two-hop neighbours of the customers improves the influence spread and product adoption. Our findings suggest that companies can take two actions to improve their support system for identifying influential customers: improve the data by incorporating data that reflects actual referral behaviour or extend the method by looking at the influence of the connections in the two-hop neighbourhood.

3 - The World Trade Web: Evolution of International Trade and Globalization from 2000 to 2013
Dimitri Robert, Olivier Van Tongerloo, Thomas Crispeels, Wouter Verbeke

This study uses social network analysis to investigate the evolution of international trade and the globalization of the economy over the period 2000-2013. We employ a directed and weighted approach to build and analyze the world trade web using the UN Comtrade's exportation data between all countries. Since visualization of such large networks is not very representative nor useful, our framework looks in detail at centrality measures on a global as well as a local level. Globally, we look mainly at the degree (also its subparts in- and outdegree) and its weighted version, the (in/out) strength. The betweenness and closeness are also analyzed, but mainly for comparison with the local levels. For these local levels, we chose to analyze the centrality measures on the second order neighborhood. This choice is based on the network variables calculated on the global level. This will allow us to find out which countries are used most in trade routes. These are not the same countries as the ones on a global level. On a final note, we analyze the network and behavior dynamics in order to calculate how the network evolves in general and how it evolves based on different criteria (same language, continent etc.).

4 - Bluetooth Tracking of Humans in an Indoor Environment: An Application to Shopping Mall Visits
Dieter Oosterlinck, Philippe Baecke, Dries Benoit

Intelligence about the spatio-temporal behaviour of individuals is valuable in many settings. Generating tracking data is a necessity for this analysis and requires an appropriate and well-documented methodology. The intention of this research is to investigate the applicability of Bluetooth tracking in an indoor setting. This paper examines the value of the method in a marketing application. A Belgian shopping mall served as a real-life test setting for the methodology. A total of 56 Bluetooth scanners registered 18.943 unique MAC addresses during a 19 day period. The results of this research indicate that Bluetooth tracking constitutes a sound approach for capturing the necessary data. The tracking data can be used to map and analyse the spatio-temporal behaviour of individuals. The methodology also provides a more efficient and more accurate way of obtaining a variety of relevant metrics in the field of consumer behavioural research. Bluetooth tracking can be implemented as a new practice for marketing research, that is less expensive while at the same time providing faster and more accurate results and insights. We conclude that Bluetooth tracking is a viable approach, but that certain technological and practical aspects need to be examined when applying Bluetooth tracking in new cases. Suggestions and recommendations are provided concerning this aspect.

■ WA-27

Wednesday, 8:30-10:00 - Building BM, ground floor, Room 20

People and Nature

Stream: Case Studies in OR
Chair: *Bartosz Martynów*

1 - Foodborne Transmission Mechanisms for Norovirus
David Lane

Norovirus causes infectious intestinal disease. Its main vector is person-to-person (P2P) contact but it also transmits via foodborne mechanisms (FB). The UK's Food Standards Agency (FSA) commissioned work to: improve understanding of FB mechanisms; give insight into the relative importance of FB transmission; indicate where FSA might target efforts. The work took an existing P2P model and transformed its exogenous one parameter treatment into a fully developed account of the underlying FB causal mechanisms. Effects modelled were: sewage contamination of bi-valve shellfish; soft berry fruits & leafy vegetable contamination; contamination of other foodstuffs via infectious food preparers. FSA provided access to experts in relevant areas. FSA took the view from the outset that it might be difficult to obtain estimates for all parameters in an extended model. Model construction involved individual expert interviews and a group working session. As predicted, it was not possible to parametrise fully this new model. However, the work contributed to FSA understanding. (i) The detailed modelling made it possible to identify parameters as known/unknown and fixed/influencable. This was useful in agenda-setting for future research and in identifying policy levers. (ii) A slightly extended version of the P2P model, re-calibrated using new data, made it possible to analyse the extreme variation in NV cases across a year and understand the relative importance of FB and P2P vectors.

2 - OR for the Public Good: Experience of a Pro Bono Project
Howard Turner

The UK has both a thriving Operational Research community and a large charitable sector; in recent years, the OR Society has promoted pro bono OR projects, where OR professionals undertake projects for free to support charitable organisations and to promote OR.

Charityworks is a charity that recruits and places graduate trainees with organisations in the third sector. We report on a pro bono OR project aimed at increasing the effectiveness and efficiency of their selection process and of the initial matching of successful candidates to organisations.

We show how examples of classic OR problems may be found in the charity setting and describe adapting standard methods for solving the Assignment Problem in this project. We comment on the experience from both sides of introducing Operational Research into a new environment, and on the benefits and challenges for analysts, clients, and the OR profession.

3 - Prioritization of Wildlife Projects in Turkey
Ozay Ozaydin

Turkey has both a rich wildlife and a rich flora, but as Turkey is a developing country, the development projects, rapid urbanization, and industrialization threatens both. Under these imminent threats wildlife management is more crucial than ever. Even though environmental issues are desperately needing attention, mainly the lack of funding makes it almost impossible to focus. In this study, an AHP model is constructed and applied in cooperation with experts from World Wildlife Fund (WWF) Turkey and academia. The main goal of this model is to prioritize the candidate projects for wildlife preservation in Turkey. These projects are from different parts of Turkey, each having its unique impact on environment and wildlife. In the constructed model, the main criteria are determined as spatial configuration, continuation, socio-politics, environment, socio-economics, and presenting regional structure. In this case study, 14 projects are taken into consideration.

■ WA-29

Wednesday, 8:30-10:00 - Building BM, ground floor, Room 7

Personnel Timetabling

Stream: Timetabling
Chair: *Pieter Smet*

1 - Multi-skilled Workforce in Dual Resource Constrained Scheduling with Learning and Forgetting
Przemyslaw Korytkowski

In this paper we develop an algorithm for a workforce scheduling in a dual resource constrained problem. Worker learning and forgetting is modeled according to a learning forgetting curve model (LFCM). The multi-skilled worker because of his wide range of competences is often transferred from one task to another, depending on the needs arising from the demand of clients and organizational needs of the company. As a result, periods of intensive work on one task will be interspersed with idle periods for this particular task. During working time, the proficiency in executing the task will increase and during the idle period the proficiency will diminish. When a worker's skills are not interrelated, i.e. experience in performing one task does not translate into experience in performing another task, the well-known learning forgetting models apply to these circumstances. Often in reality these skills are related, as they could be used for example in consecutive working posts on a production line. In this case learning forgetting models are not able to reflect the entire experience gaining process. To describe a worker's possessed skills and the task's required skills we will use the concept of competence, which is broader than skills and thus allows embracing both hard (technical) and soft expertise.

2 - Cross-Trained Workforce Allocation with Temporal Demand Flexibility in Service Industries
Christopher Kirkbride

We present a multi-period cross-trained workforce planning model with temporal demand flexibility. Temporal demand flexibility is an option to utilise spare capacity by bringing forward (early completion) or delaying (demand carryover) the completion demand. Set in an aggregate planning stage we allow for the planning of a large and complex workforce over a horizon of many months. This stage is to provide a planning link between the traditional tactical and operational stages of workforce planning. The performance of the model is evaluated across a range of supply and demand characteristics to address the value of both the modelling of temporal demand flexibility and of cross-training as a supply strategy in this domain.

3 - A rich model for home care scheduling
Federico Mosquera, Pieter Smet, Greet Vanden Berghe

It has become increasingly common to provide care at home for groups with mobility issues, such as the elderly, rather than in nursing homes or hospitals. In the past, this trend required new approaches for the efficient organization and management of staff within home care organizations in order to meet the requirements incurred by this new model of care. Solving the resulting optimization problem was, and remains, a challenging task, even for experienced human planners, given the many factors requiring due consideration. Consequently, a significant amount of attention in operations research has been devoted to developing new algorithms for the automatic scheduling and routing of home care staff.

Academic models for this problem typically focus on the problem's routing aspect. As a result, the personnel rostering and task scheduling characteristics considered in the state of the art often oversimplify the practical requirements. The present study proposes a rich model and heuristic algorithm for home care scheduling problems with particular emphasis placed upon the complex nature of both task and employee characteristics encountered in practice. Consequently, the model simultaneously addresses both operational (short-term) and tactical (mid-term) levels, resulting in greater flexibility and efficiency gains.

4 - When are personnel rostering problems easy?
Pieter Smet, Patrick De Causmaecker, Greet Vanden Berghe

Research concerning personnel rostering, and, more generally, personnel scheduling, typically focuses on solving a given problem derived from a very specific context. Consequently, a large part of the academic literature on personnel rostering introduces algorithms tailored to one specific problem. Often, general complexity claims are made, referring to NP-complete problems that sometimes merely resemble the problem under discussion. One reason for this is that structured theoretical studies on models and complexity of personnel rostering problems are lacking in the state of the art literature. The present study investigates the structure induced by particular constraints in personnel rostering problems, with the aim of identifying new rostering problems that can be solved in polynomial time. This work effectively contributes to establishing the foundations for theoretical studies concerning models for rostering, while simultaneously allowing new insights into what it is that makes personnel rostering difficult.

■ WA-33

Wednesday, 8:30-10:00 - Building BM, 1st floor, Room 113

Planning and Scheduling Approaches for Complex Manufacturing and Service Systems 1

Stream: Scheduling, Sequencing, and Applications
Chair: *Lars Moench*

1 - **Integrated Disassembly Planning and Scheduling in a Shop Floor Environment**
Udo Buscher, Franz Ehm
The aim of disassembly is to remove parts from End-of-Life (EOL) products for recycling, remanufacturing and reuse. In contrast to the literature that focuses on line oriented layouts, we consider a shop floor environment with several specialized disassembly stations. In this case every disassembly task of a product needs to be processed on a specific station. As there are various feasible disassembly sequences, the product's processing order on the machines is not fixed but restricted only by simple disassembly precedence relations among its components. Furthermore, one product might require several tasks to be processed on the same station resulting in a complex scheduling problem. We refer to the literature on integrated process planning and scheduling and adapt it to disassembly planning. We present a MIP-model where all disassembly tasks of a given set of products have to be scheduled on the stations under the objective of minimizing makespan. The obtained schedule is supposed to find both an optimal order of the products to be processed on the stations and an optimal disassembly sequence for product's components. Further, a constructive heuristic is developed and first numerical results are presented.

2 - **A Decomposition Heuristic to Reduce Costs and Increase On-Time Delivery Performance in Flow Line Scheduling for Aircraft Manufacturing**
Lars Moench, Alexander Biele
A two-stage manufacturing system with limited intermediate storage between the two stages is considered in low-volume manufacturing as found in the aerospace industry. The first stage consists of parallel mixed-model assembly lines whereas identical parallel machines form the second stage. A combined objective function is used that accounts for the total weighted tardiness (TWT) of the jobs at the second stage and the total labor and inventory costs of the jobs at the first stage. The jobs have to be assigned to one of the parallel flow lines. Then the jobs have to be sequenced on each single assembly line. Workers have to be assigned to each job and station to compute start and completion times of the jobs at each station. Assignment and sequencing decisions have to be made for the jobs at the second stage to calculate the TWT value. A random key genetic algorithm (RKGA) is responsible to assign jobs to the assembly lines and sequence them there. The RKGA is hybridized with other heuristics to determine start and completion times of the jobs at the stations of the assembly line. A list scheduling approach is used to solve the scheduling problem at the second stage. Outsourcing is applied to respect the limited storage capacity between the two stages. Results of extensive computational experiments based on randomly generated problem instances and a real-world implementation of the heuristic are presented.

3 - **Minimizing Makespan with Multiple Orders per Job in Flowshops with Item-Processing Machines**
John Fowler, Jeffrey Laub, Lars Moench
We investigate the "multiple orders per job" (MOJ) problem for flowshops with an arbitrary number of item-processing machines. Leveraging our prior related results for two machine flowshops and capacity limited lot-streaming, we propose and evaluate multiple heuristics that use the "first or closest fit" adaptation of bin-packing and a modified version of the Nawaz heuristic for optimizing makespan. We characterize solution attributes to reveal the reasons behind their relative performance. We also demonstrate the performance of a heuristic that uses a simplification of complex equations from our prior work.

■ WA-34

Wednesday, 8:30-10:00 - Building BM, 1st floor, Room 116

Scheduling Theory and Applications

Stream: Scheduling Theory and Applications
Chair: *Federico Della Croce*

1 - **Parallel-machine Scheduling of Precedence Constrained Jobs with Position-dependent Processing Times**
Bartlomiej Przybylski
We consider a group of parallel-machine problems of non-preemptive scheduling of jobs with non-empty precedence constraints and processing times depending on the positions of the jobs in a schedule. The objective is to minimize the maximum completion time or the total weighted completion time. We specify certain conditions under which these problems can be solved by scheduling algorithms applied earlier for fixed job processing times. Our results are based on a transformation between schedules of jobs with fixed processing times and schedules of jobs with variable position-dependent processing times. Advantages and disadvantages of the proposed approach are illustrated by examples.

2 - **A Branch and Bound Approach for Single Machine Scheduling in the Automotive Supply Chain**
Paul Göpfert, Stefan Bock
In this talk we consider a real-world production process of an automotive supplier that can be modeled as a single machine scheduling problem with setup times, deadlines, precedence chains and raw material availability constraints. By minimizing total weighted completion time the objective aims at attaining high production efficiency. We propose a branch and bound approach including dominance criteria and feasibility tests. Lower bounds are derived by relaxation of different constraints reflecting the aspects of the scheduling problem at hand. A computational study investigates the lower bounds with respect to the trade-off between additional effort for their calculation and enumeration tree reduction.

3 - **Preemptive job scheduling with learning effect**
Marcin Zurowski
We consider scheduling of independent jobs on parallel machines. Jobs have variable processing times that depend on positions of the jobs in a schedule. The objective is to minimize the length of schedule. For this kind of problems, we propose a few definitions of job preemption. We illustrate their advantages and disadvantages by examples. For some special cases of considered problems we show polynomial algorithms.

4 - **Minimizing the number of tardy jobs in two-machine settings with common due date**
Federico Della Croce, Christos Koulamas
We consider two-machine scheduling problems with job selection. We analyze first the two-machine open shop problem and provide a best possible linear time algorithm. Then, a best possible linear time algorithm is derived for the job selection problem on two unrelated parallel machines.

■ WA-35

Wednesday, 8:30-10:00 - Building BM, ground floor, Room 17

Searching for Patterns

Stream: Computational Biology, Bioinformatics and Medicine
Chair: *Pawel Wojciechowski*

1 - Detection of DNA Replication Origins Based on Somatic Mutation Patterns

Roman Jaksik, Marek Kimmel

Mutations in the exonuclease domain of polymerase epsilon (POLE-exo) can impair its proofreading function, leading to an increased number of context dependent mutations, most of which are either TCT->TAT or TCG->TTG. Since polymerase epsilon is responsible only for the leading strand synthesis, the mutations are observed predominantly upstream from the replication origins, while reverse-complementary mutations are characteristic for the downstream regions. This phenotype provides the possibility to specifically map the positions of replication origins in the DNA, which are difficult to identify using experimental approaches. The main goal of this study is to create an algorithm identifying and characterizing the origins of replication, based on genome wide mutation patterns derived from whole genome sequencing experiments. It is inspired by a previous study of Shinbrot et al. [Genome Res. 2014. 24: 1740]. We employ data from The Cancer Genome Atlas among which we have found 11 cases with POLE-exo-specific mutation patterns. Using our custom algorithm we identified over 2800 potential replication origins, which showed a high preference to the DNA regions in the vicinity of Alu retrotransposons, of a specific chromatin conformation and low methylation level. We hypothesize that these factors are required for the binding of origin recognition complex (ORC), which constitutes the mechanism of DNA replication initiation in human cells.

Supported by DEC-2012/04/A/ST7/00353

2 - Natural vs. Random Protein Sequences: Discovering Combinatorics Properties on Amino Acid Words

Giovanni Felici, Daniele Santoni, Davide Vergni

Casual mutations and natural selection have driven the evolution of protein amino acid sequences that we observe at present in nature. The question about which is the dominant force of proteins evolution is still lacking of an unambiguous answer. Casual mutations tend to randomize protein sequences while, in order to have the correct functionality, one expects that selection mechanisms impose rigid constraints on amino acid sequences. Moreover, one also has to consider that the space of all possible amino acid sequences is so astonishingly large that it could be reasonable to have a well tuned amino acid sequence indistinguishable from a random one. In order to study the possibility to discriminate between random and natural amino acid sequences, we introduce different measures of association between pairs of amino acids in a sequence, and apply them to a dataset of 1047 natural protein sequences and 10,470 random sequences, carefully generated in order to preserve the relative length and amino acid distribution of the natural proteins. We analyze the multidimensional measures with machine learning techniques and show that, to a reasonable extent, natural protein sequences can be differentiated from random ones.

3 - StructAnalyzer - a Tool for Sequence vs Structure Similarity Analysis

Jakub Wiedemann, Maciej Miłostan

Comparative analysis of biological sequences and structures may lead to a determination of characteristic structural and functional elements of biological compounds. Thorough exploration of sequence-structure space allows to identify molecules (proteins or RNAs) having totally different sequences but similar structures, and - on the other hand - molecules with similar sequences but different structures. The latter case is currently the most interesting from our perspective, since it allows to identify sequences that are prone to significant structural change due to small number of point mutations. An analysis of multiple sequences and structures is quite complex in terms of computational time and complexity. Therefore, the use of parallel processing is indicated in such cases in order to get the results in less time. Here, we present StructAnalyzer - a tool for parallel sequence versus structure similarity analysis.

■ WA-36

Wednesday, 8:30-10:00 - Building BM, ground floor, Room 18

Big Data: Techniques and Applications

Stream: Information and Intelligent Systems
Chair: *Xinru Ma*
Chair: *Gerhard-Wilhelm Weber*

1 - The Long-term Relationship in IPOs: Evidence from a Big Data

Xinru Ma, Bo Liu

Using a big data of IPO bidding, allocation and Post-IPO trading, we empirically investigate the economic causes and consequences of long-term relationship between bidders and underwriters in IPO underwriting process. After controlling for learning effect and inherent bidding style of institutional bidders, our results indicate that the long-term relationship between bidders and underwriters can reduce participation uncertainty, mitigate free-riding problem and increase information production for uniform price IPO auction process. As a feedback, underwriters will adjust the offer price to increase the long-term friends' allocated probability and allocated shares. Furthermore, long-term friends flip more and can obtain higher return. The results shed light on the role of long-term relationship between bidders and underwriter in price discovery process of IPOs underwriting.

2 - Heterogeneity of Innovative Activity

Alexey Myachin

The principle indices for assessing the innovative development of countries and regions are examined. The methodology for their clustering is proposed. The main approaches to the innovative activity measurement are described. The relation between the country's GDP with its innovative activity is analyzed. New methods of patterns analysis are proposed to identify innovation clusters, evaluate the stability of the innovation activity of countries/regions, and also design the dynamic trajectories of their development. These methods, called ordinal-fixed and ordinal-invariant pattern clustering, are based on the pairwise comparison of the investigated indicators. The computational complexity and properties of the methods are analyzed; their efficiency is proved in various applications. To illustrate the proposed methods, the Global Innovation Index (GII) for 2012-2015 is used. The GII consists of more than 80 indicators, divided into 7 blocks: Knowledge and technology outputs, Institutions, Business sophistication, Human capital and research, Infrastructure, Market sophistication, and Creative outputs. These blocks are used to construct patterns for more than 100 countries. The results take into account the region and income level of the country. The trajectory of development during the study period is composed for each country.

3 - A Systematic Comparison of the Fitness between Sentiment Classification Algorithms and Data Properties

Youngseok Choi, Habin Lee

Sentiment analysis is playing a significant role in electronic commerce in recent times due to its data analytics capability against large volume of data. Sentiment classification provides organizations with a tool to transform data into 'actionable knowledge' that decision maker can use in pursuit of improved organizational performance. Customer review and opinion data can be used for development of market strategy and commercial planning. Government and public sector can also take advantages of analysing citizen feedback on new policy implementation. However, in spite of such strategic values, the literature still lacks studies that provide practitioners and scholars with clear guidance on how and when to apply different sentiment classification algorithms to data obtained from different problem domains. While previous studies are focusing on increasing the accuracy of the algorithms, less effort was made to understand the impact of the linguistic properties of the dataset even though different datasets with different linguistic properties can cause the variation of performance. In this research, we propose a practical guideline for application of sentiment classification by clarifying the impact of data properties (i.e., document length, training size, and subjectivity) on the classification performance. To derive more generalised implication, we test the four different datasets from various domains with machine learning-based and sentiment orientation-based approach.

■ WA-38

Wednesday, 8:30-10:00 - Building BM, 1st floor, Room 109M

Scheduling with Resource Constraints II

Stream: Scheduling with Resource Constraints
Chair: *Simon Emde*

1 - Scheduling of Jobs in the Continuous Casting Stage of Steel Production
Asvin Goel, Oliver Herr

This contribution studies a steel production planning problem and presents a formulation for the problem of scheduling jobs in the continuous casting stage. This problem generalises the single-machine minimum tardiness family scheduling problem and is characterised by additional constraints that at any point in time the cumulative hot metal demand must not exceed the amount supplied by the blast furnace and that, because of limited storage capacity for hot metal, a minimum quantity of hot metal must be consumed at any point in time. We propose a methodology for solving the problem and evaluate its performance against a commercial mixed-integer programming (MIP) solver. Our experiments indicate that high quality solutions can be found in only a fraction of time required by the MIP-solver.

2 - A Hybrid Metaheuristic Approach for Scheduling Steelmaking and Continuous Casting Production
Eduardo Salazar

A hybrid meta-heuristic approach to scheduling orders in the steelmaking and continuous casting production is proposed. A genetic algorithm (called fuzzyGA) evaluates the schedules using a fuzzy rule based inference system, and the weakness of meta-heuristic procedures in the determination of processing start times is overcomes by embedding an evolution strategy algorithm to optimize the job start times at the first stage. The fuzzy inference process gives an overall evaluation of the schedule quality by controlling discontinuities and transit times throughout the generations of the genetic algorithm; it takes into account that discontinuities and transit times beyond the maximum allowed may exist, but to different degrees of acceptance. The general structure of the production system considers an arbitrary number of machines at each stage, producing orders of several steel grades and types (e.g. slabs and billets). Optimization criteria such as makespan and technological constraints such as continuous casting between batches and in process time of liquid steel are discussed. For illustration purpose, examples of real sized problems are solve, and further research on heuristics solution approaches are discussed.

3 - Scheduling the Replenishment of Picking Areas in Assembly Plants
Simon Emde

In recent years, many OEMs especially in the automotive industry have installed so-called supermarkets on their shop floors to feed parts to mixed-model assembly lines in a flexible and just-in-time manner. Supermarkets are small picking areas within the factory where parts are intermediately stored to be transferred, often in the form of presorted kits, to nearby workstations frequently and in small lots. While this greatly alleviates inventory concerns at the assembly line, care must be taken that the supermarket itself always be adequately stocked. We tackle the problem of determining when which part types should be taken from central receiving storage to the supermarket in what quantities, such that, on the one hand, shop floor traffic remains manageable, while, on the other hand, inventory costs are not excessive. We formalize the problem, investigate the computational complexity, and develop a bounding procedure as well as a heuristic decomposition approach. Moreover, we study the trade-off inherent in the problem between delivery frequency and in-process inventory.

■ WA-39

Wednesday, 8:30-10:00 - Building WE, 1st floor, Room 107

Robot Process Automation: Threat or Opportunity

Stream: Workshops and roundtable

1 - Robot Process Automation: Threat or Opportunity
Piotr Grzywacz

Robotic Process Automation (RPA) becomes a priority topic for decision makers around the world. It leads to dramatic reduction of costs, whilst improving service levels, data quality and reducing risks. Robots deliver repetitive, high-volume tasks efficiently, while people build relationships, provide subjective judgement, deliver exception tasks, manage change and improve their organizations. The workshop will be a place, where practical application of RPA will be discussed and presented based on real-life business cases. The participants will also have an opportunity to resolve an example RPA introduction case. The workshop is dedicated to business practitioners as well as scientists interested in business application of software robotics in different sectors of economy. We also offer an opportunity to discuss the future of robotic process automation. No pre-requisite knowledge or experience are required. Understanding of business process complexity as a valuable nice-to-have criterion.

■ WA-40

Wednesday, 8:30-10:00 - Building WE, 1st floor, Room 108

Computational and Analytic Methods in Finance

Stream: Computational Methods in Finance
Chair: *Marcus Hildmann*
Chair: *Dejan Stokic*

1 - Dynamic Pricing under Competition: A Data-Driven Approach
Rainer Schlosser

Most sales applications are characterized by competitive settings and limited demand information. Due to the complexity of such markets, smart pricing strategies are hard to derive. We analyze stochastic dynamic pricing models under competition for the sale of durable goods. In a first step, a data-driven approach is used to estimate sales probabilities in competitive markets. In a second step, we use a dynamic model to compute powerful feedback pricing strategies efficiently, which are even applicable if the number of competitors is large and their strategies are unknown. In markets with sticky prices, our strategy performs close to optimal. In the case of liquid markets, in which competitors frequently adjust their prices, we verify that our heuristic feedback strategy also yields excellent results. To be able to compare expected profits, we compute optimal response strategies in a duopoly market where the competitor's price adjustments can be anticipated. We also show that the lack of information can be (over)compensated by adjusting prices slightly more frequently than the competitor does.

2 - Performance measures Adjusted for the Risk Situation (PARS)
Roland Seydel, Christoph Peters

We introduce the new class of Performance measures Adjusted for the Risk Situation (PARS), which include individual risk characteristics in the performance measure. The risk characteristics of an institution is determined by its future cash flows, typically on the liabilities side of its balance sheet. PARS have zero volatility under the investment strategy replicating these liabilities cash flows, thereby aligning the risk-free strategy of the firm with the interests of its major bond/stockholders. We give several examples of cash flow structures for individuals and firms, showing how their PARS can be defined. In the context of a debt manager, we demonstrate how PARS can be applied to the dynamic control of bond portfolios via sensitivities.

It is nowadays widely recognized that to assess the performance of a fund or trading business, the risk associated with the trading strategy has to be considered as well; frequently, so-called risk-adjusted performance measures, or RAPM, are employed. But what is risk? RAPM-related papers implicitly assume that risk is any deviation from holding cash in the bank account. In this paper, we argue that this is not the right notion of risk in general; rather the notion of risk depends on the situation of the institution in question. In a typical setting, risk depends on the size and time of cash flows to be paid to bond holders (in general: creditors) and stock holders (in general: owners).

3 - Analytic comparisons of Nash equilibrium, Stackelberg competition and cooperative solutions for games
Fellipe Santos, Adriano Lisboa, Amanda Dusse, Douglas Vieira

Defining the type of interaction in game theory helps to give more meaning to the results. The types of interactions are classified in cooperative and non-cooperative, whether the players cooperates with each other or not. In non-cooperative games, two types of interactions stand out: Nash equilibrium, where all players know each others strategies, but they cannot improve their payoff only changing their own strategy, and Stackelberg competition, where a player, the leader, moves first, assuming the best reply of the second-moving player, the follower. Although many studies have been done in this field, the relation of expected payoff among different types of interaction is still not clear. Having a previous knowledge of the expected payoffs can help the players to define their strategies. The aim of this study is to establish some relations among these three game strategies. The fundamental idea comes from the analysis of the feasible region for these types of strategies. It is noticeable that Stackelberg leader has a feasible region that is larger and includes all Nash equilibria and, hence, it is better than, or at least equal to, all Nash equilibria. Similarly, the feasible region for a cooperative game is larger and includes all non-cooperative game solutions, so that they compose the best possible solutions for a game. Numeric examples can be used to demonstrate these relationships, which are applicable to any game since no premises on functions are considered.

■ WA-41
Wednesday, 8:30-10:00 - Building WE, 2nd floor, Room 209

OR in Agribusiness

Stream: OR in Agriculture, Forestry and Fisheries
Chair: *Marcela Gonzalez-Araya*

1 - Supply chain management in food industry by integrating value function and outranking multicriteria methods
Concepcion Maroto, Marina Segura, Baldomero Segura

An essential problem in supply chain management is to evaluate suppliers, where the trend is to look for partnerships with few reliable providers. The literature has dealt mainly with the supplier evaluation only for selection considering one product, based on multiple criteria approaches. The general problem with many products and suppliers is not easy to solve in a changing context. The objective of this paper is to propose a methodology to assess suppliers in order to qualify and select them, as well as to monitor and control their performance, based on a multiple criteria and group decision making. Firstly, specific criteria of the products have been defined and, secondly, those related directly to suppliers, as well as their performance measures. In both cases, the criteria are grouped into two categories: critical and strategic. Then, an approach based on value function method, AHP and PROMETHEE has been applied to qualify and assess providers by considering all relevant quantitative and qualitative criteria from a group decision making perspective. The proposal allows qualifying suppliers, evaluating products from one or several suppliers, classifying and selecting the best suppliers and monitoring suppliers periodically. The methodology, which has been validated in a food industry, provides a very useful graphical tool to establish the best relationships with its suppliers, react to market changes or new products and control risks of the supply chain.

2 - An optimization model for planning apple harvest in several orchards with share resources
Marcela Gonzalez-Araya, Javier Gomez-Lagos, Masly Rivera-Moraga, Wladimir E. Soto-Silva
One of the main factors that affect the fresh apple quality is the ripening point at which the fruit is harvested. For this reason, harvest planning should consider this factor and schedule the efficient use of resources when the fruit is in its picking time. The main resources used during the apple harvest are labor, equipment and machinery, where labor is the more scarce and critical resource. In this sense, if the number of harvester is not enough to pick the fruit when is mature, the quality of fruit could be damaged. This situation become more complicated when labor is shared by several orchards belonging to a same company. This is very common in Chilean companies. In order to schedule and assign harvest resources in a better way during a season, an optimization model for supporting planning decisions of several orchards with share resources is developed, aiming to achieve the desired fruit maturation parameters. The model seeks to minimize labor costs, machinery use, loss of fruit quality, number of harvest days in a season and idle labor. The model was applied to a case study considering three apple orchards.

3 - Assessing eco-efficiency of specialized dairy farms using data envelopment analysis
Wenjuan Mu, Argyris Kanellopoulos, Corina van Middelaar, Jacqueline Bloemhof
The global demand for milk and dairy products is expected to increase because of population growth and changes in human diets. To meet future demand for milk and dairy products we need to increase productivity, reduce environment pressure and maintain economic farm viability. Current dairy farming practices that eliminate inefficiencies and achieve highest level of economic performance per unit of environmental impact need to be identified. Such farming practices can be used as benchmarks to improve eco-efficiency of the European dairy sector. Eco-efficiency refers to the delivery of competitively priced goods that satisfy human needs while reducing environmental impacts and resource intensity. Data Envelopment Analysis (DEA) is a commonly used benchmarking technique that enables calculations of efficiency score by taking into account multiple indicators simultaneously. Using DEA, this study showed the potential to benchmark eco-efficiency of specialized dairy farms using a reduced set of environmental indicators instead of using a full set, substantially reducing data-requirements.

4 - Stochastic contribution to the Fruit Supply Chain planning
LluisM Pla, Jordi Mateo, Wladimir Soto-Silva, Marcela Gonzalez-Araya, Francesc Solsona
Processing plants are central for the operation of fruit supply chains. One of the main aspects to consider is fruit transportation to the processing plant. Hence, this work proposes a two-stage stochastic linear programming model to support the fruit transport planning from the storage facilities to the processing plant. The aim of the model is to minimize the daily transportation costs and associated costs of different storage facilities from where fruits are supplied to the plant in order

to meet the demand. The model considers plant processing capacity, fruit demand, number and type of trucks available and the inventory of fruit in each type of storage facilities. Finally, the model was applied to a real case study of a processing plant located in the O'Higgins Region (Chile), where reported savings only in transport costs reached about 16 percent.

■ WA-42

Wednesday, 8:30-10:00 - Building WE, 1st floor, Room 120

Energy Efficiency in Buildings

Stream: Long Term Planning in Energy, Environment and Climate
Chair: *Gilles Guerassimoff*

1 - Improving energy efficiency in the residential and tertiary sector by data analysis
Gilles Guerassimoff

This presentation exposes the methodologies developed to establish tools framework for residential and tertiary building's energy consumption analysis including behavioral aspects. These methods give a sample of results that aim at helping the inhabitant in reducing their own consumption by the analysis of data provided by a sample of sensors. These analyses provide simplified indicators to assess the potential of energy efficiency in different environments We have used the results of two main experimentations involving on the one hand households with one smart meter and a temperature sensor; on the other hand two different tertiary buildings with different activities have been equipped with some sensors. We present some specificities of the load curve of some appliances to enhance the energy efficiency potential regarding not only the new technologies, but also the behavior that can explain some troubles in the energy consumption load. Then with different data analysis we propose some kind of relevant information to encourage the users in changing their habits to improve their efficiency in energy consuming. Some examples are shown to point out the difficulties in the identification of the real improvement in the long term.

2 - Energy Efficiency improvement by the way of identification with sensors use
Ghassene Jebali, Therese Peffer

To reduce energy consumption in buildings many efforts have been made to find new approaches to manage energy consumption in buildings. In this light, the intelligent management of power consumption in buildings is a major concern for providers and consumers of energy. Model identification to optimize the energy consumption One of the most important problems in many areas of science and engineering is the modeling of input/output properties of a system. Modeling systems based on the connection input/output is often referred to as system identification. These models establish relations between the factors given by a sensors network. Machine learning to optimize the energy consumption The challenge to reduce energy consumption is not limited only to the structural and physical nature of the building; we must also take into account the users' behavior. In fact, energy efficiency in buildings can be defined as the ratio between energy consumption and users' comfort. But, while it is simple to measure the energy consumed using different sensors, comfort is much harder to assess. In this context, it is necessary to develop new control systems more advanced than traditional control systems. The goal is to use machine learning methods in order to control the services of a building intelligently while taking into account its actual usage and not only its physical properties.

3 - Load curve analysis at households scale for energy efficiency
Elise Pupier

All stakeholders in the energy field acknowledge a growing need for higher consumers' involvement in energy use. This will help them be more aware while bringing them more serenity with respect to their bill, their comfort, and their ecological footprint. The residential sector accounts for 40% of the total energy consumption in the world and over 35% of the electricity consumption. Moreover, distribution network operators, have to anticipate more and more local production and consumption peaks. These issues require improvements in ways to conserve energy and to adapt demand response. Many studies show that the knowledge for each device of real-time consumption would be an essential tool to help households to control their consumption. The deployment of smart meters gives the opportunity to collect real-time power consumption data, the second step is to disaggregate load curve between each use. The startup WattGo, based on consumption data from a panel of hundreds of households, develops algorithms of disaggregation with machine learning methods. They recognize patterns of device use, " lineaments ", and can thus detect appliance consumption in real-time. WattGo has also collected socio-economic data about this panel. They can be crossed with energy use data, to understand better determinants of appliance use. From this information, a protocol will be implemented to study the potential of several kinds of incentives to promote energy conservation and load management

■ WA-43

Wednesday, 8:30-10:00 - Building WE, ground floor, Room 18

DEA and Performance Measurement 3

Stream: DEA and Performance Measurement
Chair: *Alec Morton*

1 - Evaluation of efficiency and marginal rate of transformation of international tourist hotels by a meta-frontier DEA model
Ming-Miin Yu

In a highly competitive environment, individual international tourist hotels need to increase their performance to maintain competitiveness. In addition, trade-offs between inputs or outputs in the production process can provide information to help analysts and managers make the choices between alternative production plans. Since the marginal rate of transformation represents partial derivatives or slopes of the production frontier at particular points, they can be obtained by efficient facets of data envelopment analysis frontier. In addition, international tourist hotels may face the different production frontiers. In order to calculate the performance and marginal rate of transformation with considering the heterogeneity problem, we offer an output-oriented meta-frontier data envelopment analysis method to measure efficiency. By comparing the curvatures of the group frontier and meta-frontier, the relative the marginal rates of transformation between a specific group and the whole industry can be obtained. The proposed method is applied in an empirical example of the Taiwanese international tourist hotels. The results may provide valuable information to help analysts and managers make the choices between alternative production plans.

2 - Comparison of Bayesian and Monte Carlo Estimators for Incidence of Inefficiency in Data Envelopment Analysis
Mehmet Güray Ünsal

In this study, the performance of Bayesian estimators is compared against to Monte Carlo estimators for incidence of inefficiency. According to the simulation results, although Monte Carlo estimators give better performance in some cases, esspecially when the total number of variables increase, Bayesian estimators results are better than Bayesian estimator's results according to the least mean absolute error criteria. Furthermore, it can be seen that the latent variable adjustment improves the performance of Bayesian estimators.

3 - Full Weight Space Efficiency Analysis: A marriage between data envelopment analysis and Probability Theory
Yongjun Li, Yuanchang Zhu, Alec Morton

Traditional data envelopment analysis (DEA) models allow each Decision Making Unit (DMU) to choose its favorable input and output weights to maximize its efficiency. However, one cannot guarantee that weights chosen are in reality. This paper develops a Full Weight Space Efficiency Method (FWSEM)to illustrate the performance of a DMU considering all possible weights.Specifically, in this paper we (a) construct a closed weight space; (b) propose several intuitive methods analyse maximum efficiency, the average efficiency, the efficiency cumulative distribution function and probability density function, to improve decision-making; (c) relate our method to traditional and non-traditional DEA models. In a numerical example, we present a comprehensive analysis of a data in a reported study and show how our methods can reveal additional and complementary insights.

4 - Inventory Record Accuracy and Performance of Fashion Stores
Amir Shabani, Sander de Leuw, Wout Dullaert

It is widely believed among both academics and practitioners that inventory record inaccuracy negatively affects inventory management performance. Inventory record inaccuracy refers to the difference between the recorded inventory and the actual physical available inventory. This phenomenon is usually examined at the level of a typical warehouse. However, it is a complex task to study when there are discrepancies in inventory at a retailer or shop level. Specifically, measuring the performance of a retailer requires taking into account both sales and inventory performance. The objective of this study, therefore, is to investigate the relationship between performance of fashion retailers and inventory record inaccuracy. In the fashion industry the result of this work is quite important as the fashion industry has to cope with a number of challenges such as high demand uncertainty, short selling seasons, overseas supply points, long lead-time etc. Because the existing network data envelopment analysis (DEA) formulations cannot be applied, a novel two-stage DEA model is developed.

■ WA-47

Wednesday, 8:30-10:00 - Building WE, 1st floor, Room 115

Robust Optimization in Supply Chain Management

Stream: Robust Optimization
Chair: *Byung Do Chung*

1 - Adaptive Inventory Control Under Demand and Lead Time Uncertainty: A Robust Optimization Approach
Andreas Thorsen

Multi-period inventory control problems are challenging to solve when demands, lead times, and costs can vary over time. Many papers from the past decade use robust optimization to solve inventory control problems, but most only consider demand uncertainty and assume zero (or fixed) lead times. In this research we investigate adaptive (i.e., multi-stage) robust optimization models for inventory control under demand and lead time uncertainty. In particular, we investigate linear decision rules as well as new robust basestock-like policies that explicitly consider the number of outstanding orders and their age. In this talk we present these models and discuss computational results in terms of cost and computation time. An adaptive robust optimization model may be a realistic context for many inventory control applications, and its solution may be less conservative than its static counterpart, as over-conservatism (compared to complementary methods, such as stochastic optimization) is a well-known downside of RO. The value of adapatability for this problem is examined by benchmarking the results against a static robust optimization approach.

2 - Affinely Adjustable Robust Optimization for Supply Chain Planning under Uncertainty
Byung Do Chung

Supply chain planning involves determining the required production quantity and managing raw materials and finished goods for cost minimization or profit maximization. Demand forecasting importantly determines production planning, but future demand is not easy to forecast in practice. We consider a multi-period, multi-product supply chain planning problem in which the demand is uncertain and its probability distribution is not available. To address the demand uncertainty, two types of robust optimization models are proposed. First, a robust counterpart is developed to determine the here-and-now decision. Next, an affinely adjustable robust counterpart is developed to determine the wait-and-see decisions by approximating a robust solution with a linear decision rule. Numerical studies demonstrated the effect of uncertainty and the price of robustness. The proposed affinely adjustable robust optimization approach can be used to reduce the average cost, the standard deviation of the realized cost, and the worst case scenario cost. The obtained solution is less sensitive to demand uncertainty and improves solution robustness.

3 - Matheuristic algorithms for large-scale stochastic optimization under risk averse constraints
María Merino, Unai Aldasoro, Laureano Fernando Escudero, María Araceli Garín, Gloria Perez

A Cluster Primal Decomposition methodology is proposed for solving medium- to large-scale multistage stochastic mixed-integer optimization models. It consists of partially relaxing non-anticipative constraints, breaking the problem in independent cluster scenario submodels. Moreover, we propose a risk averse strategy based on a time-inconsistent Stochastic Dominance (SD) along a given horizon for a production planning stochastic problem. It is an extension to selected stages along a time horizon of a mixture of the first-and second-ordered SD measures for two-stage. Additionally, the new methodology has been implemented in sequential devices, but it has also been analyzed the effect of using parallel computing in two HPC strategies. We present our current computational experience, comparing the risk neutral approach and the tested risk averse strategies, several algorithms versus plain use of IBM ILOG CPLEX optimizer and showing the speedup and efficiency obtained in the computational cluster ARINA provided by the SGI/IZO-SGIker at the UPV/EHU.

4 - Comprehensively managing uncertainty in supply chains via robust optimization
Giuseppe Stecca, Giovanni Felici, Giacomo Liotta

Planning production and distribution of global supply chains is a task which must take into account a multitude of parameters and decision variables. Under uncertain scenarios the problem of global supply chain long-term planning should be modeled using several assumptions.

For industries such as automotive, the modeling should consider multi-period resource allocation and the dynamics of several parameters. This work considers a supply chain cost optimization model that takes into account also CO2 emission costs, and measures the impact on the planning cost when the related parameters are uncertain. The problem is addressed by using the theory of robust optimization applied to network strategic planning.

Uncertainties are considered also in demand and in production technology. The problem is modeled and solved by using a commercial solver; a realistic case in the automotive industry is used for testing. The study allows researchers and practitioners to draw consideration on the practical interest of such models and their computational tractability.

■ WA-48

Wednesday, 8:30-10:00 - Building WE, 1st floor, Room 116

Sustainable Supply Chains

Stream: Energy/Environment and Climate

Chair: *Argyris Kanellopoulos*

1 - The Environmental Impact of Supply Chain Coordination
Dimitris Zissis, Georgios K.D. Saharidis, Emel Aktas

Lack of coordination among the supply chain members leads to inefficiencies the whole chain. We consider a supply chain with two rational players; one supplier and one retailer. The supplier produces a single product in a lot-for-lot fashion, while the retailer works under the EOQ model. Thus, the retailer decides on the order size and then completed lots are directly forwarded to him. We provide the opportunity to the supplier to use a discount mechanism, in order to coordinate the supply chain by manipulating the retailer's decision (order size) with result to affect the frequency of deliveries, if supplier ensures lower individual cost. We mathematically prove that in this model (without contracts and coalitions) the coordination is feasible, because it is in their self-interest. Our objective is to evaluate the environmental impact of coordination; i.e., the reduction of freight trips between the two players. We devise exact expression for the reduction of trips, under different scenarios concerning the utilization of the fleet and different the nodes' location. Moreover, we evaluate the performance of the coordination on the environment (i.e., fuel consumption and emissions) via numerical scenarios that cover realistic parameter values.

2 - Determining the carbon emissions from adding the load to a truck
Marcel Turkensteen

Many green logistics studies try to minimize the carbon emissions by altering the load on the vehicle. In green routing, a vehicle can serve customers with large demand on a route first in order to reduce the emissions from the load on the vehicle and in green inventory control, one can reduce the delivery frequency in order to have fewer but better utilized vehicles to reduce carbon emissions. There is often a trade-off between the distance driven and the load on the vehicle. Currently, most studies compute the carbon emissions of adding load under very specific conditions, such as transport with a given vehicle under given driving conditions. Thus, it is very challenging to determine the carbon emission savings from such measures in general.

To resolve this, we suggest an easy and generally applicable measure, the percentage load-based emissions (PLBE). We conduct a review study on papers in operations research and transportation science that report carbon emissions or fuel consumption for different load factors. Using regression analysis, we find that the PLBE increases on average by about 0.5% per additional ton gross vehicle weight, starting from about 18% for a 5 ton vehicle, but with large variation around this average. To make these results applicable to green routing and inventory control decisions, we provide guidelines on how to use these PLBE values.

3 - Designing the biomass-based sugar supply chain using a whole-chain optimization model
Argyris Kanellopoulos, Jeroen Zwietering, Jochem Jonkman, G.D.H. (Frits) Claassen, Jacqueline Bloemhof

The abolishment of the sugar beet quota policy is expected to affect the demand and supply of white sugar at EU level. Lower price of sugar will have a cascading effect on the supply of sugar beet and consequently the viability of the chain as a whole. To remain competitive, the European sugar industry will have to adapt to these new developments. Recently, alternative biomass-based processing technologies have become available. These technologies require small scale facilities that can reduce transportation costs substantially and enable production of biomass-based products like bioethanol and biogas from crop residues. The potential of alternative technologies to mitigate the negative impacts of policy changes have not been evaluated yet at chain level. The objective of this research is to design competitive biomass-based sugar supply chains that benefit from alternative technologies. We develop a multi-objective Mixed Integer Linear Programming model to optimize decision making at individual links of the sugar supply chain i.e. beet production and processing. The model was applied to re-design the sugar supply chain in the Netherlands. We found that investment on small scale bio refining facilities that enable production of bio-ethanol and biogas increases profitability of the chain as a whole. However, to maintain supply of sugar beet, additional profits at processing level should be transferred to farms in the form of price support for sugar beet production.

4 - A Stochastic Mixed Integer Program to Optimize Environmental Water Release Decisions
Simranjit Kaur, Avril Horne, Alysson Costa, Natashia Boland, Rory Nathan, Michael Stewardson, Joanna Szemis

Increasing extraction and river regulation to meet agricultural, hydropower and urban needs has led to significant changes in flow regimes of rivers all over the world, leading to a well-documented decline in their ecological health. One strategy to restore river ecosystem health (for example, in Australia) is the allocation of a limited volume of water to the environment that can be released from various reservoirs into the river. The limited volume of environmental water is often insufficient to meet the demands of all species and ecological processes associated with the river. Moreover, species may have conflicting flow demands. For example, a constant low flow may be required to provide habitat for macro-invertebrates, whereas high flows may be needed to stimulate spawning of a fish species in the same season. Thus, complex trade-off decisions are required around timing, volume and location of environmental water releases to achieve best environmental benefit. These decisions become more complex under the uncertainty of future climate. In this research we model this problem as a Stochastic Mixed Integer Program. The climate uncertainty is represented by a discrete number of possibilities that broadly represent possible future states, which allows the model to make decisions that hedge against future uncertainty. The Yarra river system in Victoria, Australia is used as a case study.

■ WA-51

Wednesday, 8:30-10:00 - Building PA, Room D

Nonsmooth Optimization

Stream: Nonsmooth Optimization
Chair: *Gonca Inceoglu*
Chair: *Adil Bagirov*

1 - Weak subgradient algorithm in nonconvex optimization
Gulcin Dinc Yalcin, Refail Kasimbeyli

In this study, weak subgradient based solution algorithm that does not require convexity on neither the objective function nor the set of feasible solutions is introduced and various step size parameter formulations for the presented algorithm are analyzed. At every iteration, to generate a new solution, the algorithm uses weak subgradients of the objective function at the point generated in the previous iteration. In this paper we introduce different step size parameters. Convergence properties of the presented algorithm are investigated for various step size parameters. The performance of the algorithm is demonstrated on test problems and results are discussed.

2 - An Incremental Algorithm for Clusterwise Regression
Gurkan Ozturk, Adil Bagirov, Emre Çimen, Arshad Mahmood

Clusterwise regression consists of finding a number of regression functions each approximating a subset of the data. In this paper, a new approach for solving the clusterwise linear regression problems is proposed based on a nonsmooth nonconvex formulation. We present an algorithm for minimizing this nonsmooth nonconvex function. This algorithm incrementally divides the whole data set into groups which can be easily approximated by one linear regression function. A special procedure is introduced to generate a good starting point for solving global optimization problems at each iteration of the incremental algorithm. Such an approach allows one to find global or near global solution to the problem when the data sets are sufficiently dense. The algorithm is compared with the multistart Spa th algorithm on several publicly available data sets for regression analysis.

3 - Chance-Constrained Geometric Programming: Lognormal distribution
Vahid Roomi, Rashed Khanjani
Geometric programming is a well-known technique for solving a variety of engineering optimization problems. Geometric programming has a lot of applications in engineering problems such as integrated circuit design, engineering design, project management and inventory management in which some of the problem's parameters are estimated by deterministic values. The conventional geometric programming models require the known and deterministic values for all parameters. However, the coefficients in the real-world GP problems are often imprecise and ambiguous. The impreciseness and ambiguity associated with the coefficients in geometric programming can be represented by random variables. Stochastic geometric programming can be used to deal with such situations. Since in conventional geometric programming the parameters are positive, in this study we use lognormal distribution.

In this paper, we propose chance constrained geometric programming model for solving stochastic geometric programming model in which some coefficients are assumed to be characterized by random variables with lognormal distribution. In stochastic environments, the deterministic coefficients in conventional geometric programming model become random variables with lognormal distribution. We will show that the proposed stochastic geometric programming can be converted into conventional geometric programming.

4 - A Global Optimisation Algorithm to Maximum Margin Clustering
Sattar Seifollahi, Adil Bagirov, Ehsan Zare Borzeshi, Massimo Piccardi
Maximum-margin clustering (MMC) is an extension of support vector machines for clustering. It partitions a set of unlabelled data into multiple groups by finding hyperplanes with the largest margins. Although existing algorithms have shown promising results, there is no guarantee of convergence to global solutions due to the non-convexity of the optimisation problem. In this paper, we propose an algorithm that is able to effectively find global or near-global solutions to the MMC problem. This algorithm is based on the combination of k-means or other alternative clustering algorithm and the support vector machines. The clustering algorithm is applied to the whole data set to find the cluster partition with a given number of clusters. Then, the support vector machine algorithm is applied using its nonconvex formulation and starting from the clusters generated at the first step. Each optimisation problem is solved by applying a local search algorithm. Experimental results demonstrate that the proposed algorithm is more efficient than other state-of-the-art algorithms for solving the MMC problem.

■ WA-52

Wednesday, 8:30-10:00 - Building PA, Room C

Vector and Set-Valued Optimization IV

Stream: Vector and Set-Valued Optimization
Chair: *Elena Molho*

1 - Henig Proper Efficiency for Vector Equilibrium Problems on Linear Spaces
Juan Luis Rodenas, César Gutiérrez, Vicente Novo
A concept of Henig proper efficiency for approximate equilibrium problems through improvement sets is introduced on real linear spaces not necessarily endowed with a topology. We characterize these solutions via scalarization by using some convexity assumptions and algebraic counterparts to the topological concepts. Finally, we compare the obtained results with the previous ones existing in the literature and we show the achieved improvements.

2 - Vector Quasi-Equilibrium Problems for the Sum of Two Multivalued Mappings
Livia-Mihaela Miholca, Gabor Kassay, The Vinh Nguyen

In this paper, we study vector quasi-equilibrium problems for the sum of two multivalued bifunctions. The assumptions are required separately on each of these bifunctions. Sufficient conditions for the existence of solutions of such problems are shown in the setting of topological vector spaces. The results in this paper unify, improve and extend some well-known existence theorems from the literature.

3 - Stability by Set Convergences: from Vector to Set Optimization
Enrico Miglierina

The notions of set convergences revealed to be very useful to study stability properties in vector optimization. Indeed, some results that show how the convergence of feasible region implies the convergence of efficient frontier are known. After a brief review of these results, the main aim of the talk is to extend this class of results to the broader framework of set optimization, that recently received an increasing attention in the literature.

4 - Some Sensitivity Results in Convex Multiobjective Optimization
Elena Molho

Condition numbers are widely used in scalar optimization both as tools for sensitivity analysisand as instruments that may give precious insights on the numerical aspects of the problem. We develop a first attempt to define an appropriate notion of condition number for multiobjective optimization problems. We consider the case of m convex differentiable objective functions with Lipschitz continuous gradients and we consider the weakly Pareto efficient solution map on a ball in Rn under componentwise uniform tilt perturbations, in the sense that each component of the objective function will receive the same tilt perturbation. Two alternative approaches to conditioning are proposed: the first one adopts a local point of view around a given solution point, whereas the second one considers the solution set as a whole. Moreover, the two approaches are consistent: the global condition number for a given multiobjective optimization problem is finite if and only if the local one is finite at every weakly efficient solution. A pseudodistance between functions is defined such that the condition number provides an upper bound on how far from a well-conditioned function f a perturbed function g can be chosen in order that g is also well-conditioned. For both the local and the global approach an extension of the classical Eckart-Young distance theorem is proved, even if only a special class of perturbations is considered.

■ WA-53

Wednesday, 8:30-10:00 - Building PA, Room A

Line Balancing, Lot-Sizing and Planning with Metaheuristics

Stream: Metaheuristics
Chair: *Marc Sevaux*

1 - Automated Design of Heuristic-Based Solution Approaches for Lot-Sizing Problems
Luis Filipe Araujo Pessoa, Bernd Hellingrath, Fernando Buarque de Lima Neto

Metaheuristics (MH) have been successfully applied to solve a multitude planning tasks. Given their ability to find good solutions in reasonable amount of time, they are able to tackle complex problems. However, MH components must be tailored towards the problem at hand: parameters' values and operators usually have to be changed and selected properly, or even specific heuristics have to be added. Additionally, it is often necessary to adapt the algorithm again whenever the problem formulation changes. This task is laborious, not trivial and often relies on the user's expertise. In order to overcome those drawbacks, several approaches for automating the design of MHs have been proposed. Among them, Hyper-Heuristic (HH) seeks to automatically select or generate suitable low-level heuristics (e.g. MH components, problem-specific heuristics) for effectively finding good solutions. Particularly, Lot Sizing Problems (LSP) can profit from the use of a HH approach. Besides the great amount of heuristics of different kinds developed for the different variants of LSP, changes in the planning requirements might imply in changes on the problem formulation (e.g. production levels, allowance of backlog/overtime, time window restrictions). Therefore, this work aims at increasing the generalization algorithm abilities by conceiving a hyper-heuristic approach for LSP, as it can (i) reduce dependencies on users and (ii) automatically tailor the methods to distinct variants of the problem.

2 - Minimizing Non-Machining Times in Automatic Tool Changers
Fehmi Burcin Ozsoydan, Adil Baykasoğlu

Automatic tool changers (ATCs) hold multiple cutting tools, with respect to the process plan requirements of the parts. According to these plans, ATCs are rotated from one slot to another, where the next needed cutting tool is positioned. The time elapsed through this rotation is referred as ATC indexing time, which is the first part of the non-machining times in ATCs. Tool switching problem (TosP), where the cutting tools, located on ATCs are switched between consecutive parts, represents the second part of the non-machining times. In flexible manufacturing systems, ATCs are commonly utilized throughout machining operations in machining centers. Therefore, minimization of non-machining times here is crucial for such systems. These two problems (ATC indexing and ToSP) are separately addressed as NP-hard problems in the literature and are solved independently thus far. In the present work, with the assumption of cutting tool duplications on ATCs, we put forward the first attempt in the literature by solving these problems simultaneously via a neighborhood based threshold accepting strategy. The results are compared with the lower bounds obtained by a method proposed in the present work. Promising outcomes are expected to contribute to the possible future work of this research field.

Acknowledgements: The present work is supported by The Scientific and Technological Research Council of Turkey (TUBITAK) under grant number: 214M240

■ WA-54
Wednesday, 8:30-10:00 - Building PA, Room B

Splitting methods for convex programming

Stream: Convex Optimization
Chair: *Xiaoming Yuan*

1 - An Algorithmic Framework of Generalized Primal-Dual Hybrid Gradient Methods for Saddle Point Problems
Xiaoming Yuan

The primal-dual hybrid gradient method (PDHG) originates from the Arrow-Hurwicz method, and it has been widely used to solve saddle point problems. We further consider how to generalize the PDHG and propose an algorithmic framework of generalized PDHG schemes for saddle point problems. This algorithmic framework allows the output of the PDHG subroutine to be further updated by correction steps with constant step sizes. We investigate the restriction onto these step sizes and conduct the convergence analysis for the algorithmic framework. The algorithmic framework turns out to include some existing PDHG schemes as special cases; and it immediately yields a class of new generalized PDHG schemes by choosing different step sizes for the correction steps. In particular, a completely symmetric PDHG scheme with the golden-ratio step sizes is included. Theoretically, an advantage of the algorithmic framework is that the worst-case convergence rate measured by the iteration complexity in both the ergodic and non-ergodic senses can be established.

2 - Extended ADMM and BCD for Nonseparable Convex Minimization Models with Quadratic Coupling Terms: Convergence Analysis and Insights
Caihua Chen

In this talk, we consider the large-scale convex non-separable minimization models with quadratic coupling terms. We firstly extend the 2-block ADMM to the linearly constrained convex optimization and prove that the sequence generated by the ADMM converges in point-wise manner to a primal-dual solution pair. Moreover, we apply randomly permuted ADMM (RPADMM) to nonseparable multi-block convex optimization, and prove its expected convergence for a class of nonseparable quadratic programming problems. When the linear constraint vanishes, the 2-block ADMM and RPADMM reduce to the 2-block cyclic BCD method and randomly permuted BCD (RPBCD). Our study provides the first iterate convergence result for 2-block cyclic BCD without assuming the boundedness of the iterates. We also theoretically establish the expected iterate convergence result concerning multi-block RPBCD for convex quadratic optimization. In addition, we demonstrate that RPBCD may have a worse convergence rate than cyclic BCD for 2-block convex quadratic minimization problems. Although the results on RPADMM and RPBCD are restricted to quadratic minimisation models, they provide some interesting insights: 1) random permutation makes ADMM and BCD more robust for multi-block convex minimization problems; 2) cyclic BCD may outperform RPBCD for "nice" problems, and therefore RPBCD should be applied with caution when solving general convex optimization problems.

3 - Inertial proximal ADMM
Junfeng Yang

We propose inertial version of the proximal ADMM for linearly constrained separable convex optimization. Convergence and rate of convergence results are established, and some umerical results are given to illustrate the benifits gained by the inertial extrapolation.

Wednesday, 10:30-12:00

■ WB-01

Wednesday, 10:30-12:00 - Building CW, AULA MAGNA

Keynote Stephen J. Wright

Stream: Plenary, Keynote and Tutorial Sessions
Chair: *Dolores Romero Morales*

1 - Optimization in Data Analysis
Stephen Wright

Optimization formulations and algorithms are central to modern data analysis and machine learning. Optimization provides a collection of tools and techniques that can be assembled in different ways to solve problems in these areas. In this tutorial, we survey important problem classes in data analysis and identify common structures in their formulations as optimization problems and common requirements for their solution methodologies. We then discuss key optimization algorithms for tackling these problems, including first-order methods and their accelerated variants, stochastic gradient methods, and coordinate descent methods. We also discuss nonconvex formulations of matrix problems, which has become a popular way to improve tractability of large-scale problems.

■ WB-02

Wednesday, 10:30-12:00 - Building CW, 1st floor, Room 7

Algorithms in Continuous Optimization

Stream: Algorithms and Computational Optimization
Chair: *Derya Dinler*

1 - Nonlinear Chance Constrained Problems: Optimality Conditions, Regularization and Solvers
Martin Branda, Lukas Adam

We deal with chance constrained problems (CCP) with differentiable nonlinear random functions, where we assume that the distribution is discrete. We allow nonconvex nonlinear functions both in the constraints and in the objective. We reformulate the problem as a mixed-integer nonlinear program, and relax the integer variables into continuous ones. We approach the relaxed problem as a Mathematical problem with complementarity constraints (MPCC) and regularize it by enlarging the set of feasible solutions. For all considered problems, we derive necessary optimality conditions based on Frechet objects. Further, we discuss relations between stationary points and minima. We propose two iterative algorithms for finding a stationary point of the original problem. The first is based purely on the relaxed reformulation, whilst the second one employs its regularized version. Under validity of verifiable constraint qualification, we show that the stationary points of the regularized problem converge to a stationary point of the relaxed reformulation and under additional condition it is even a stationary point of the original problem. Moreover, we show that the second algorithm may converge to a global minimum of the original problem even when starting from its local minimum. We conclude by several examples and show good numerical properties of the proposed solvers.

2 - Stopping Criteria for Stochastic Searches in Global Optimization
Carlos Fernando Ospina Trujillo, Juan Carlos Riaño Rojas

Most of the literature related with the algorithms of stochastic search for optimization, trust in the number of iterations as the stopping criterion, because analysis of convergences has proven that these converge in probability to the optimum value. This number of iterations is intimately related to the number of function evaluations. Initially, this is a weakness of this criterion, due to the number of function evaluations that it is necessary for the convergence is bigger and unknown. Therefore, high numbers of iterations should be performed in order to find the random walk of searching, and also the experiment should be repeated several times to find the nearest optimum value. Then, using other stopping criteria that have into account the past events could avoid this process and improve the solution approximations. In this work, many test problems are examined using different stopping criteria. The analysis is carried out using some algorithms that present a great degree of robustness: Simulated Annealing, Improving Hit and Run, and Hide and Seek. Depending on the method, the variation of the criteria is necessary and evaluated.

3 - Multiple-criteria approach to data stream mining
Janusz Granat

Information and telecommunication systems are the source of massive amount of data that, in many cases, should be processed and analyzed almost in real time. Data sets grow in size because they are increasingly being generated by numerous sensors or activities of large number of users. Such data streams are one of the main sources of so called big data. The classical learning algorithms are not efficient for data streams. The new methods are being developed to overcome shortcoming of existing algorithms.

It can be observed advances in development of algorithms that are based on online optimization. Nevertheless, most formulation of such optimization problems deal with a scalar cost function. In the paper [1], where open challenges for data stream mining are discussed, the importance of research on online algorithms that consider more than one criterion is stressed (e.g. accuracy, memory, reactivity or adaptability).

This paper is focused on online multiple criteria approach to data stream mining. In particular, two main achievements will be presented: 1.The multiple-criteria algorithm based on stochastic gradient descent (SGD). 2.The algorithm for dynamic updates of Pareto efficient solutions. The performance of the developed algorithms will be demonstrated on the problem of event detection in telecommunication network.

[1] G. Krempl, at al.: Open challenges for data stream mining research. ACM SIGKDD Expl.-Special issue on big data. Vol. 16, issue 1, June 2014

■ WB-03

Wednesday, 10:30-12:00 - Building CW, 1st floor, Room 13

Preference Learning 6

Stream: Preference Learning
Chair: *Krzysztof Dembczynski*

1 - Preference Elicitation for Recommender Systems
Dietmar Jannach

Recommender Systems have become a natural part of our online experience. Such systems for example make personalized buying suggestions to us on e-commerce sites, they point us to new videos on streaming platforms or make recommendations for friends or groups to join on social networks.

To be able to make such personalized recommendations, the underlying algorithms need knowledge about the user's needs and preferences. In many real-world systems the preference models of the users are estimated by observing and interpreting their shopping and navigation behavior or by making inferences based on user-provided explicit preference statements for the items.

In most academic research, the preference information is typically assumed to be given, most commonly in terms of datasets consisting of millions of item ratings. In reality, however, such rating information might not be available and implicit preference information on the other hand can be noisy. In this talk, we will focus on preference elicitation and refinement techniques for recommender systems. We discuss challenges of acquiring and interpreting user actions and review user interaction mechanisms that can help us to end up with more accurate and context-specific preference profiles.

2 - Understanding Transparent and Complicated Users in Content Based Recommendation
Peter Vojtas

In this talk we are concerned with user understanding in content based recommendation based on explicit ratings. We describe our model based on assumption that users have weights and ideal values for some attributes. Our main motivation comes from IFORS Conference Plenary Session talk of Smith-Miles, K.: Understanding strengths and weaknesses of optimization algorithms with new visualization tools and methodologies in Barcelona, July 2014. Instead of graphs as instances and coloring as task we consider users as instances and preference learning as task. A transparent user is the one where method(s) work well, complicated user is the one where almost nothing helps to predict his/her behavior. We describe two sets of experiments. First with artificial data - we try to connect complexity of a user in terms of weights ratio and position of ideal points in data distribution. Second we refer on experiments on (integrated) four different movie data sets with user explicit ratings. We use several metrics to evaluate experiments. We trace performance of our methods and metrics also as a distribution along each single user.

3 - Tuning learning to rank methods - NEKST semantic search engine use case
Dariusz Czerski, Karol Grzegorczyk

NEKST is a first polish semantic search engine created by researchers of the Institute of Computer Science PAS. The project was founded by the Operational Programme Innovative Economy. One of the biggest challenges stated against any search engine is returning top k high relevant results for user queries. The family of learning to rank methods is a sensible solution for such kind of problem. The approach learns how to rank query-document records described by many independent features. We present a case study of tuning learning to rank methods for the search engine created from the scratch. It will be shown which features are most important for modeling the ranking function. In case of new search engine the lack of user clicks occurs what makes creation of the training set based on user activity difficult. It will be presented how to prepare a small but effective training set based on iterative process of judging results of a small set of diverse queries.

4 - Predicting diverse rankings in extreme classification
Krzysztof Dembczynski, Kalina Jasinska

Extreme classification refers to multi-class and multi-label learning problems with very large output spaces involving even millions of labels. In this setting, the learning algorithms are usually optimized and empirically verified in terms of ranking-based losses such as Precision@k or NDCG@k (normalized discounted cumulative gain). Thanks to that only few top labels are predicted for a given test example. Unfortunately, this solution favors the most popular labels (the most frequent) and ignores the long tail of rare labels. Alternative approaches rely on predicting subsets of labels that optimize performance measures that treat all labels equally. An example of such a measure is macro F-score. There is, however, a problem how to turn optimal macro F-score predictions into a ranking of top labels, which is usually the desired output of the algorithm. During the talk we will formally state the problem and indicate several possible solutions.

■ WB-04

Wednesday, 10:30-12:00 - Building CW, ground floor, Room 6

Resource Efficiency in Supply Chains and Shared Logistics

Stream: Environmental Sustainability in Supply Chains

Chair: *Gerald Reiner*
Chair: *Emel Aktas*

1 - Collaborative logistics models in urban areas: Current status and evidence from the Fast Moving Consumer Goods sector
Eleni Zampou, Theodora Trachana, Pavlos Eirinakis, Vasileios Zeimpekis

Collaborative logistics, especially in urban freight distribution operations, is gaining traction as a way to increase logistic efficiency and decrease costs. Our aim is to identify distinctive types of logistics collaboration between logistics service providers (LSPs), manufacturers and retailers, discuss their applicability and evaluate their benefits in both logistics and environmental terms. By conducting eight in-depth interviews with logistics practitioners, we firstly identify three different types of collaboration that involve stakeholders sharing the use of vehicles as well as their storage areas. The difficulty in finding a reliable party to lead the collaboration, unhealthy competition, the immaturity of the market and the lack of collaboration culture of the 3PL companies are the impediments that respondents agree with most. However, empirical evidence on the corresponding benefits of collaboration seems to be adequate for overcoming the suspiciousness and reluctance in the sector. Building on the evidence from the in-depth interviews, we formulate different what-if scenarios for the suggested types of collaboration and we estimate their benefits based on actual freight distribution data.

2 - A simulation-optimization approach for intermodal transport planning under travel time uncertainty considering multiple objectives
Martin Hrusovsky, Emrah Demir, Werner Jammernegg, Tom Van Woensel

The growing road freight transport contributes to increased traffic volumes on roads that lead to congestion, disruptions and delayed deliveries of goods and negatively influence the environment and society. As an alternative, different transport modes can be combined in intermodal transport chains in order to exploit their advantages and reduce the negative impact of transport. In order to efficiently coordinate the actors in intermodal transport chains, advanced planning algorithms are required to consider individual characteristics of each transport mode (e.g. fixed schedules) and create robust plans that minimize the risk of disruptions. Moreover, planning algorithms should also react quickly on severe disruptions that cause infeasibility of the original transport plan. In order to fulfill these requirements, we present a simulation-optimization approach for intermodal transport planning that considers uncertain travel times and combines three different objectives - cost, time and emissions. In the proposed methodology, agent-based simulation is used to represent the transport network with uncertain travel times and possible disruptions. Based on the current state of the network, a mixed-integer linear program is integrated to generate optimal transport plans for each customer. These plans are created either before the start of the transport (offline planning) or during transport execution when the offline plan becomes infeasible due to a disruption (online planning).

3 - Sustainable Distribution of Online Groceries in the Cities
Emel Aktas, Michael Bourlakis, Dimitris Zissis

Grocery retail sector in the UK amounted to '174.5B in 2014 with fierce competition among the retailers that are striving to delight their customers with new services, one of which is purchasing groceries online. Over the past few years, online grocery retail market has grown faster than the grocery retail sector with an annual growth rate of 15%, reaching to '7.5B in 2014 owing to increased urbanisation and the growing number of cash-rich time-poor customers. Online grocery purchases are fulfilled mainly by two distribution models: Home Deliveries where the customer's orders are delivered to their requested address and Click & Collect where the customers chose a location to pick up their groceries after having ordered them online, both in a pre-determined time window. In particular, fulfilment of home deliveries is undertaken by the retailer's own fleets which are branded and used as an advertising medium for the service. The existing distribution model is a competitive game, which raises the total logistics costs; ’21 per order. In this work we present preliminary results about the online grocery market as part of the U-TURN Project funded by the EU H2020. Our aims are to identify collaboration opportunities and to propose collaborative strategies for the distribution of online purchases of groceries in order to improve the economics of the operation and to reduce the negative impacts on the environment (emissions) and the society (traffic).

■ WB-06

Wednesday, 10:30-12:00 - Building CW, ground floor, Room 2

Urban and territorial planning in MCDA 2

Stream: Multiple Criteria Decision Aiding
Chair: *Marta Bottero*
Chair: *Isabella Lami*

1 - How to improve decisions about new hospitals’ location: the role of Multicriteria Spatial Decision Support System

Alessandra Oppio

Site selection for urban facilities is a crucial topic in planning decision processes for the several side effects they produce and the multiple criteria involved, especially for healthcare facilities. Nevertheless, the location problem has been ignored by most of the existing evaluation systems that are mainly focused on the intrinsic performances of healthcare structures. Starting from a deep literature review and the analysis of European case studies, the research proposes Multicriteria Spatial Decision Support System (MCSDSS) divided into four criteria (Functional quality, Location quality, Environmental quality, Economical aspects), each in turn divided into sub-criteria, with the aim of assessing the land suitability for new healthcare structures, in order to improve the transparency and robustness of the decision-making process. The MC-SDSS proposed has been tested for the site selection of "La Città della Salute", an innovative healthcare facilities in Milan, Italy. The combined use of Multicriteria Decision Analysis (MCDA) and Geographic Information System (GIS) allows to address choices by an integrated knowledge about territory and by the explicit consideration of the spatial dimension of decision problems. This integrated approach takes advantage of both the capability of GIS and the flexibility of MCDA and it is able to manage complex decisions problems, characterized by several interests at stake and uncertainty.

2 - Generating combinations of alternatives for urban regeneration: a Decision Analysis approach

Alberto Colorni, Alessandra Oppio, Valentina Ferretti

Large urban development projects launched over the past thirty years have shown some critical issues related to the implementation phase. As a consequence, the current practice seems oriented toward minimal and widespread interventions as urban catalyst rather than to large developments, in order to achieve a satisfying balance among environmental quality, economic growth and social well-being. The concept of urban catalyst refers to interventions that can be built in a short time and spontaneously are able to improve the surrounding environment. On one hand, this new idea of planning might solve the problem of large developments’ feasibility evaluation, but on the other hand, it rises an evaluation demand related to the selection of coalition of projects within a multidimensional and multi-stakeholder decision context. This study aims to propose a framework for the generation of feasible coalitions of actions in the context of urban regeneration processes and for their evaluation using a MCDA approach. Given the decomposition of the concept of feasibility into three main criteria (environmental, economic and social), the proposed evaluation framework supports decision makers in exploring different combinations of actions in the context of urban interventions meant as catalyst. A first test of the evaluation framework on a pilot case study of urban regeneration in the city of Milan (Italy) is proposed.

3 - A Multi-Criteria Spatial Decision Support System (MC-SDSS) for valorization strategies in Regional Park of Partenio

Giuliano Poli, Simona Panaro, Maria Cerreta

Urban and territorial planning requires a multi-dimensional approach that combines local community’s knowledge with the specialists’, for properly arranging specific decisional issues and trying to solve unstructured complex problems. In multi-dimensional context, the operational framework of MCDA aids the decision makers to make suitable decisions through the monitoring, the management and the assessment of the local resources. During the last three decades, MCDA in combination with GIS have improved the evaluation, the interaction among the local stakeholders and the design of new scenario. Actually, Intelligent Decision Making Support System and VGIs provides remarkable insights implementing the knowledge processes and the problem structuring. The research work aims to provide a Multi-criteria Spatial Decision Support System (MC-SDSS) to define a common framework for the knowledge and the management of economic, natural, cultural resources and the evaluation of impacts of urban and territorial policy on 27 municipalities near the "Regional Park of Partenio", in Southern Italy. The MC-SDSS’s prospects are to let local knowledge emerge through data-set of context-aware indicators using a cross-scale approach, designing new geography beyond the municipal boundaries. The MCDA methods in synergy with spatial analysis techniques highlight the strong relationship among local resources and situated policy strategies.

4 - Decision-support framework for the selection of the road alignment through mountain terrain

Drazenko Glavic, Marina Milenković, Milos Mladenovic

One of the significant issues in road designing is the selection of the optimal route alignment. This issue arises in the situation when new road alignment or motorway alignment need to be defined for a newly designed road or motorway. Considering there are multiple solutions, with its advantages and disadvantages, as well as a range of conflicting criteria for selecting the optimal route alignment, this issue belongs to the group of multicriteria decision-making (MCDM) problems. The MCDM-based methodology will be applied in this paper using PROMETHEE method. The methodology will be implemented on a case study on real example. The results and optimal solution will be in function of various traffic, financial, and environmental criteria. Sensitivity analysis will be conducted to show stability of optimal solution and stability of rank order.

■ WB-08

Wednesday, 10:30-12:00 - Building CW, 1st floor, Room 9

OR and Real Implementation 1

Stream: OR and Real Implementation
Chair: *Belarmino Adenso-Diaz*

1 - Efficient Preventative Maintenance Scheduling Policies for Windfarms

Jesús Maria Pinar-Perez, Diego Ruiz-Hernandez, David Delgado-Gomez

The high cost of machinery of heavy industrial equipment (wind turbines, coal mills, and so on) combined with the limited accessibility by human resources to the engines and components, requires the use of complex maintenance scheduling systems in order to fulfill the requisites of high availability, reliability, maintainability, and safety. In this paper we address the problem of scheduling preventative maintenance interventions in a wind farm, where equipment is subject to wear due to use and adverse climate conditions and it is also to vulnerable to shocks that may induce failures or, even, breakdowns. We propose a formulation that takes into account different potential sources of failure and develop a maintenance intervention policy aimed at mitigating the negative impact of wear as well as the probability of breakdowns. Numerical investigation evaluates the performance of the proposed heuristic and compares it with more general intervention policies used in practice.

2 - Cost And Waste Minimization In The Design Of Logistic Networks

Belarmino Adenso-Diaz, Sebastián Lozano, Antonio Palacio

We proposed a biltiobjective multi-product model for a production/distribution supply chain logistic network with four echelons. Multiple components to elaborate each product are considered. The aim of the problem is to minimize the total cost of the network, including the fixed cost of open facilities and the transportation costs between them, and to minimize the total waste of components and products, including the total waste of the facilities and the total waste of transport. Five factors (number of alternatives, complexity and variability of costs, waste and demand) with two levels (low/high) each one are considered as cases for the experimentation. The problem is solved using the ϵ-constraints method and results are compared using four different measures.

3 - Dominance network analysis

Laura Calzada-Infante

The performance of countries in the Olympic Games can be studied using a complex network analysis approach that takes into account their size and resources. The key concept is the dominance network, which is a directed graph in which nodes represent the participating nations and the arc length represents the weighted difference in the number of medals won by the two countries. An arc from country a to country b exists only if the latter has won more medals than the former and, in addition, it is smaller in population and in terms of GDP. This dominance network has transitive links, additive shortest paths and a layered structure. Global and node-specific measures (such as density, average path length, diameter, network efficiency, clustering coefficient, closeness and betweenness centrality) can be computed. It is also possible to visualize this dominance network. The proposed approach is illustrated on the Beijing 2008 Olympic Games.

4 - Real-Time Field Service Engineer Scheduling Problem with Emergencies and Collaborations: a Simulation-Optimisation Approach

Daniel Guimarans, Hanna Grzybowska

We address the real-time field service engineer (FSE) routing and scheduling problem encountered in human resources operations. For many companies the assignment of FSE to jobs is challenging due to the dynamic occurrence of job requests. This adds up to contractual conditions generally imposing hard service time windows and high service standards, e.g. maximum response time to an emergency. The problem also includes further constraints defining (i) collaborations between the FSE (if needed), and (ii) different levels of jobs' emergency (the higher the job emergency the faster reaction is required). An additional factor, usually neglected, which needs to be considered is the comfort of the FSE regarding the route stability. We account for this aspect by introducing a modification of the objective function aimed at minimising disturbances in the original plan, i.e. minimise differences in addition to traditional distance and time costs. In this work, we define the model for the routing and scheduling FSE problem at hand and propose an event-driven simulation based optimisation approach using Large Neighbourhood Search to solve it. This research is a result of a commercial engagement with industry and provides results for the real-life scenarios.

■ WB-09

Wednesday, 10:30-12:00 - Building CW, 1st floor, Room 12

OR Methods in Consumer Behavior Research

Stream: OR Methods in Consumer Behavior Research

Chair: *Birol Yüceoglu*

1 - Prediction of Customer Loyalty for Online Retailers

Birol Yüceoglu, S. Ilker Birbil, Işıl Öztürk

We propose a knowledge discovery process for predicting customer loyalty in online fast-moving consumer goods retailer. Our choice of methodology for prediction is using various machine learning algorithms. A successful application of machine learning algorithms in this context requires definitions of 'customers' and 'churning customers'. After setting forth our proposed definitions, we explain our data cleaning steps as well as feature engineering process. We conduct extensive numerical experiments of the proposed methodology on a dataset obtained from a leading Turkish online retailer. Our study concludes with the presentation of our observations and insights.

2 - The validity analysis on major factors of customer satisfaction

Sisi Cui, Peng Zhang, Wei Yu, Hong Seung Ko

In the global competitive business environment, a company must get a new customer and retain the customer at the same time for bringing about profits. In brief, it is necessary that companies make the acquired customer continuous repurchase for increasing their profits. In order to make the customer repurchase, companies must give the high satisfaction on the product to their customers above all. It is because that the customer who got the high satisfaction on a product should repurchase the product repeatedly. We consider that there are some related factors which bring the high customer satisfaction in the repurchase behavior. Therefore, in our research, we disclose the factors which make direct influences to the customer satisfaction for repeating and verify the validity by the correlation analysis.

3 - Term-structure analysis of hidden order in the limit order book: evidence from the E-Mini S&P 500

Pongsutti Phuensane, Julian Williams

The Hidden order is currently increasingly popular as a standard feature of electronic limit order book markets. The invisible order allows traders to hide all, or partially hide their orders to avoid exposure to risk. We propose a new hidden order detection algorithm for the limit order book to investigate the impact of invisible orders on the market environment using E-mini S&P500 data. The original data set includes 428,540,484 rows with 4 columns from trades data and 3,797,936,125 rows with 44 columns from limit order book data. We then modulate this time-series data into a term-structure style. Our algorithm shows 43% all of the trade volume is involved with invisible liquidity. We also find that price impact is decreased and market quality is improved with the presence of hidden order both during high and low-frequency trading periods. We use this measure to study the association between hidden order and other observed market environments. Our analysis finds aggressively hidden order activity when trading volume is increased.

■ WB-10

Wednesday, 10:30-12:00 - Building CW, ground floor, Room 1

ANP Applications 3

Stream: Analytic Hierarchy Process / Analytic Network Process

Chair: *Petr Fiala*

1 - Dynamic multi-criteria project portfolio management

Petr Fiala

The use of project portfolio management is increasingly becoming a tool for promoting the strategy of the organization, which is a very important role. This is not about managing individual projects, but their networks where relationships exist among projects. The most important evaluation criteria are time, cost, resource utilization, risk, and quality of the project. This paper aims to verify the ability to model and solve the problem of multi-criteria project portfolio using the Analytic Network Process (ANP) model. An important characteristic of project portfolio management is dynamics. Project opportunities come in time and it is necessary to decide which will be accepted for creating a dynamic portfolio of projects and which will be rejected. The aim of the paper is to develop a general model, which would be completed for the specific needs of problems. The basic ANP model is completed by specific sub-networks. The sub-networks are used to model important features of the problem. The most important features in our ANP-based framework for dynamic portfolio management are captured in sub-networks as dynamic flow of projects, and time dependent resources. Time dependent priorities in the ANP model can be expressed by forecasting using pairwise comparison functions.

2 - Selection of the Maritime Seaport Software for the Management of the Operations at an International Seaport

Dogan Ozgen, Arzum Ozgen

Seaport management and shipping are key maritime activities which increased their importance due to sustaining and maintaining the rapid growth of international trade. Therefore, port management became the center of interest and the focal point of research to improve the efficiency of related processes. Dealing with all the complexities of port operations and maximizing overall productivity of management systems necessitate adaptable technology solutions and an experienced consulting partner. The usage of data and knowledge management software products beside streamlining and integrating all of business subsystems in maritime seaport management may result in a better cost and human resources savings. This research explores the application of a hybrid multi-criteria decision making (MCDM) procedure for the evaluation of various Maritime Seaport Software (MSS) alternatives. The proposed evaluation framework integrates three methodologies: DEMATEL, Analytic Network Process (ANP) and VIKOR. Based on adopted methodology and determined criteria which are interdependent, the best MSS selection for the seaport management can be achieved.

3 - A Multi Criteria Evaluation of Online Shopping Websites for Turkish Consumers

Kubra Yikilmaz, Y. Ilker Topcu

Attitudes of consumers towards buying products or services is shifting from traditional retail formats to online stores as Internet has changed the ways in which products and services are marketed to consumers fundamentally. At online shopping, consumers spend less time, reach stores easier, and can compare a wider set of alternatives of products or services with more information. Because of the high number of online shopping websites, the online shopping market is very competitive. Therefore, understanding consumers' attitudes at online shopping, determining factors affecting the purchasing process, and assessing importance of these factors will gain strategic advantage to companies operating online shopping websites. As the related factors are several, conflicting, weighted, and incommensurable, a multi criteria decision making approach is necessitated for the evaluation of online shopping websites with respect to these factors. Accordingly, Analytic Hierarchy Process (AHP), a widely used multi criteria decision making method, is utilized for the evaluation. After identifying the related factors based on the literature survey and the managers of six leading companies serving in online Turkish market, potential consumers are posed pairwise comparison questions in accordance with AHP. As a result, the importance of evaluation factors as well as the preferences of consumers for online shopping websites are revealed.

■ WB-11

Wednesday, 10:30-12:00 - Building CW, 1st floor, Room 127

Probabilistic Models

Stream: Probabilistic Models
Chair: *Giulianella Coletti*

1 - Preference relations agreeing with conditional Choquet expected values with respect to conditional belief or plausibility functions

Davide Petturiti, Giulianella Coletti, Barbara Vantaggi

The aim is to provide axioms assuring the representability of a preference relation on an arbitrary set of (conditional) gambles through a specific functional involving a (conditional) non-additive measure of uncertainty. More precisely, we consider a problem in the ambit of decisions under uncertainty, i.e., we study situations where a (not necessarily complete) preference relation is given on an arbitrary set of gambles and the decision model of reference is the Choquet expected value with respect to a belief or a plausibility function. For this aim we introduce two rationality principles which are necessary and sufficient conditions for the existence of a belief or a plausibility function such that the corresponding Choquet integral represents the relation. Sometimes a decision maker could be either not able or not interested in giving preferences among gambles, but he could only be able to specify his preferences under the hypothesis that a particular event happens. In other words, he could not be able to express his preference relation under a generic scenario, but could assess it under various scenarios, which are taken into account at the same time. So we need to consider the conditional Choquet expected value with respect to a conditional belief or plausibility function as decision model. The choice among the different notions of conditioning for belief or plausibility functions heavily impacts on the properties of the relations represented by the above model.

2 - Imprecise probability assessments and the Square of Opposition

Giuseppe Sanfilippo, Niki Pfeifer

There is a long history of investigations on the square of opposition spanning over two millenia. A square of opposition represents logical relations among basic sentence types in a diagrammatic way. The basic sentence types, traditionally denoted by A (universal affirmative: "Every S is P"), E (universal negative: "No S is P"), I (particular affirmative: "Some S are P"), and O (particular negative: "Some S are not P"), constitute the corners of the square, and the logical relations–contradiction, contrarity, subalternation, and sub-contrarity–form the diagonals and the sides of the square. We investigate the square of opposition from a probabilistic point of view. To manage imprecise assessments which generally are non-closed or non-convex sets, we generalize the notions of coherence for interval-valued probability assessments to the case of imprecise (in the sense of set-valued) probability assessments. We interpret a basic sentence type as a pair (F,I), where F is a sequence of conditional events and I is an imprecise probability assessment on F. Moreover, by means of the notion of g-coherence, we introduce the above mentioned logical relations among our probabilistic interpretation of the sentences. Then we show how to construct probabilistic versions of the square of opposition by forming suitable tri-partitions. Finally we present applications of the probabilistic square of oppositions to study defaults and the semantics of quantified statements.

3 - Non-additive integrability for vector-valued functions and atomicity

Domenico Candeloro

In this paper we present some results concerning Gould integrability of vector valued functions with respect to a monotone measure not necessarily additive. In particular finitely purely atomic measures are considered, and as an application a Radon-Nikodym theorem in this setting is obtained.

■ WB-12

Wednesday, 10:30-12:00 - Building CW, ground floor, Room 029

Advances in Discrete-Continuous Optimization and Control

Stream: Combinatorial Optimization
Chair: *Gerhard-Wilhelm Weber*

1 - A Constraint Programming Approach to Flexible Manufacturing Cell Formation with Worker Assignment
Filiz Şenyüzlüler, Seyda Topaloglu, Adil Baykasoğlu

Cell Formation (CF) deals with grouping the machines and parts in manufacturing systems according to their compatibility. The complexity in production environment can be handled by these well-designed systems. Manufacturing processes are surrounded with lots of complex constraints, which should be considered carefully and represented clearly for obtaining high efficiency and productivity. Constraint Programming (CP) is a new approach to combinatorial optimization and provides a rich language to represent such complex constraints easily. On the other hand, the CF problems are well suited to be solved by CP approach since the problem has many constraints such as part-machine requirements, availabilities in the system in terms of capacity, machine and worker abilities. In this study, the CF problem is modeled using machine, part processing and worker flexibilities together using the knowledge of operational capabilities of machines and workers. The assignment of parts, machines and workers to cells is done concurrently on the operational basis. Ten case problems are generated and different search phases of CP are defined for the solution procedure. The CF problem is modeled in both CP and integer programming. The computational results demonstrate the efficiency of CP.

2 - Data science, machine learning, ternary and other hard decision problems: how copositive optimization can help
Immanuel Bomze, Paula Amaral

Most algorithms currently employed by automated data analysis are based on criteria leading to optimization problems which are notoriously hard to solve. By consequence, often heuristic and/or incomplete routines are used. However, both false-positive and false-negative results can be literally lethal, so it is mandatory to have quality guarantees. Only exact optimization methods can assist in this situation. The task complexity is partly due to the discrete (or mixed-integer) structure, and partly to non-convexity of the functions involved, even if only continuous decision variables are considered. We present an example of this phenomenon, namely yes/no decision with an abstention possibility. A similarity-based clustering/prediction criterion considering this third option seriously, leads to a ternary fractional quadratic optimization problem which is very hard from the worst-case complexity point of view. Applications include analysis of social networks via graph tripartitioning. Copositive optimization transforms both difficulty aspects, discreteness and nonconvexity, into a linear optimization problem over a convex (matrix) cone, pushing all problem complexity into the description of the cone. This approach allows for developing tractable approximations of these hard problems, building upon interior-point optimization technology. The resulting bounds can serve as a benchmark on the quality of decision, and may be used for alerting human supervision in an automated way.

3 - Interior Point Methods and Column Generation
Jacek Gondzio

Advantages of interior point methods (IPMs) applied in the context of column generation will be discussed. Some of the many false views of the combinatorial optimization community on interior point methods will be addressed and corrected.

This is a joint work with Pablo Gonzalez-Brevis and Pedro Munari.

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J. Gondzio and P. Gonzalez-Brevis, A new warmstarting strategy for the primal-dual column generation method, Mathematical Programming A 152 (2015), pp. 113–146.

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■ WB-13

Wednesday, 10:30-12:00 - Building CW, ground floor, Room 3

VeRoLog: Heuristics for VRP variants 1

Stream: Vehicle Routing and Logistics Optimization
Chair: *David Di Lorenzo*

1 - A New Formulation for the Close Open Mixed VRP
R. Aykut Arapoglu, Abdurrahman Yildiz

In the classical capacitated vehicle routing problem (CVRP), all vehicles are required to return to the depot after visiting a set of customers. In this study, we propose a new parametric formulation for the Close Open Mixed VRP which includes both closed and open routes simultaneously. While closed routes are followed by the vehicles owned by the company, open routes are generally operated by rental vehicles. We assume a set of homogenous vehicles with identical capacity. The objective is to find a route for each vehicle minimizing the total distance traveled. The model is formulated as an integer programming problem and solved by using GAMS software. Small sized test problems from the literature can be solved optimally; however, larger instances require heuristic procedures. To this end, we also propose an SA based heuristic procedure. Computational results obtained by using a set of benchmark instances are presented and compared with the results given in the literature in terms of both computation time and accuracy.

2 - Heuristic algorithm for arrival times with driver hours of service in truck transport
Gideon Mbiydzenyuy

The problem of estimating arrival times in truck transport with accountability for driver hours of service regulations is addressed. The heuristic algorithm aims to improve how the arrival time of trucks is determined by transport planners in order to influence decision making concerning future plans but also ongoing activities at the consignee expecting the arrival of the shipments. The construction of the heuristics is based on a practical scenario of the challenges facing involved actors when estimating arrival times, e.g., longer journeys in which they must decide if the driver shall drive 9 hours or 10 hours in one day ((EC) No 561/2006). The intuition behind the heuristics is that current driving time for each driver is discounted recursively per given activity and the cumulative time discounted from all activities is used as a basis for estimating arrival times, when the last activity has been completed. The order of the activities is based on the order of the schedules from the company system, such as a fleet management system. Relevant service elements build on the proposed heuristics have also been developed, and the service is currently being tested within an ongoing project (NEXTA). The plan is to present the algorithm and the results at the upcoming EURO conference.

3 - A novel matheuristic approach based on sets of independent moves in CVRP problems
David Di Lorenzo, Tommaso Bianconcini, Alessandro Lori, Fabio Schoen, Leonardo Taccari

In this paper we propose a quite standard, tabu based, CVRP algorithm equipped with a very large neighborhood search component based on the solution of a MIP program. The proposed approach consists in choosing a set of admissible moves (swaps between groups of customers, insertions of customers in a route, ...) through the solution of a MIP model. Choosing a set of improving moves to be applied simultaneously produces significantly better results than adopting a greedy strategy in which best single moves are adopted first. Preliminary numerical results are promising.

■ WB-14

Wednesday, 10:30-12:00 - Building CW, 1st floor, Room 125

Optimization in Liner Shipping 2

Stream: Maritime Transportation
Chair: *David Pisinger*

1 - Liner shipping network design - a new decomposition
David Pisinger

Liner shipping is the foundation for global commerce, but international shipping is responsible for about 2.7% of the global CO2 emission. It is therefore important to develop decision support tools for designing liner shipping networks, minimizing energy consumption.

Formally, the liner shipping network design problem is to construct a number of routes operated on a weekly schedule such that a given set of demands can be transported at minimum operational cost. Only a few MIP models have been proposed for this problem, and generally these models are only able to solve small problems to optimality.

Hence, most algorithms are based on a two-stage decomposition: First, a number of routes are constructed, and then a multi-commodity network problem is solved to flow the demands through the network. However, due to the complexity of solving large-scale multi-commodity flow problems with time constraints, it is only possible to search a small subset of routes.

In this talk we present a different decomposition based on first flowing the demand, and then constructing routes that cover the flow. The proposed relaxation is a time-constrained network design problem with edge setup costs. This problem is also NP-hard to solve, so a heuristic approach is used based on variable-size neighbourhood search. At the end of the presentation it is discussed how solutions to the relaxed problem can be used to construct routes for the original liner shipping network design problem.

2 - Disruption Policies in Liner Shipping
Nursen Aydin, Afshin Mansouri, Habin Lee

Liner vessels encounter many uncertainties during their services such as varying weather conditions and disruption at ports. Disruption during the voyage of a vessel may cause delay and result in deviation from the planned schedule. In this study, we work on disruption problem in liner shipping by considering the uncertainty in port service times. We focus on various recovery strategies including cruise speed variation and port skipping. We develop stochastic dynamic programming models to provide approximate solutions. To derive managerial insights, we conduct numerical studies by using real shipping data.

3 - Using Fourier-Motzkin Elimination to Produce Efficient Cargomix Models for Revenue Management
Mai Ajspur, Rune Jensen

A cargomix model is a large set of linear inequalities that express how many containers of various types – defined by weight class, height and reefer-property – it is possible to stow in each bay of a container vessel without breaking i.a. seaworthiness, capacities and stacking rules. These models are often very large, prohibiting them from use in liner shipping companies' revenue management. The reason is that the models include information about where the cargo is stowed, whereas the dependencies between the mere number of each type is sufficient for revenue management. To use these cargomix models for revenue management it is therefore necessary to abstract the location information away. Theoretically, this can be achieved by use of the Fourier-Motzkin Elimination method (FME). At each step of this algorithm, a variable is eliminated whereby the number of inequalities potentially grow quadratically, causing the intermediary systems as well as the running time to potentially become extremely large. Although redundant inequalities can be removed using e.g. CPLEX, this is also computationally expensive, and hence FME is often viewed as unfit for use. In our work, we use a hierarchical decomposition of the models and a parallelized version of FME with redundancy removal to handle the high combinatorial complexity. Our results so far show that FME is a promising approach for computing abstract cargomix models with a small resulting size.

■ WB-15

Wednesday, 10:30-12:00 - Building CW, 1st floor, Room 126

Replenishment and Coordination

Stream: Supply Chain Management
Chair: *Matthias Lech*

1 - The replenishment problem in two-echelon distribution network on the example of pharmaceutical industry
Michal Jakubiak

Lack of products is a very common occurrence. No good sought by the recipient at the time of interest may cause negative reactions, which mildest consequence may be to leave the store and lost the benefit from the sale. Providing the availability of products appeared to be the crucial condition for generating income from the sales as well as making possible for the companies to conquer new markets. In this paper we study an inventory system on the example of distribution network in pharmaceutical industry. The problem of replenishment in multi-echelon network is very important for availability product maintenance. Replenishment orders have to be coordinated in a way that the capacity at the manufacturer is utilized, the replenishment costs are minimized and product's availability is increased. We present a simple approach to determine the parameters of the replenishment policy.

2 - Agricultural Cooperative Pricing of Premium Product
Nur Cavdaroglu, Burak Kazaz, Scott Webster

We consider the problem of price-setting by a cooperative (co-op) for an agricultural product with the following characteristics: (1) the open-market price depends on yield and on quality and (2) the quality is influenced by farmer investments over the growing season. The co-op purchases product from its members according to a quality-dependent price schedule. To be viable over the long-term, the price schedule must be competitive with the open market from both the perspective of the farmer and the co-op. One alternative for achieving this condition is to set prices that largely mimic the open market, and indeed, we find this approach in use at a major co-op that we studied.

We identify a simple pricing scheme that shows potential to improve performance, and we characterize the drivers and the magnitude of performance improvement. We show that improvement is largely dictated by the significance of the co-op's brand equity—the degree to which the co-op can command a higher price for the product than a farmer. For the case of risk-averse farmers, we show how the pricing scheme can be augmented by crop insurance, and that performance improvement is greater in the presence of risk aversion. Both farmer risk aversion and cooperative brand equity that is increasing in quality are present in the premium olive oil industry that motivates this work. Data suggest profit improvement opportunities for both the farmer and the co-op by employing the proposed pricing approach.

3 - A software framework for establishing Supply Chain Coordination scenarios
Matthias Lech

Based on schemes for the coordination of complex contracts in buyer-supplier-settings we propose a software framework to establish coordination scenarios that are based on automated negotiations carried out by two or more autonomous software agents with the option to include mediator agents. The goal is to facilitate decentralized Supply Chain Coordination while having low requirements for the disclosure of private information. Our framework covers the context of lot-sizing, inventory-control and job scheduling.

4 - Analysis of a Price Only Contract in a Reverse Supply Chain
Majid Biazaran, İsmail Serdar Bakal

Many Original Equipment Manufacturers (OEM) fully or partially outsource take back activities. However, decentralization caused by outsourcing may result in significant inefficiencies. Although several contracting mechanisms have been proposed to reduce the inefficiencies in the forward chains, the effectiveness of these contracts has not been fully investigated in reverse chains. In this study, we investigate a two-echelon reverse supply chain, consisting of a remanufacturer and a collector in a single-period setting. Collector is in charge of acquiring used products from end customers by paying an acquisition price per unit of used products. The collected products are then sold to the remanufacturer who faces a random demand for remanufactured products. We first consider the centralized setting and derive the optimal acquisition price. Then, we study the decentralized setting under remanufacturer's lead (RL) and collector's lead (CL). Under both RL and CL, we demonstrate that as long as the total cost of reverse activities are constant, the channel performance is independent of how these costs are distributed among the parties. We also show that there exists a wholesale price that can coordinate the decentralized channel under both RL and CL, which allocates positive profit to both parties. Furthermore, through an extensive experimental study, we compare the centralized channel performance to the decentralized channel performance.

■ WB-16

Wednesday, 10:30-12:00 - Building CW, 1st floor, Room 128

Ambulance Fleet Management 2

Stream: Healthcare Logistics
Chair: *Amir Rastpour*

1 - Using Simulation/Optimisation for Better Ambulance Re-Deployment
Andrew J Mason, Oddo Zhang, Andy Philpott

The ambulance re-deployment problem involves making real-time decisions on the positions at which idle ambulances should wait to maximise the long run on-time performance of the system. We present an approach in which a mixed integer programming (MIP) model is used to determine when ambulances should be moved, and to where; this MIP gives us our redeployment policy. We have embedded this model in the Predict simulation developed by the The Optima Corporation system, and use this to evaluate performance of our approach for Auckland, New Zealand. The performance of our MIP model depends on its objective coefficients. We adjust these coefficients - and thus tune our redeployment policy - using simulation optimisation in which a Nelder-Mead Simplex algorithm is used with an objective function given by the number of on-time calls as produced when running our simulation with the embedded re-deployment MIP. Results are presented and insights given.

2 - Dynamic Programming for Ambulance Fleet Management
Amir Rastpour, Armann Ingolfsson, Greg Zaric, Mehmet Begen

We use dynamic programming to model ambulance systems. Our model can potentially assist ambulance dispatchers to proactively avoid states at which most, or all, of scheduled ambulances are busy by taking appropriate actions timely. Possible actions that we consider are: Calling in additional ambulances from neighboring cities, expediting the service, and repositioning available ambulances following a desired compliance table. The objective is to maximize the expected proportion of time that the system spends in states with low utilizations by using reward functions that penalize being in high-utilization states. We use a detailed simulation model to validate our results.

3 - Ambulance Capacity Model with Dynamic Ambulance Management Aspects
Geert-Jan Kommer, Martin van Buuren

Dynamic ambulance management is a strategy to reposition ambulances in time in order to optimize coverage and realize short response times. In case of static management, after a service, ambulances return to their stations and wait there for the next service. In our research we study the efficiency gains of dynamic ambulance management in relation to the size of the ambulance fleet and developed a capacity model that includes these efficiency gains. The model takes into account a number of regional geographical characteristics, like the density of the road network and the shape of the region, that facilitate or impede the effect of dynamic management. Based on these variables, we clustered regions in classes with more or less gains of dynamic management. The effect of dynamic management is estimated by use of simulation models. Simulations were done for static and dynamic management with different numbers of ambulances and initial configurations for the locations of ambulances. We estimate the effect of dynamic management in the range of 95% performance. The effect is a performance gain up to 1.0 percentage point in rural regions up to 3 percentage points in metropolitan regions. In terms of the number of ambulances needed, the same performance can be achieved with up to 3% less ambulances. Application of these results in a capacity model needs more fine-tuning of the base model as it seems that the base model does not provide a level playing field for the regions.

■ WB-17

Wednesday, 10:30-12:00 - Building CW, ground floor, Room 0210

Retail Logistics Planning 2

Stream: Demand and Supply Management in Retail and Consumer Goods
Chair: *Dominik Kress*

1 - Efficient Handling of Peak Demand in Robotic Mobile Fulfillment Systems
Marius Merschformann, Tim Lamballais Tessensohn, René de Koster, Leena Suhl

Our work focuses on robotic mobile fulfillment systems in e-commerce distribution centers. These systems were designed to increase pick rates by eliminating unproductive travel time, while ensuring that orders are shipped as fast as possible. The main task here is to coordinate thousands of robots and solve interdependent resource allocation problems to turn homogeneous item crates into ready-to-ship packages. The main focus is order assignment in conjunction with pod storage assignment and task allocation. In short these decide (in the same order) which orders are assigned to which pick station, where to park the pods when bringing them back to the inventory and how the tasks are allocated to the different robots. The specific context shall take into account that a distribution center may be subject to heavy order peaks.

During these peaks orders have to be buffered naturally as pick stations are at their capacity limit. In our investigation we focus on identifying mechanisms capable of exploiting differences in the demands over time as well as switching certain mechanisms during runtime to better adapt to the situation at hand. The main goal is to increase the overall order throughput of the system.

2 - Balancing transportation and handling costs in the retail supply chain
Rob Broekmeulen

Retailers have increased their product availability with the introduction of Automated Store Ordering (ASO) systems. These systems assist replenishment decisions in a complex stochastic environment, based on forecasting and inventory control models. To increase the efficiency of the operations, retailers must also improve transportation and handling processes without reducing the product availability. Aspects such as weekly demand patterns and in-store replenishment processes due to limited shelf space have a profound effect on the workload in the supply chain from retail DC to the stores. Retailers can optimize transportation and handling processes by concepts such as order advancement and order consolidation. We developed novel approximations that can determine the impact of changing the ASO parameters on the expected (backroom) inventory, the expected number of order lines and other relevant measures for workload optimization in a multi-product setting with lost sales. We illustrate our approach in a case study involving a periodic delivery scheduling problem at a Dutch retailer.

3 - Approaches for effective sizing of backroom storage facilities in retail food stores
Pedro Amorim, Maria Pires, Ana Camanho

Backrooms are crucial in modern retail stores and face great challenges. Despite having similar functions to conventional warehouses, backrooms have particularities that deserve a distinct analysis. In this presentation we address two distinct approaches for sizing the backroom storage facilities. Both approaches use linear programming model, but one has a top-down approach (data envelopment analysis methodology) and the other a more traditional bottom-up approach (operations management methodology). The merits of each approach are discussed.

4 - A basic partition problem to assign storage space in group-based storage systems
Dominik Kress, Nils Boysen, Erwin Pesch

We consider a basic partition problem that subdivides stock keeping units (SKUs) into disjoint subsets, such that the minimum number of groups has to be accessed when retrieving a given order set under a pick-by-order policy. We formalize this SKU partition problem and show its applicability in a wide range of storage systems that are based on separating their storage space into groups of SKUs stored in separate areas; examples are carousel racks and mobile shelves. We analyze the computational complexity and propose two mathematical models for the problem under consideration. Furthermore, we present an ejection chain heuristic and a branch and bound procedure. We analyze these algorithms and the mathematical models in computational tests.

■ WB-18

Wednesday, 10:30-12:00 - Building CW, ground floor, Room 023

Computing and OR - Emerging Applications 2

Stream: Computing
Chair: *Gerhard-Wilhelm Weber*
Chair: *Arsham Atashi Khoei*
Chair: *Ali Hamidoglu*

1 - Problem-oriented computation services integration process simulation.
Zoia Runovska, Vlad Kucher

Solving complex problems by methods of operations research may lead to new problems which require a set of problem-oriented services for solving typical computational tasks related by the scheme of solving initial problems. Modern approach for the development of the system and technical solutions is based on the concept of Service-Oriented Architecture (SOA). To simplify multiple references and service composition with various applications, approaches of unified control of remote service access are to be developed, theoretical bases of mathematical-information modelling of dynamic processes and of the accompanying set of ontologies are to be elaborated. In this regard, the work is introducing a mathematical scheme of a formal service description and a formalization of interfacing services and types of links specific to the service interaction. Search for services and their selection are based on their semantic attributes regardless of physical location. This assumes a developed ontology of the studied area and its objects (service inputs/outputs, restrictions on the service implementation and the results of service execution) provided with semantic annotations. An algorithm for generating the required structure to address the task is proposed. Of the allocated in accordance with the algorithm sets of service interaction patterns the optimal scheme can be chosen by managing service execution sequence, methods of parallelization, load balancing and data transfer routes.

2 - Integer Programming and Heuristic Approaches for the Dominating Tree Problem
Selin Akifoglu, Mustafa Kemal Tural

Let G=(V, E) be a simple undirected edge-weighted graph, where V and E denote the set of vertices and edges of G, respectively. The Dominating Tree Problem (DTP) searches for a minimum weighted tree in G, say DT, such that each vertex either belongs to DT or is one-hop away from DT. This problem is an NP-hard but a practical problem. The solution of the DTP is used to construct a backbone for wireless sensor networks, which have a wide usage in many industrial and consumer applications. In this paper, different integer programming formulations of the problem are introduced and optimal solutions of some instances in the literature are provided for the first time. For larger instances, heuristic algorithms are proposed and compared with the algorithms from the literature.

3 - Low Carbon Weber Problems
Arsham Atashi Khoei, Mustafa Kemal Tural, Haldun Sural

The Weber location problem locates a facility in a plane so that the sum of weighted Euclidean distances from the facility to the customers is minimized. Sending vehicles from the facility to the customers for delivering/picking goods results in a significant amount of CO2 emissions affecting citizens' quality of life and the climate. We consider an extension of the Weber problem, named as the Low Carbon Weber Problem (LCWP). The LCWP decides on the location of the single facility and the speeds of the vehicles serving the customers within the one-sided time windows so as to minimize the total amount of carbon dioxide emissions. We also consider time-dependent congestion that limits the vehicle speeds in the LCWP, called as the time-dependent LCWP (TD-LCWP). We formulate the TD-LCWP as a second order cone programming problem which can be efficiently solved to optimality. Computational results are provided to compare the solutions of the Weber problem, the LCWP, and the TD-LCWP in terms of carbon dioxide emissions in different congestion patterns.

■ WB-19

Wednesday, 10:30-12:00 - Building CW, ground floor, Room 021

Stochastic Optimization in Logistics

Stream: Transportation and Logistics
Chair: *Luca Bertazzi*
Chair: *Francesca Maggioni*
Chair: *Rosario Paradiso*

1 - A Two-Stage Stochastic Location-Inventory Problem
Mehdi Amiri-Aref, Walid Klibi, Mohamed Zied Babai

A multi-period location-inventory optimization problem characterized by uncertain customer demand and supply lead-time is studied in this work. It tackles, at the strategic level, the design of a distribution network which consists of a set of available suppliers, multiple potential distribution centers and a set of demand zones. At design time, daily uncertain demand is issued from demand zones and the opened distribution centers must be supplied given an uncertain lead-time. The demand uncertainty is modeled with a nonstationary distribution with seasonal trend and the lead-time uncertainty is modeled with a known distribution. Considering that, a scenario-based approach is used to model the demand and lead-time uncertainty in a two-stage setting. Moreover, a daily reorder point (r, Q) inventory control policy at the distribution centers is considered. With these features, a stochastic two-stage mathematical model integrating the inventory control decisions with location-allocation design decisions is proposed. The objective function of this model maximize the total expected profit of the distribution network. Given the solvability issues of the obtained model, the sample average approximation method is applied and a heuristic solution approach is developed to cope with realistic-size instances. Based on an illustrative case, we show the impact of inventory decisions on the strategic location-allocation decisions and discuss the sensitivity of the results to the demand and

2 - A Solid Waste Management Problem with Stochastic Parameters in a Tactical Level of Planning
Claudio Gambella, Francesca Maggioni, Daniele Vigo

We describe a problem of waste flow allocation in which the uncertainty in the waste generation amounts is explicitly considered in a Two-Stage Multiperiod Stochastic Programming formulation. The study is motivated by the availability of historical data of some waste commodity generated in the cities under the responsibility of a large company in the waste treatment in Italy. The main features of the waste management network of the Emilia-Romagna region of Italy was also known from a consulting company. The proposed stochastic model considers a monthly waste flow allocation in a yearly planning horizon. Computational results are referred to a set of scenarios obtained by historical data. Standard stochastic measures such as Expected Valued of Perfect Information and Value of Stochastic Solution are reported.

3 - Investments in Shipping Capacity under Uncertainty: Maximizing the Rate of Return
Giovanni Pantuso, Ove Mørch, Kjetil Fagerholt, Jørgen Glomvik Rakke

Decisions regarding investments in shipping capacity expansion or renewal require taking into account both the operating fitness and the financial performance of the investment. However, while several operating requirements have been considered in the operations research literature, the corresponding financial aspects have not received as much attention. In addition, investors in ships need to face the uncommonly high uncertainty affecting the maritime business. We present a stochastic programming model for the renewal of shipping capacity. The new model maximizes the Average Internal Rate of Return (AIRR). Maximizing the AIRR sets stricter return requirements on money expenditures than classic profit maximization models and may describe more closely shipping investors' preferences. We illustrate how the resulting nonlinear model can be linearized to ease computation. Based on data from a major liner shipping company, worldwide leader in the transportation of rolling equipment, we compare the AIRR maximization model with a profit maximization model. Results show that while maximizing profits results in aggressive expansions of the fleet, maximizing the return provides more balanced renewal strategies which may be preferable to most shipping investors.

4 - Production and Inventory Routing Problem under uncertainty for agri-food products
Rosario Paradiso, Demetrio Laganà, Roberto Musmanno, Antonio Violi

The aim of this work is to study and explore integrated methods to manage the production and the distribution of product with quick perishability. A very important field of application of this techniques could be the agri-food market. The agri-food supply chain (ASC) indicates all the activities from production to distribution that bring agricultural and other food products from the farm to the table. The freshness of the products is critical in order to ensure an high customer satisfaction in term of quality. This is not simple, because of the uncertainty of the demand and the quick perishability that makes high inventory level economically unsustainable. In order to manage all this issues, a stochastic model for a Production and Inventory Routing Problem is formulated and an algorithm to solve it is proposed.

■ WB-20

Wednesday, 10:30-12:00 - Building CW, ground floor, Room 022

Cutting and Packing 3

Stream: Cutting and Packing
Chair: *Horacio Yanasse*

1 - The cutting stock problem with a reduced number of different patterns
Horacio Yanasse, Calvin Costa

In the cutting stock problem we want to cut large pieces (the objects) to obtain smaller ones (the items) that are required. The problem is to find a set of cutting patterns (the way the objects are to be cut) and how many times each pattern has to be cut (their frequencies) so that all the demand of the items is satisfied and some objective function or a set of objective functions is optimized. In this work we address a particular case of the problem where the change of cutting patterns requires a significant set up time therefore affecting the productivity of the machine. Hence, a reduced number of different patterns is desirable in a cutting plan. We consider the problem of minimizing the number of objects subject to an upper bound on the number of different patterns in a solution. We present a mathematical formulation for this problem and some limited computational test results.

2 - Cutting stock problem with usable leftovers: implications for sustainability
Adriana Cherri, Karen Coelho, Edmea Cássia Baptista, Charbel Jabbour, Edilaine Soler

This work proposes an innovative solution for cutting stock problem with usable leftovers (CSPUL) and its implications for sustainability. In such problem, a set of standard objects or non-standard objects (retails), which are available in stock, must be cut in order to produce a set of demanded items, optimizing an objective function and allowing that a certain amount of retails return to the stock to meet future demands. Different from the CSPUL, in this work, retails in stock in addition to being used, they can be sold to companies, which use them as raw material. Furthermore, the retails that can be generated for stock are previously defined and have limited quantities for each type. This problem has the objective of maximizing the profit and, to solve it, a mathematical model and two heuristic procedures were proposed. Due to the particularities of the problem, we observe that the proposed strategy solution has implications for sustainable management, in terms of environmental, economic and social issues. More precisely, the proposal aligns with the objectives of the Cleaner Production (CP) which aims to not generate leftovers, use them internally or use them externally. The possibility of generating retails makes the companies more competitive in the market, while incorporating environmental aspects in their operation strategies and, consequently, make better their image and profitability.

3 - The two dimensional multiperiod cutting stock problem
Kelly Cristina Poldi, Silvio de Araujo

The multiperiod cutting stock problem arises in the production planning and programming in some industries. The demanded items are required in different periods of a finite planning horizon. In several cases, it is possible to anticipate or not the production of items and, such anticipation could lead to a better combination of items, generating lesser waste. Unused inventory in a certain period becomes available to the next period, all together with new inventory which may be acquired. A column generation approach is used to solve the problem. Computational experiments regarding data from a small metallic structures industry were carried out and showed that effective gains can be obtained when compared multiperiod model with the lot for lot solution.

■ WB-21

Wednesday, 10:30-12:00 - Building CW, ground floor, Room 025

Methodology of Societal Complexity and Economy

Stream: Methodology of Societal Complexity
Chair: *Dorien DeTombe*
Chair: *Cor van Dijkum*

1 - Variable Structure Optimal Control Problem with Delay and Its Application in Compram Method
Akaki Arsenashvili

This study relates to optimal control problem for two stage variable structure control system and its application for handling complex societal problems in a transparent and structured way. Handling in this case means analyzing, policy making, decision making and guiding and evaluating the interventions. We consider optimal control problem where law of movement on the both stage is described by ordinary differential equations with delay arguments. These two stages are connected by the continuity initial condition. For this the finite conditions of the first stage are the initial conditions for the second stage, which unites them into a unique system. Optimal control is also the transition moment from one stage of system to another one. Confirmed that using Compram method the change of the structure may occur, when we need to pass the mentioned stage of investigation and go to the next one or change the decision inside the stage. It is also necessary to make into consideration the time delay factor of receiving the information and decision transmission. Moreover, general results are specified for a linear variable structure time-optimal control problem and an illustrative example is considered.

2 - A Heuristic Approach for Welfare-oriented Periodic Food Recovery and Distribution Problems
Hanna Grzybowska, Divya Jayakumar Nair, David Rey

We address the food recovery and distribution problem encountered in food rescue operations. The emergence of non-for-profit food rescue organizations has attracted practitioners to design innovative solutions to recover surplus food from local sources (e.g. farmers, restaurants, supermarkets, etc.) and distribute it to welfare agencies. The rescued food may include perishable goods and that need to be delivered immediately. Further, food rescue operations often rely on the periodic provision of surplus food by local sources. Hence, the food rescue problem can be represented as a periodic pick-up and delivery vehicle routing problem. In contrast to traditional routing problems, the objectives of food rescue operations go beyond cost-driven optimization models. In the context of welfare maximization, equity-oriented objective functions are prevalent to ensure a fair division of the goods recovered. In this paper, we focus on the development of periodic vehicle routing models for food rescue operations. We build on existing work and introduce efficient heuristic algorithms to tackle the problems on realistic scenarios involving hundreds of pick-up and delivery locations. The heuristic algorithms combine scheduling and routing decisions while providing a fair division of the recovered surplus food.

3 - Group Decision Support by Hierarchical Clustering from the Viewpoint of Ignorance of a Decision Maker
Tomoe Entani

The decision problem in this study is that a group of decision makers assigns the importance weights to several alternatives. A decision maker gives the comparisons of all the pairs of alternatives, which are often chosen from a list of cardinal numbers corresponding to verbal statements. However, these given comparisons are often inconsistent each other. One of the reasons of inconsistency is ignorance of a decision maker. S/he always does not know the precise weights of all alternatives. In this study, in order to reflect it into the weights, a pseudo alternative consisting of all alternatives is added. The weights assigned to each alternative and pseudo alternative are summed up to one, although it remains unclear which of alternatives has the latter weight. The model to obtain the individual weights from his/her comparisons is proposed by minimizing the weight of pseudo alternative. Then, the grouping process is achieved by hierarchical clustering, in which individuals are merged into clusters one by one in a bottom up scheme. When a pair of individual weights is combined into a group weight, the Dempster's combination rule is utilized, so that ignorance of the group becomes smaller than that of each individual. It seems to be natural that ignorance is gradually decreased as the grouping process proceeds. In order, a pair of individuals/subgroups whose ignorance, pseudo alternative's weight, is greater than the others' is grouped until all become a group.

■ WB-22

Wednesday, 10:30-12:00 - Building CW, ground floor, Room 027

Real-World Applications of Operations Research

Stream: Combinatorial Optimization
Chair: *Fabio Furini*
Chair: *Enrico Malaguti*

1 - MIP Formulations for a Rich Real-world Lot-sizing Problem with Setup Carryover
Xueying Shen, Filippo Focacci, Fabio Furini, Virginie Gabrel, Daniel Godard

A rich lot-sizing problem is studied in this manuscript which comes from a real-world application. Our new lot-sizing problem combines several features, i.e., parallel machines, production time windows, backlogging, lost sale and setup carryover. Three mixed integer programming formulations are proposed. We theoretically and computationally compare these different formulations, testing them on real-world and randomly generated instances. Our study is the first step for efficiently tackling and solving this challenging real-world lot-sizing problem.

2 - Relocation in electric car sharing systems
Daniele Vigo, Enrico Malaguti, Filippo Masini

We consider a car sharing system operated by electric vehicles with limited battery capacity. The vehicles are made available at renting stations, where they are also charged, and can be returned to any station in the system (two ways system). We assume that customer requests are known in advance, and hence relocation of unused vehicles can be used to satisfy the users demand by providing charged vehicles where and when needed. The day-by-day operations of the system are modeled on a time-space network, and a Mixed-Integer Linear Program is used to maximize the value of the satisfied customers requests. Alternative ways of modeling the charging and discharging process of the vehicles battery are discussed. In addition, we also consider a free-floating system, where vehicles cannot be booked in advance, and can be left in any parking slot in the streets. The modeling ideas we propose can be extended to the latter case, where relocation is used to re-balance the vehicles distribution in the system. Extensive computational experiments on realistic instances obtained from existing car sharing systems and public transportation services are presented, showing that the aforementioned integer formulation can be solved in acceptable computing time for instances of realistic size. The impact of relocation on the system performance is analyzed and discussed.

3 - Real-World Knapsack Problem with Setup
Fabio Furini, Michele Monaci, Emiliano Traversi
We consider a variant of the knapsack problem in which items are partitioned into classes, each characterized by a fixed cost and capacity incurred in case some item of the class is selected. We present alternative Integer Linear Programming formulations of this problem and introduce efficient algorithms for solving the associated Linear Programming formulations and a branch-and-bound algorithm to compute the optimal solution of the problem. An extensive computational analysis shows that our algorithms outperform the state-of-the-art algorithms for this problem.

■ WB-23

Wednesday, 10:30-12:00 - Building CW, ground floor, Room 028

Green Maritime Logistics

Stream: Green Logistics
Chair: *Harilaos N. Psaraftis*

1 - Speed optimization with route improvements
Line Reinhardt, David Pisinger
In liner shipping the increased focus on emissions and the low freight rates of maritime container freight increases the focus on green cost reduction measures. Clearly reducing fuel consumption also reduces the emissions resulting in a win-win situation. Methods for speed optimization reducing bunker consumption for a given path has previously been developed and applied to predetermined routes where the transit times of demand is ensured. In this paper we will combine the speed optimization with a local search method for optimizing the port call order thus arriving at a even lower bunker consumption. Clearly when changing the routes some demands may be discarded due to transit time penalties or rerouted with a delay penalty. Moreover in the speed optimizer we consider the possibility of allowing for longer round trip time, slow steaming, at the cost of inserting vessels where the transit time of the demand is required to be satisfied or otherwise penalized. Preliminary results are presented for a real-life size liner shipping network.

2 - The cost of green maritime liner shipping: a bi-objective optimization approach
Ali Cheaitou, Pierre Cariou
Maritime transportation, and especially liner services, represent the backbone of international trade. Liner services transport containerized goods following fixed schedules between a number of ports. There exists a cubic relationship between the sailing speed of the vessels in a liner service and its bunker fuel consumption and consequently operating costs. Moreover, reducing the sailing speed of vessels requires adding more vessels into the service in order to guarantee a weekly call at each port in the service. In a competitive market, there may exist also a relationship between the sailing speed and the transport demand where customers can switch to a faster liner service if the sailing speed of their usual liner service is reduced, which constitutes an elastic demand case. On the other hand, vessel speed reduction is a mean to reduce greenhouse gas emissions from maritime transportation that is proportional to fuel consumption. In this context, we propose two bi-objective optimization models for elastic and inelastic demand cases based on the profit or the cost and on CO2 emissions. Pareto sets are then identified using three different bi-objective optimization methods. The models are tested using two services deployed in January 2010. The results show that if a CO2 tax is added, to be efficient, its value should be much higher in the case of elastic demand than in the case of inelastic demand.

3 - Modal shifts and decision models under the new sulphur limits within Emission Control Areas
Thalis Zis, Harilaos N. Psaraftis

The anticipated increased operating costs for Ro-Ro operators in the North Sea and the Baltic due to stricter regulation on sulphur emissions may result in increased fares. This in turn may lead to a modal shift towards land-based modes either due to lower costs, or due to a possible shutting down of certain services that can become unprofitable. While some services had seen considerable change in advance of January 1st 2015 when the 0.1% sulphur limits came into force, the parallel drop in fuel prices have rendered implications of the new regulation unclear. An enhanced bi-level freight logit model is presented that allows the estimation of modal changes between different maritime operators and also road-based alternatives. The model captures the effects of changes in fuel prices on freight surcharges, and the implication of operational changes (speed, frequency of service, abatement technology deployed) on mode choice and route profitability. The model is tested on data from a Ro-Ro operator, and sensitivity analyses on simulated data are conducted. For all scenarios, comprehensive emissions inventories are constructed to illustrate the environmental implications of the new regulation limits. The findings can be used to design a set of policies that mitigate the negative repercussions of the stricter sulphur limits on maritime trade and the environment. The paper also reviews other decision models that have appeared in the literature in the context of the sulphur problem.

4 - A multiple ship pickup and delivery problem with speed optimization and alternative objectives
Harilaos N. Psaraftis, Min Wen, Dario Pacino, Christos Kontovas

The purpose of this paper is to investigate a multiple ship pickup and delivery problem with simultaneous speed optimization and under alternative objective functions. A branch and price algorithm is developed that considers (a) fuel consumption as a function of payload, (b) fuel price as an explicit input, (c) freight rate as an input, and (d) in-transit cargo inventory costs. The alternative objective functions are minimum total trip duration, minimum fuel consumption (or emissions) and minimum total cost. Computational experience with the algorithm is reported on a variety of scenarios.

■ WB-24

Wednesday, 10:30-12:00 - Building BM, 1st floor, Room 119

Energy-Aware Scheduling 1

Stream: Project Management and Scheduling
Chair: *Jan Weglarz*
Chair: *Joanna Józefowska*

1 - Integer and Constraint Programming Approaches for the Continuous Energy-Constrained Scheduling Problem
Christian Artigues, Margaux Nattaf, Pierre Lopez, Tamas Kis

This paper addresses a scheduling problem with a cumulative, continuously-divisible and renewable resource with limited capacity. During its processing, each task consumes a part of this resource, which lies between a minimum and a maximum requirement. A task is finished when a certain amount of energy is received by it within its time window. This energy is received via the resource and an amount of resource is converted into an amount of energy with a non-decreasing, continuous and possibly non-linear efficiency function. The goal is to minimize the resource consumption. We propose constraint propagation algorithms, mixed integer linear programming approaches and valid inequalities for the problem.

2 - Scheduling Preemptable Jobs on Parallel Machines under Power and Energy Limits
Grzegorz Waligora, Rafal Rozycki, Jan Weglarz

We consider a problem of scheduling preemptable, independent jobs on parallel, identical machines. Each job requires for its processing both a machine and an amount of a single, doubly-constrained, continuous resource which is power/energy. Processing speed of a job at a time depends on a temporal usage of power. This relation is expressed by an increasing and strictly concave speed function. We consider two optimization problems in which P and E denote respectively: the known limit for available power, and the available amount of energy. The first is a problem of defining a minimum level of one of the parameters P or E, under the assumption that the minimum makespan is calculated only on a basis of a known value of the other parameter (thus, these are optimization problems with only one active constraint: either on power or on energy). The second is a problem of finding a minimum level of one parameter (P or E), under an assumed value of the makespan (these are typical server problems). In the proposed approach we divide the problems into two classes: (a) when the number of jobs is not greater than the number of machines, and (b) the other ones. The former class is easier since all jobs can be processed in parallel. For the latter class, a more complex approach based on sequences of combinations of jobs has to be applied. In both cases we formulate lemmas allowing to determine the amount of power or energy necessary for completion the set of jobs in a minimum time.

3 - Heuristic for Energy-Efficient Network Task Scheduling in Virtual Data Centres
Marek Mika

Ones of the most important elements of today's data centre infrastructures are computer networks which interconnect data centres, users and large number of end devices. As new technologies like programmable networks became available to network operators new opportunities appeared which made possible to develop virtual data centres. It is a natural evolution of the centralized, single-located data centre in which very important role play high capacity and long reach transport networks. Nowadays the traffic generated by huge data centres is very high, which results in increased energy consumption by computing and networking equipment. Thus, one of the most important challenge from the point of view of the owner/operator of such network is to minimize the energy consumed by the networking equipment. The problem of minimizing the consumed energy in computer networks in virtual data centre is defined and a mixed integer programming model of the problem is proposed. This model has been used to optimally solve the small size instances of the problem using one of the well-known commercial optimization software packages. A simple and fast heuristic algorithm has been developed to find semi-optimal solutions of the larger size instances. Its efficiency has been verified on the basis of computational experiment.

4 - When to Apply a Power Consuming Machine to Minimize the Schedule Length
Rafal Rozycki, Grzegorz Waligora

We consider a problem of scheduling preemptable, independent jobs on parallel, identical machines to minimize the schedule length. It models a real situation of scheduling computational jobs on parallel processors in a computer system. Each job requires an amount of power and a machine for its processing. The processing rate of a job is related to the amount of power allotted to this job at a moment. The machines are driven by a common power source of limited capacity. We assume that a machine uses a constant amount of power even if it is idle. Nevertheless, it is possible to reduce a constant power usage of a machine by turning this machine off. We propose a method of solving the considered problem which is based on a general discrete-continuous methodology. We show the conditions for which a parallel, sequential or mixed execution of jobs is optimal.

■ WB-25

Wednesday, 10:30-12:00 - Building BM, ground floor, Room 19

Behavioural Operations Management

Stream: Behavioural Operational Research
Chair: *Jelle de Vries*

1 - An Inventory System with Quasi-hyperbolic Discounting Rate
Xiaobo Zhao, Yun Zhou, Jinxing Xie
We consider a periodic-review inventory system with stochastic demands for innite horizon, in which the manager has a time-inconsistent preference with quasi-hyperbolic discounting rate. We model the inventory system as an intra-personal sequential decision problem. It is shown that the ordering decision follows a base-stock policy but has a systematic bias in that the base-stock level is lower than the standard optimal level. We extend our analysis to a supply chain that comprises a perfectly rational supplier and a quasi-hyperbolic retailer. The results show that the time-inconsistent preference of the retailer can cause considerable loss on system performance. We propose a contract with delay-in-payment and income-sharing for such a supply chain. It is shown that the contract can achieve the eectiveness of de-bias for the retailer and reach the goal of coordinating the supply chain to improve the performance.

2 - Forecasting Temporal Changes in Biases
Sundara Natarajan Panchanatham, Rahul R Marathe
In manufacturing setups, a finite work is to be completed before a due date. Different workers allocate their leisure time in different manner based on their sensitivity to cost. Existing models have focused on procrastination and wage design for a single contract, where the manager (principal) has complete information of worker's (agent's) sensitivity to immediate cost. We propose a multi-contract model that captures the learning, planning and manipulative efforts using the cost of quality and updates the cost sensitivity parameter at the end of every contract. We focus on the situation where the quality of work at the end of contract contradicts the initial prediction of quality by the manager's perception of worker's type. Thus, the model portrays delay as a healthy trait in some situations. Our work also concentrates on temporal changes of cost sensitivity for gains. Our work compares and contrasts the different types of workers and the ways of designing wage structures and incentives to effectively extract work from them in multiple contracts. Finally, we plan to validate our results using experiments.

3 - Trust-Aware Decision Support Mechanism for Supply Chains
Diego de Siqueira Braga, Bernd Hellingrath, Fernando Buarque de Lima Neto
Organizations in a supply chain face a vast number of problems, such as how to make decisions concerning production planning and inventory management. They are not isolated, their decisions are interdependent and impact on and are impacted by their partners, which makes the planning problem even harder. Trust is seen as one of the most important dimensions in developing and maintaining fruitful business relationships and has deep impact at the decision-making process in the SC planning. Furthermore, trust influences SC management success as it can facilitate communication and collaboration between SC participants. Though very important, trust is, until now, not explicitly present in the SC planning. There is a need for trust-aware decision-support mechanisms that explicitly incorporate the trust factor into the decision-making process in order to efficiently share information and assets, and make decisions about whether to trust an information source. The proposed decision mechanism is based on computational trust and reputation models. It will be used to investigate the social factors/human behavior (e.g. opportunistic behavior, misinterpretation or misuse of information and further) that influence the decision about procurement, information exchanged and its use on SC planning, as well to assess its impact on the Bullwhip Effect - one of the biggest efficiency problems shown by SCs which describes the phenomenon of increasing order variances upstream a supply chain.

4 - Individual differences in work rate variability: review and propositions
Kenneth Doerr

In this talk I will present a review of management science research on individual differences in work rate variability, from its beginnings in time and motion studies, to current day behaviorally-based research. Both empirical descriptive research, and prescriptive models and their applications will be reviewed. I will draw out unresolved issues related to (1) the nomological network of individual differences in work-rate variability, which appears to be different from the nomological network of individual productivity (mean work rate), and (2) the consequences of individual variability on group productivity, which appears to depend on the way group work is organized, and the time-urgency of work. I will offer three propositions related to these unresolved issues, and present preliminary results from two experiments which provide mixed support for these propositions.

■ WB-26

Wednesday, 10:30-12:00 - Building BM, 1st floor, Room 109D

Optimization for Business Analytics

Stream: Business Analytics and Intelligent Optimization
Chair: *Richard Weber*

1 - Multivariate time series made sparse by Mixed Integer Nonlinear Programming
Emilio Carrizosa, Alba V Olivares-Nadal, Pepa Ramírez-Cobo

Vector autoregressive (VAR) models constitute a powerful and well studied tool to analyze multivariate time series. Since sparseness, crucial to identify and visualize joint dependencies and relevant causalities, is not expected to happen in the standard VAR model, several sparse variants have been introduced in the literature. However, in some cases it might be of interest to control some dimensions of the sparsity, as e.g. the number of causal features allowed in the prediction. To authors extent none of the existent methods endows the user with full control over the different aspects of the sparsity of the solution. In this paper we propose a sparsity-controlled VAR model which allows to control different dimensions of the sparsity, enabling a proper visualization of potential causalities and dependencies. The model coefficients are found as the solution to a mathematical optimization problem, solvable by standard numerical optimization routines. The tests performed on both simulated and real-life multivariate time series show that our approach may outperform both the standard and Group Lasso in terms of prediction errors specially when highly sparse graphs are sought, while avoiding the VAR's overfitting for more dense graphs.

2 - Visualizing data as objects by DC (difference of convex) optimization
Vanesa Guerrero, Emilio Carrizosa, Dolores Romero Morales

In this talk we address the problem of visualizing in a bounded region a set of individuals, which has attached a dissimilarity measure and a statistical value. This problem, which extends the standard Multidimensional Scaling Analysis, is written as a global optimization problem whose objective is the difference of two convex functions (DC). Suitable DC decompositions allow us to use the DCA algorithm in a very efficient way. Our algorithmic approach is used to visualize two real-world datasets.

3 - Dynamic Clustering for Crime Analytics
Richard Weber, Georg Peters

The recent trend in Data Science, Big Data, and related areas has led to an enormous amount of data available in almost all areas that affect our daily life. Business, health care, and engineering are just some examples. Another one deals with security-related issues and inspired research in crime analytics, where data mining is used to find pattern in criminal activities. Examples can be found where police wants to better understand and prevent crime in public places. Other applications are fraud detection and cybercrime. Among all data mining approaches, clustering is one of the most commonly used overall and also in crime analytics. Since the phenomenon under study, i.e. criminal activities, is highly dynamic, the respective methods for analysis should be able to adapt to a changing environment. That is where dynamic clustering is of special interest. The recently proposed Dynamic Clustering Cube (DCC) is a tool to categorize existing approaches for dynamic clustering and also shows gaps for future research. In this talk, we will present the DCC for the particular case of crime analytics and map some of the existing applications into this cube.

■ WB-27

Wednesday, 10:30-12:00 - Building BM, ground floor, Room 20

OR for Development and Developing Countries 1

Stream: OR for Development and Developing Countries
Chair: *Laura Lotero*
Chair: *Elise del Rosario*

1 - How can a new university change the productive matrix of a country
Andreas Griewank

As Dean of the school of Mathematical Sciences and Information Technology at Yachay Tech I am charged with helping to improve the competitiveness of Ecuador in two key areas of science and technology. Yachay means knowledge and wisdom in the indigenous Quechua language. On the initiative of the president rafael Correa it was founded just two years ago and follows similar well known projects in the Middle East and East Asia, but also lesser known ones like UTEC (Peru) in Latin America. The political and commercial sponsors look for both, international recognition, preferably with some respectable position in one of the university rankings and economical improvements, particular in terms of technology transfer and personell qualifications. Arguably this has worked in South Korea with the Korean Advanced Institute of Science KAIST at the center of the science city Daedeok Innopolis. We will discuss whether and how this success can compete under very different conditions in Latin America.

2 - Challenges and opportunities in the optimization of freight transportation in Antioquia and Coffee Region, Colombia
Laura Lotero, Javier Dario Fernández-Ledesma

Freight transportation and logistics is a key process that contributes to the economy, competitiveness and development of a region. In Colombia, South America, there are identified deficiencies in infrastructure, such as lack of modernization and maintenance of roads and low spatial coverage, low multimodality and high logistic costs that affect the freight logistics performance and therefore the supply chain management. This is also the case of many regions in developing countries. In this communication, we present the main trends, challenges and opportunities for the optimization of freight transportation in Antioquia and the Colombian Coffee Region. Antioquia is one of the main departments of Colombia with more than 6 million inhabitants and shares borders with the coffee region, making it the largest coffee producer zone in the country. Colombia is known for its coffee quality and it is one of the main drivers of the economy in the country. Finally, we present the key parameters, variables and constraints to introduce an optimization model for the freight logistics in this region.

3 - An Optimal People Allocation Engine for Software Development Projects
Girish Palshikar, Rajiv Srivastava, Abhay Sodani, Viswanath Ganesan, A.p. Srinivas, Kishore Padmanabhan

In the knowledge-intensive, people-centric IT industry, with workforce and projects distributed across the globe, it is crucial to ensure the best use of employees' expertise across projects, so as to maximize timely delivery of high-quality software up to customer's satisfaction. Project leaders raise requirements for open project positions at any time. Each input requirement declares one position available in a project, and gives detailed specifications for that position in terms of the business unit, customer, location, technology skills along with the proficiency level in each skill, role, grade, start date etc. Input data about each eligible employee is given in the form of an employee profile, derived from her work and training history. Information in the employee profile includes the employee's current and past projects, roles, experience, trainings, skills with associated proficiency levels etc. The objectives ensure that the capabilities of the employees are used in the best possible way and each provides a different perspective on "good" allocations. Some objectives make use of machine learning predictive models (e.g., predicting role, predicting availability date). This bulk optimal allocation system is implemented and is undergoing trials in a large multi-national IT company. The system shows improvements in quality of allocations over the first-come-first-served, one-at-a-time manual allocations.

4 - Forecasting the Results of the 2014 Elections in South Africa
Hans W. Ittmann

Within a democracy elections are held regularly. A variety of election forecasting methods exists. In what is described in this paper the forecasting system is based on the election results. The predictions are thus made after the election as soon as the first results from the various voting districts are released. These results are released randomly and based on experience since the 1994 election the forecast is fairly accurate with around 10 to 15 per cent of results known. Various assumptions are made in the forecasting model. While the results are released randomly it is not clear how the bias of how results are released would affect the predictions. This is impossible to determine it beforehand. In the paper the mathematical formulation of the problem ("fuzzy clustering") will be presented and discussed while an example of a cluster will be presented. The forecasts as achieved in a number of elections, both national elections and local elections will be presented. These show how close to the final results are after around 10 to 15 per cent of the results have been released. Based on these experiences in the past the expectation was that the results, and accuracy, of the national elections in 2014 will follow the same pattern. This turned out to not be the case and this will be discussed.

■ WB-29

Wednesday, 10:30-12:00 - Building BM, ground floor, Room 7

Educational Timetabling

Stream: Timetabling
Chair: *Greet Vanden Berghe*

1 - The Pros and Cons of the Complex Goal Programming Model for University Timetabling
Veronika Skocdopolova

In this paper the complex goal programming model for university timetabling is briefly presented. Then the pros and cons of this model are discussed. Goal programming is a technique for multi-criteria decision making. The main advantage of using goal programming for timetabling is the possibility of implying soft constraints. The soft constraints in this model concern with teachers' preferences or capacities of classrooms etc. Another plus is dealing with different conflicting aims such as maximisation of teachers' preferences or maximisation of classroom capacity utilization. Using a complex model for university timetabling instead of a multi-stage model enables special constraints, such as the limit of days each teacher has lectures or allocation of computer classes. On the other hand, with the advantages, there are also disadvantages. The key disadvantage of a complex model is the computation time. The cons of goal programming is that the decision maker has to set the goals and weights carefully.

2 - A Hybrid Shuffled Complex Evolution Algorithm for the Examination Timetabling Problem
Nuno Leite, Fernando Melício, Agostinho Rosa

A memetic algorithm is proposed for solving the second International Timetabling Competition (ITC 2007) - Track 1, examination timetabling. A neighbourhood operator based on the concept of Kempe Chains, extended to work on the ITC 2007 instances, is proposed. A study of the effect of the local search cooling schedule on the optimisation of examination timetables is presented. A variant of the local search algorithm, which performs less evaluations, is presented.

In the hybrid method, the population is organised in sub-populations which evolve independently by applying a local search step; in this step, a mutation operator and the SA metaheuristic are used. A single neighbourhood operator (Shift move, where a random exam is moved into a different randomly chosen timeslot and room) was implemented. This operator tries to move exams in a feasible way using the Kempe Chain procedure. If it is not possible to apply the move, then this is set to be infeasible and ignored by the upper level operator (mutation operator or local search neighbourhood move operator).

The initial solution population is constructed by means of a Saturation degree graph colouring heuristic. Conflict-based statistics are used to prevent repetitive assignments of exams to the same values (period and room).

The experimental evaluation of the hybrid method shows that it is competitive with state-of-the-art methods, attaining the lowest cost on three datasets.

3 - A Mixed-Integer Linear Programming Model For Invigilator Scheduling Problems
Sedat Belbag, Mustafa Cimen, Mehmet Soysal

This paper concerns a real life invigilator scheduling problem confronted in two major universities in Turkey. Invigilation scheduling decisions are currently made manually in these universities. The manual scheduling aims to balance the number of invigilation duties among invigilators while assigning sufficient number of invigilators for each exam. In this study, we propose a Mixed-Integer Linear Programming (MILP) model for optimizing invigilator scheduling decisions. Our model adds to the invigilation scheduling literature by (i) treating exam lengths as a factor in fair distribution of examination duties among the invigilators, (ii) prioritizing the assignment of invigilators to the exams of their own expertise, and (iii) incorporating several hard and soft constraints simultaneously. Our numerical experiments are based on real data obtained from Business Administration departments of Gazi University and Hacettepe University. Results of the numerical experiments show that the use of the proposed model would significantly improve the manually-made scheduling in terms of fair distribution of duties, expertise-based assignment and successive assignments.

■ WB-30

Wednesday, 10:30-12:00 - Building BM, 1st floor, Room 110

Optimal Control Applications

Stream: Optimal Control Applications
Chair: *Gernot Tragler*

1 - Discussion of stability properties and the approximation of bang-singular-bang optimal controls
Ursula Felgenhauer

We consider optimal control problems with scalar control function under bound constraints in the particular situation, when the control consists of two bang arcs at the time interval ends, and one singular arc in the interior. As in case of continuous control functions, second-order optimality conditions play an essential role in analyzing the solution stability under data perturbation. However, in case of partly singular controls, these conditions yield rather weak coercivity properties w.r.t. control variations. This circumstance causes several difficulties in utilizing second-order growth estimates, first, in proving Lipschitz stability results for the controls as elements of some Lebesgue space, and secondly, in proving convergence for approximation methods of Newton type, but also classical discretization approaches.

It will be discussed, how the problem linearization together with the well-known Goh transformation allow to get first stability results near certain reference solution. Further we point out, which difficulties occur for applying similar techniques in iterative approximation schemes. For the special case of semilinear problems where the control enters the dynamics linearly with constant coefficients, convergence is shown for a Josephy-Newton method, and for Euler type discretization in the canonical system.

2 - robust adaptive control of a quadrotor
M Navabei, H. Mirzaei

In recent years, quadrotor helicopters with vertical takeoff and landing capabilities have a significant role in civilian usages like rescue mission, video surveillance and also military operations in hazardous locations. The quadrotor has a nonlinear, coupled and underactuated dynamics which poses serious challenges in control system design. This paper proposes a robust adaptive control strategy to solve attitude/altitude tracking and stabilization problem of a quadrotor unmanned aerial vehicle (UAV).

3 - Build agent based computational models for smart grids
Nhat Vinh Vo, Josef Haunschmied, Raimund Kovacevic

As decentralized electricity supply systems, smart grids can be modelled by cooperative game approach and it is possible to use an agent based simulation. Our project BiB4SGrid deals with mathematical models including batteries and leading players are operator, households and aggregator. In this study, we use the environment-rules-agents (ERA) framework to build agent based computational models. Agent for environment (including natural environment, operator and aggregator), agents for household, agents for devices and agents for rules and rule makers are described. Communication mechanisms are also set up. These results will be applied later to simulations with test scenarios which are led by another group of research.

4 - Dynamic Drug Policy: Optimally Varying the Mix of Treatment, Price-Raising Enforcement, and Primary Prevention Over Time
Gernot Tragler, Jonathan Caulkins

A central question in drug policy is how control efforts should be divided among enforcement, treatment, and prevention. Of particular interest is how the mix should vary dynamically over the course of an epidemic. Recent work considered how various pairs of these interventions interact. This paper considers all three simultaneously in a dynamic optimal control framework, yielding some surprising results. Depending on epidemic parameters, one of three situations pertains. It may be optimal to eradicate the epidemic, to "accommodate" it by letting it grow, or to eradicate if control begins before drug use passes a DNSS threshold but accommodate if control begins later. Relatively modest changes in parameters such as the perceived social cost per unit of drug use can push the model from one regime to another, perhaps explaining why opinions concerning proper policy diverge so sharply. If eradication is pursued, then treatment and enforcement should be funded very aggressively to reduce use as quickly as possible. If accomodation is pursued then spending on all three controls should increase roughly linearly but less than proportionally with the size of the epidemic. With the current parameterization, op- timal spending on prevention varies the least among the three types of control interventions.

■ WB-31

Wednesday, 10:30-12:00 - Building BM, 1st floor, Room 111

Location and Routing in Humanitarian Logistics

Stream: Humanitarian Operations
Chair: *Sibel Salman*
Chair: *Melih Çelik*

1 - An optimal strategy for the Online Multi-agent k-Canadian Traveler Problem on edge-disjoint graphs
Sibel Salman, Davood Shiri

The multi-agent k-Canadian Traveler Problem (k-CTP) is a vehicle routing problem, where traveling agents receive a graph as input in which at most k edges are blocked. An agent discovers the status of an edge when he/she reaches an end node of the edge. The objective is to provide an online strategy such that at least one of the agents should find a feasible route from its initial location (O) to a given destination (D) with minimum cost. The problem is an online optimization problem that generalizes k-CTP by the existence of multiple agents. To measure the performance of online strategies, competitive ratio is introduced in the literature, which has been defined as the maximum ratio of the cost of the online strategy over the cost of the offline strategy after removing blocked edges from the network over all instances of the problem. Two versions of multi-agent k-CTP has been introduced in the literature, with complete and limited communication. We analyze the problem in which there exists an external decision maker who can communicate with the agents before they start their travels. We introduce an online strategy which is optimal for both cases with complete and limited communication in edge-disjoint graphs. We also show that enabling all of the agents to communicate does not improve the competitive ratio of deterministic strategies in edge-disjoint graphs.

2 - Multi-vehicle synchronized prize-collecting arc routing for connectivity problem
Vahid Akbarighadikolaei, Sibel Salman

A common consequence of natural disasters is the destruction of buildings and bridges resulting in blocking road segments by the fallen debris of the buildings or lampposts. In the immediate disaster response phase, roads should be recovered by clearing the debris or reconstructing damaged segments to ensure accessibility to all the critical regions. We study an arc routing problem that seeks to optimize the routes of multiple work troops that are originally positioned in a supply node, to dispatch and regain the connectivity of the network by clearing a subset of the blocked roads, and distribute the emergency goods to affected areas. We maximize the total prize gained by reconnecting roads network components within a specified time limit. The main objective of this research is to provide an efficient solution method to generate a synchronized work schedule for the work troops. We developed an exact MIP formulation to solve this problem. However this formulation falls short to solve larger instances, hence, we developed a math-heuristic method to derive upper bounds for such cases. In this method, we solve a relaxation of the exact formulation using lagrangian relaxation. We developed another math-heuristic method by separating the problem into single vehicle problems and updating the prizes to obtain a lower bound to the addressed problem. We compare the results from the proposed methods computationally on both systematically generated and Istanbul road data.

3 - Pre-disaster Unmanned Air Vehicle base location and routing for road damage assessment and repair
Melih Çelik, Seyyed Kian Farajkhah

The devastating effects of disasters often deem parts of urban road networks unusable. Over the recent years, satellite imagery has played a pivotal role in assessing road damage and the implementation of subsequent road repair operations. As satellites present a number of limitations including high cost, data sharing restrictions, and long times needed to acquire the images, a more recent trend is the use of unmanned air vehicles (UAVs), which can capture the imagery in shorter time, at lower cost, and with higher resolutions.

In this study, we consider the problem of locating UAV bases in anticipation of a large-scale disaster in an urban environment. The routes of UAVs, which are subject to flight time limitations, are also determined in the pre-disaster stage to assess the extent of damage on the road network in the immediate aftermath of the disaster. This damage information sheds light into how the limited repair resources are used to repair segments of the road network, through which relief supplies will be distributed from a set of supply points to demand locations.

We propose a two-stage stochastic programming approach for this problem, where first-stage decisions consist of base locations and UAV routes, and the second-stage is comprised of road repair and relief routing decisions. Using small-sized instances, we aim to analyze the structure of the optimal solutions, and use the results of this analysis to develop a heuristic approach for larger instances.

4 - Risk-Based facility location by using fault tree analysis in disaster management
İbrahim Akgün

We develop an optimization model that minimizes the risk that a disaster-prone area may be exposed to because it is not supported by facilities located for pre-positioning supplies. The risk is calculated as the multiplication of threat, vulnerability of the area, and consequence. The vulnerability is computed by using fault tree analysis and incorporated into the optimization model innovatively. The resulting nonlinear integer program is linearized and solved as a linear integer program.

■ WB-33

Wednesday, 10:30-12:00 - Building BM, 1st floor, Room 113

Planning and Scheduling Approaches for Complex Manufacturing and Service Systems 2

Stream: Scheduling, Sequencing, and Applications
Chair: *Georg Weichhart*

1 - Risk Control of Job Shop Scheduling with Random Machine Breakdowns
Shudong Sun

The paper addresses the job shop scheduling problem with random machine breakdowns by using schedule-risk measure we have developed. A machine breakdown will postpone the finishing time of the interrupted operation, and then may delay the schedule makespan. Once a schedule runs, it will face a risk of deteriorated stability and makespan. To control the schedule-risk, a method of inserting time-buffer among operations of a schedule is studied. A heuristic procedure based on greedy algorithm which will insert time-buffer at the operation located in the critical path of the schedule, is developed. In ordere to improve the efficiency of the heuristic procedure, a quick location measure of inserting time-buffer which combine the probability and influence range of the machine breakdown on an operation, is presented. An extensive simulation-based analysis of the performance of the proposed method has been conducted. The results show that our method can decrease the schedule-risk significantly and the quick location measure can improve efficiency of inserting in a large extent.

2 - An approach for consistency between global and local scheduling decisions in complex manufacturing
Rezvan Sadeghi, Stéphane Dauzere-Peres, Claude Yugma

The operational level in semiconductor manufacturing can be divided into a global level and a local level. The global level refers to the scheduling decisions and production control for the whole fab, while the local level deals with those issues in each work area. The global level provides objectives or constraints for the local level. In this study, we propose a synchronized simulation-optimization approach which ensures consistency between decisions taken at the global level and local scheduling decisions. The goal is to guide the production in real time at the local level so that global objectives are reached. The approach is composed of two parts: A Linear Programing (LP) model that determines production targets to optimize global objectives and a multi-method simulation model to represents the local level for the whole fab. Our approach regularly updates the production targets for the local level by applying the LP model during the simulation, and the scheduling rules in the simulation model try to follow the targets. A set of experiments on industrial instances will be discussed. We believe the approach could be applied to other complex manufacturing systems.

3 - Optimizing Cycle Times in Robot Based Manufacturing Lines
Tobias Hofmann

The use of industrial robots in the automotive industry noticeably changed the view of production plants and led to a tremendous increase in productivity. Nonetheless, rising technological complexity, the parallelization of production processes, as well as the crucial need for respecting safety issues pose new challenges for man and machine. Furthermore, the progress shall proceed: production cannot be too fast, too safe or too cheap.

This is the topic that me and my colleagues from TU Chemnitz tackle within the ERDF research project viRAL (Validierte Inbetriebnahme von Roboteranlagen mit automatischer Logik- und Lageprüfung) joint with Voith Engineering Services GmbH and Fraunhofer IWU in Chemnitz. Our goal is to create tools that make the commissioning process more reliable by verifying the programs of robots and logical controllers. This in particular includes optimizing the schedule of robots in order to ensure desired cycle times already in the planning phase.

The talk will be about a periodic scheduling problem as it typically appears in the context of generating train timetables as well as why and how the mathematical models used in this field are well applicable to our scheduling problem. We will adapt a proposed model by Serafini and Ukovich in 1989 to the industrial environment, yielding a Mixed Integer Linear Program.

4 - Distributed optimisation of schedules in production networks
Alexander Hämmerle, Georg Weichhart

Our work is motivated by distributed manufacturing scenarios, where jobs have to be scheduled on machines located in geographically distributed job shops. The problem we tackle can be characterised as flexible job shop scheduling with transportation times between machines, with total weighted tardiness as objective. The problem is formulated as a linear program, and by relaxing machine capacity constraints we get a Lagrange problem whose structure allows the decomposition into independent one job scheduling problems. These subproblems are solved with dynamic programming and alternatively with variable neighbourhood search. The Lagrange problem is solved with an iterative auction protocol, aiming at an equilibrium for resource prices. Price update is governed by subgradient calculations; we study the effect of various methods for price discrimination on the convergence of the auction. Feasibility repair of solutions of the Lagrange problem is achieved with a list scheduling heuristic. For benchmarking we use existing problem instances for flexible job shop scheduling. So far we have studied static scheduling problems. However, we believe it is in dynamic scenarios, where local disturbances impact schedule execution, that a distributed optimisation method is at its most impressive. In future research we will investigate into dynamic scheduling on subproblem level as reaction to a local disturbance, and into escalation to other subproblems through adapted resource prices.

■ WB-34

Wednesday, 10:30-12:00 - Building BM, 1st floor, Room 116

Realistic Production Scheduling

Stream: Scheduling Theory and Applications
Chair: *Ruben Ruiz*

1 - An Iterated Greedy algorithm for the unrelated parallel machine scheduling problem with additional resources
Eva Vallada, Fulgencia Villa, Luis Fanjul

In this work, an Iterated Greedy algorithm (IG) is proposed for the unrelated parallel machine scheduling problem with additional resources and the objective to minimise the maximum completion time or makespan. Both, processing times of the jobs and resource consumption of the jobs, are machine dependent. The Iterated Greedy method starts from a solution provided by a heuristic and there are two phases: destruction and construction. Moreover, after the construction, different local search procedures are applied in order to improve the solution. A benchmark of instances is also proposed considering small, medium and large instances as well as different ways to generate the processing times and the resource consumption: uniform and correlated distributions. An exhaustive experimental evaluation is carried out using the proposed benchmark, comparing the results against the most effective heuristics proposed for the same problem. Moreover, results are analysed by means of statistical analysis in order to identify which method shows the best performance.

2 - Just-in-time criteria in job shop scheduling: MiniZinc formulation
Zoran Rakicevic

Modern production systems tend to implement such a planning concept that will ensure that the products are made just at the moment when they should be used or sold. Any deviation from the planned completion time may cause an increase in waiting and idle time, tardiness and delays, inventory costs and delay costs, and penalties that need to be paid to customers if the due date is not met. This paper presents a concept of a just-in-time job shop scheduling problem. A just-in-time criterion of a schedule is a total measure of time deviation between the particular job scheduled time and the planned time for that job to be finished. Two main criteria of this deviation are: job earliness and job tardiness. Besides these, several other criteria can be derived: e.g. total, average or weighted sum of earliness and tardiness, mean average deviation, average square deviation, and total costs of tardiness and earliness with cost of work in progress. For the practical experiment, an example of job shop problem with just-in-time criteria function was developed in the MiniZinc modelling language. Additionally, the concept of multi-objective optimization with different standard criteria and just-in-time criteria was applied to the observed model.

3 - New effective models for the scheduling of unrelated parallel machines with sequence dependent setup times
Ruben Ruiz, Federico Perea, Luis Fanjul

The unrelated parallel machines scheduling problem with the additional consideration of machine and job sequence dependent setup times and makespan minimization is an important and general problem for the manufacturing industry. It deals with the assignment of n jobs to m machines that are disposed in parallel. At each machine, a setup operation must be carried out after processing one job and before processing the next one. This setup depends on the job sequence and on the machine and therefore, the job schedule at each machine must also be obtained. Its exact solution has eluded researchers for a long time for anything larger than a few jobs and machines. In this work we present several alternative mixed integer linear programming formulations, obtained after modelling the problem following other well known settings in the optimization literature. These models mimic special cutting and packing scenarios, flow problems, heterogeneous fleet vehicle routing and m-traveling salesman, among others. We compare several different formulations against a standard model and a very efficient formulation adapted from the literature. The results, obtained after solving thousands of small and medium instances show that some of the proposed formulations are extremely efficient and allow solving to optimality some medium sized problems of practical use in practice with state-of-the-art solvers.

■ WB-35

Wednesday, 10:30-12:00 - Building BM, ground floor, Room 17

Models and Knowledge Discovery in Biology

Stream: Computational Biology, Bioinformatics and Medicine
Chair: *Andrzej Polanski*

1 - Optimization Based Polyhedral Region Approach for Multi-Class Data Classification Problem
Fatih Rahim, Metin Turkay

We address the multi-class data classification problem by a mixed integer linear programming model (MILP). There are various approaches that represent the data sets of different classes by a set of hyper-boxes or polyhedral regions. However, they either focus on binary data classification or use an iterative approach that prevents finding global optimal solutions. Moreover, the hyper-boxes are not as flexible as the polyhedral regions in data representation. We represent the data sets of each class by a set of polyhedral regions that are defined by hyperplanes. The regions of different classes are disjoint and split each class's data sets into subsets. A single MILP model is used to construct the regions and assign the data points to regions that minimizes the total number of regions and misclassified data points. In addition, a preprocessing step is proposed to decompose the problem into smaller MILPs considering convex separation of data from different classes. In order to assign data points to classes in the testing phase of classification, we evaluated two approaches, based on the convex hulls of subsets formed and the regions defined by the hyperplanes. We tested our approach on benchmark problems and compared with the methods from the literature. We conclude that our polyhedral region approach via MILP provides competitive results in terms of prediction accuracy.

2 - Overlay of Multiple Information Layers for Disease-Oriented Knowledge Exploration and Hypothesis Generation
Piotr Gawron, Marek Ostaszewski, Reinhard Schneider

Current high-throughput techniques, e.g. genomics, produce biomedical data of large dimensionality and complexity. At the same time there exists numerous available literature and annotated databases relevant for human health. The process of integration of this information is challenging but yields great potential in accurate formulation of research hypotheses and data interpretation, especially for life sciences and medical experts. To address these challenges we developed MINERVA platform, allowing intuitive exploration of large diagrams of molecular interactions curated from literature. MINERVA features functionalities for mapping of experimental data and their interpretation in the context of health-related mechanisms. In order to allow intuitive overlay of information from multiple bioinformatic databases, we provided mapping interfaces between MINERVA and Drugbank, ChEMBL and Clinical Toxicogenomic Database. Finally, we enabled a mapping of genomic variants on the map, together with visualization of protein structures for selected elements. In effect, we were able to overlay a number of information layers in Parkinson's disease map, a repository hosted on MINERVA platform. Time-resolved experimental data, mapped together with genomic variants enabled precise interpretation of mechanism of action of PD-related drugs and chemicals. We believe that this approach of interactive knowledge aggregation supports biomedical experts in their task of interpreting complex data.

3 - ModeLang - a New Approach to Biologists-Friendly Modelling
Tomasz Prejzendanc, Szymon Wasik, Jacek Blazewicz

The main way of modelling - systems of differential equations - are requiring a lot of time for adopting models for specific purpose and, which is the case, require to go into deep mathematical definitions. One of the answers is multi-agent systems modelling. ModeLang is the new approach to modelling which allows definition in the form of controlled natural language. User is able to note interactions in the subset of natural language, e.g., English. Afterwards the data is being processed by the software to simulator, which is allowing users to retrieve results afterwards. Modelling using ModeLang is helpful approach for specialists in various fields of science including mostly tested bioinformatics, but also, e.g., economy.

4 - Chemotherapy Science Algorithm (CSA) to Solve Knapsack Problem
Mohammad Hassan Salmani, Kourosh Eshghi

Optimization is one of the most important fields of study in science and engineering where researchers seek to make the best and probably the most practical decisions. Solving real and hard optimization problems is an intractable issue which calls for generating an approximate solution by virtue of meta-heuristic algorithms. In this study, we propose a new well-developed population-based meta-heuristic algorithm according to chemotherapy method to cure cancers that mainly search the infeasible region. As in chemotherapy, Chemotherapy Science Algorithm (CSA) tries to kill unsatisfactory (especially infeasible) solutions (cancers and bad cells of the human body); though, this would unavoidably risk incidentally destroying some appropriate solutions (healthy and good cells of the human body). To line up chemotherapy process with CSA, different conceptual terms and definitions containing Objective Function (OF), Infeasibility Function (IF), Cell Area (CA), and Random Cells (RCs) are presented and defined in this paper. A short glance to the literature of algorithms and optimization indicates that IF and OF are mainly applicable as considerable criteria to compare each pair of generated solutions. Furthermore, we test CSA and its structure using a benchmark Knapsack Problem.

■ WB-36

Wednesday, 10:30-12:00 - Building BM, ground floor, Room 18

Information and Intelligent Systems 4

Stream: Information and Intelligent Systems
Chair: *Roman Senkerik*
Chair: *Pakize Taylan*
Chair: *Gerhard-Wilhelm Weber*

1 - On Temporal Density Extrapolation Using Kernels
Georg Krempl, Marianne Stecklina

Concept drift due to the nonstationarity of distributions is a well-known in data stream mining. However, most stream mining approaches focus on supervised adaptation from labelled data. These approaches are not applicable when labels are not available or labels are considerably delayed. We address this challenge by proposing a change mining approach that models and extrapolates change patterns in distributions. It is based on kernel-based temporal density extrapolation, where a set of pseudo-points is used in combination with spatio-temporal kernel density estimation. We show how this approach can be used for temporal density extrapolation, which allows to forecast future density distributions and to build anticipative stream classifiers.

2 - Recent Advances in Modern Swarm and Evolutionary Algorithms
Roman Senkerik

Swarm and evolutionary algorithms are modern heuristic methods, based on natural processes that have wide applicability in many optimization problems. Recently, the research aimed on swarm and evolutionary algorithms and its intersec- tion/hybridization with unconventional approaches and techniques is focused not only along the traditional trends but also on the understanding and analyzing principles, with the new intention of mutual intersections of these interesting fields of research. This work will discuss the proposed intersection of interesting fields of research, i.e. deterministic chaos, complex systems, complex networks analysis and swarm and evolutionary algorithms. This work is focused on two main fields. Firstly, how the dynamic of chaotic systems and their "randomness" can be utilized inside swarm and evolutionary algorithms in order to increase its performance. And secondly, this research deals with the complex networks framework for evolutionary and swarm based algorithms. The population is visualized as an evolving complex network, which exhibits non-trivial features. This research is discussing existence of various kinds of dynamics and behavior pattern inside swarm and evolutionary algorithms, feedback adaptive approaches, geometrical and graph analysis, visualization and its impact on the performance.

■ WB-38

Wednesday, 10:30-12:00 - Building BM, 1st floor, Room 109M

Scheduling with Resource Constraints III

Stream: Scheduling with Resource Constraints
Chair: *Farzad Pargar*

1 - Single Machine Scheduling with Sequence-dependent Setup Times, Precedence Constraints and Dynamic Ready Times
Yiyo Kuo, Yen-Hung Yeh

This project proposed a single machine scheduling problem in which sequence dependent setup times, precedence constraints, dynamic release times are all taken into consideration. Scheduling problems which take dynamic release time into consideration is rare in literature. Some of them base on the manufacturing process of steel, assume that the release times are depending on the resource that used. The more resource used the earlier the release times. In this research, the dynamic release times are depending on the completing time of other jobs and their corresponding waiting times. Therefore the release times of some jobs are unknown. The object of the scheduling problem is minimizing the makespan. A mixed-integer programming (MIP) model is first formulated. Then a variable neighbourhood search (VNS) is proposed for minimizing the makespan. In the VNS the operation, based on the ideal of simulated annealing, the worse neighbourhood solutions still have opportunity to be accepted and then replace the current solution.

2 - Algorithmization of the Procedures in the Execution of Construction Processes
Jarosław Górecki

The course of construction processes is to a large extent of a routine nature. The performance of routine processes has a strictly defined technology for the execution of operation sequence, many times checked in practice. The defined and checked up in a series of executions is also the organisation of repeatable construction processes. The algorithms of technological procedures are developed in the form of technological cards. The technological cards are arranged in the fashion which enables their application in building production for the use by on-site contractors for the execution of repeatable build construction processes. A separate group of the algorithmized procedures in the execution of construction processes are those that regulate the functioning of the execution of a construction project. Documents regulating the functioning of risk management should be considered basic procedures, and they should provide comprehensive solutions to a range of problems including construction costs, quality of construction, environmental protection, occupational health and safety. An example of such an algorithm is the probabilistic prediction algorithm for the determination of the cost of construction project, including risk analysis, elaborated within the doctoral thesis of the author, along with a software called COMAR-Jarek Górecki'. The elaborated simulator of the probabilistic prediction of construction costs finds its both experimental and practical application.

3 - Resource utilization techniques for reducing setup times/costs through scheduling
Farzad Pargar, Jaakko Kujala, Osmo Kauppila

Learning effect and combination of setups can be used to optimize resource utilization in manufacturing and maintenance systems. In this paper, we demonstrate how the usage of these techniques through scheduling can help keep costs down and allows companies to operate according to budget and time constraints. Learning effect is a technique that can model improvement in worker's ability as a result of repeating similar tasks. By considering learning effect in manufacturing systems, a schedule can be determined that places jobs that share similar tools and fixtures next to each other. By using this technique, we schedule set of jobs in a hybrid flow shop environment such that their makespan time and total tardiness are minimized. Another technique to reduce setup times/costs is to combine setup activities. In the maintenance of systems consisting of multiple components, costs can be saved when several components are jointly maintained. By using this technique, we schedule maintenance and renewal projects of various components such that the total costs of maintenance and renewal projects and their relevant setup costs are minimized. We developed mathematical programming models that incorporate these aspects of the problem and test the performance of the proposed models on a set of problem instances. Experimental results show that the proposed techniques perform well in reducing setup times/costs and eliminating the setups itself through scheduling.

■ WB-39

Wednesday, 10:30-12:00 - Building WE, 1st floor, Room 107

Risk, Uncertainty, and Decision 2

Stream: Risk, Uncertainty, and Decision
Chair: *Stefania Minardi*

1 - α-Maximin for Ambiguity with Probability Weighting: An Experimental Investigation
Emmanuel Kemel

In his two-color paradox, Ellsberg (1961) argued that most decision makers prefer a risky option giving a prize with probability 0.5 to an ambiguous option giving the same prize with the winning probability lying somewhere between 0 and 1. Many subsequent Ellsberg-like experiments refined the two-color example by focusing on the general case where the winning probability p belongs to subintervals. The present paper reports the results of an experimental investigation on choices where the decision maker knows that she will get x with a winning probability lying somewhere in a given interval, and y otherwise. We postulate that decision makers evaluate these ambiguous bets by subjectively combining the values of envelope (extreme) lotteries, whose probabilities correspond to the lower bound and the upper bound of the interval. We elicited this model in a laboratory experiment involving 62 subjects. All components of the models are estimated at the individual level using discrete choice modelling. We observe that probability weighting of the upper bound is radically different from probability weighting of the lower bound: the former is concave whereas the later is convex. Additionally, the convex combination of these two functions allows to recover the inverse-S shape probability weighting generally observed for risk. Therefore, our model not only explains ambiguity attitudes but also offer a new insight to understand the shape of probability weighting under risk.

2 - Confidence in Beliefs and Decision Making
Brian Hill

The standard representation of beliefs in decision theory, by probability measures, is incapable of representing an agent's confidence in his beliefs. However, as shall be argued in this talk, the agent's confidence in his beliefs plays, and should play, a central role in many of the most difficult decisions which we find ourselves faced with. For instance, in many currently topical decisions requiring scientific expertise, such as environmental policy making, science perhaps does not provide us with as much confidence as we might have liked in our most informed beliefs concerning the relevant issues. Understanding and making such decisions would therefore require a decision theory that departs from the (standard) Bayesian account, and in particular a theory that incorporates the decision maker's confidence in his beliefs.

In this talk, we present parts of an on-going project which aims to formulate and defend a relatively tractable representation of agents' belief states and a normatively reasonable theory of decision which recognises and incorporates confidence in belief. Such a theory can provide a guide for the sorts of decisions just mentioned, and hence be able to inform decision analysis. We briefly discuss some of its consequences for real-life decision making, particularly in the face of radical uncertainty.

3 - Subjective Contingencies and Limited Bayesian Updating
Stefania Minardi

We depart from Savage's (1954) common state space assumption and introduce a model that allows the agent to have a subjective view of the uncertainty that she is facing. In the revealed preference paradigm, our theory allows the analyst to uniquely identify the decision maker's subjective state space on the basis of her choices. Taking as primitive a collection of preferences conditional on information, we impose a certain structure on the way the agent responds to arrival of new information, including a subjective version of the dynamic consistency axiom. According to our representation, the decision maker's subjective contingencies are coarser than the analyst's states; she uses an additively separable utility with respect to her set of contingencies; and adopts an updating rule that follows the Bayesian spirit but is limited by her perception of uncertainty. A representation akin to subjective expected utility is derived as a special case. We also discuss the types of inference errors that the agent makes because of her coarse perception of uncertainty.

■ WB-40

Wednesday, 10:30-12:00 - Building WE, 1st floor, Room 108

Empirical Methods in Finance

Stream: Computational Methods in Finance
Chair: *Marcus Hildmann*
Chair: *Dejan Stokic*

1 - Firm value and its size: A model of cooperation and agency costs
Julián Benavides

Countries differ in the size and nature of the firms they generate. Although well functioning institutions are likely to generate economic development, the social capital of a country, with roots in social values such as the importance of families, the generalized level of trust in strangers or social characteristics such as ethnic homogeneity and dominant religion, interact with a country's institutions to influence the operation and continuity of firms. An important variable absent in agency cost analyses is the extent of cooperation among the manager and the investors. We study the combined effect of institutions and social characteristics on the size and performance of the firms. To explore these issues, we developed a simple model of a firm with two or more parties, an entrepreneur and one or more investors, where some of them are characterized by non-paternalistic altruism. Two types of cooperation are studied: 1) generalized cooperation, a concept close to social capital; and 2) discriminating cooperation, a concept close to cooperation with relatives. These types of cooperation affect managerial private benefits differently; while generalized cooperation reduces agency costs, discriminating cooperation may enlarge them, until the manager becomes highly close toward his cooperating investor. The model results portrait different empirical predictions relative to managerial decisions influencing firm characteristics like market value, size and ownership.

2 - A Termination Rule of the Automatic Balancing Mechanism in the Japanese Pension System
Masanori Ozawa, Tadashi Uratani

The government activated an automatic balancing mechanism to ensure the financial stability of the pension system last year. Under this mechanism, pensioners experience a reduction in their benefits every year, with the reduction rate depending roughly on the size of the working population. The government evaluates the pension performance every five years, although there is no definitive rule to terminate the mechanism. Therefore we consider a pension finance model for the pension system using stochastic process, which is investigated termination conditions of the mechanism under some economic and population scenarios. As a result of simulations, we have obtained a rule to terminate the mechanism with sustainability of the pension system.

3 - An Investigation on Relative Importance of Individual Characteristics of Auditors Performing Financial Audit Using DEMATEL Method
Mehmet Özbirecikli, V. Alpagut Yavuz

Especially high profile financial crisis experienced all over the world in the beginning of 2000s showed that independent auditing of financial statements of corporations has a crucial role in preventing misleading financial information from being used by stakeholders in their decision making process. Many fraudulent cases indicated that lack of independency and due professional care of auditors resulted in failure of audit process. It is seen from some research studies that individual characteristics of auditors have been measured using different variables in various auditing studies. These variables are auditor's ethical reasoning, goal orientation, professional scepticism, auditor's virtue and personality type. In this study, we aim to assess the relative importance of individual characteristics of auditors performing financial audit using expert opinions. Decision Making Trial and Evaluation Laboratory (DEMATEL) is one of the Multiple Attribute Decision Making (MADM) technique that was successfully applied in various cases to explore the relationship between factors. The main advantage of DEMATEL is to assist the decision makers in understanding the relationships between elements and criteria prioritization according to the types of relationships and their interdependencies. The practical results of this study can offer useful insights for authorities setting standards and oversighting audit procedures being performed by independent auditors.

■ WB-41

Wednesday, 10:30-12:00 - Building WE, 2nd floor, Room 209

OR in Clinical Decision Support 1

Stream: OR in Clinical Decision Support
Chair: *Szymon Wilk*

1 - A Multi-criteria Decision Approach for Drugs for Rare Diseases Assessment
Sarah Ben Amor, Abdallah Neily

Evaluating Drugs for Rare Diseases (DRDs) for the purpose of reimbursement and beyond represents a tremendous challenge for most health care priorities. A consensus is set about the irrelevance of cost effectiveness analysis to evaluate such drugs. The appeal for multi-criteria decision aid (MCDA) models seems reasonable, as the evaluation of DRDs is indeed multifaceted. However, the application of MCDA for the purpose of evaluating DRDs is yet primitive and simplistic. The present work tries to tackle the issue of evaluating DRDs from a decision maker angle by adopting an innovative robust ordinal regression MCDA method, UTADIS-GMS, that helps the decision maker discern between the DRDs based on their multi criteria value.

2 - Multi-criteria Optimisation and Decision-making in Radiotherapy
Sebastiaan Breedveld, Rens van Haveren, Linda Rossi, Steven van de Water, Tine Arts, Abdul Wahab Sharfo, Mischa Hoogeman, Wlodzimierz Ogryczak, Ben Heijmen

In radiotherapy, treatment of cancer patients requires a personalised treatment plan. The plan describes how the dose (damage) resulting from irradiation is distributed inside the patient. The goal is to optimally irradiate the tumour, while keeping the doses to the healthy organs as low as possible. Distributing the dose over the different healthy organs is a multi-criteria problem with 10-30 correlated criteria. In current worldwide clinical practice, the multi-criteria optimisation and decision-making is performed by a human operator in an interactive trial-and-error procedure. Due to the complexity and dimensionality of the problem, this manual approach often results in suboptimal treatment, and a higher probability of developing complications. By formulating the decision-making as a lexicographic goal-programming manner, multi-criteria treatment planning can be automated using a stepwise optimisation. The resulting plans are in general of equal/superior quality than the manually generated plans. The development of the Lexicographic Reference Point Method (LRPM), reduces the sequential approach to a single optimisation (speed-up factors of 12-20x). Additionally, the trade-offs are defined globally, resulting in more clinically desired trade-offs. Automated treatment planning has many advantages, of which performing objective studies in designing new treatment protocols, and objective patient selection for improved radiotherapy techniques with limited availability.

3 - Using Clinical Data to Predict Surgical Overtime: An Artificial Neural Networks-based Method
Jun-Der Leu

Predicting surgical time is critical in allocating the capacity of a surgical facility. The data and the model used are essential to achieve good medical predictions. In this study, we used clinical data to identify the factors that influence surgical overtime, and designed a model based on an artificial neural network (ANN) to support the surgical overtime prediction. The proposed model was applied to a hospital with 780 clinical beds, where 10 clinical departments and 141 basic types of surgical procedure were considered. To test the model's prediction quality, the same clinical data and variables were executed by a naive Bayesian classifier model. The results showed that the ANN-based model had a better predictive ability than the Bayesian classifier. This approach can be applied to hospitals with healthcare information systems capable of collecting large amounts of clinical data.

■ WB-42

Wednesday, 10:30-12:00 - Building WE, 1st floor, Room 120

Program Planning and Robustness

Stream: Operational Research in Financial and Management Accounting
Chair: *Markus Puetz*

1 - Tax effects on short-term program planning with several production sites
Markus Puetz, Matthias Amen

In contrast to capacity utilization, cycle time, production costs, service costs, delivery level or service level, and/or warehousing costs, tax effects usually are not taking into account within commonly approaches of short-term program planning. Due to the fact that taxes are relevant for value-based management, this presentation addresses the consideration of tax effects on short-term program planning. The modelling of tax effects as cost components that are import for decision making in the area being considered is introduced at first. Based on the role of trade tax collection rates at municipal level in Germany and its consequences for managerial accounting, this includes the handling of different trade tax collection rates concerning to various production sites. Subsequently, an approach for effective short-term program planning with several production sites and different trade tax collection rates is presented. Finally, practical aspects of the application of the proposed approach in the area of managerial accounting are depicted.

2 - Modelling time to default for SMEs operating on the Polish market
Anna Matuszyk, Agnieszka K. Nowak

The aim of the project was to find the determinants influencing the companies' survival probability. In this research not only the financial ratios calculated using the financial statements were analysed but also other factors were considered, including: geographical location (i.e. unemployment rate and the average salary in the region), branch, size and legal form of the company. The data consisted of almost 2600 companies operating on Polish market between 2006 and 2013, so the whole economic cycle was covered.

3 - Accounting Measures for Robustness
Matthias Amen

Usually classical accounting figures are used in approaches for solvency measurement and rating purposes. The new approach of this presentation is to apply the idea of robustness for analysing sets of financial statements.

It is possible to transform methods from various areas, e.g. planning or finance, to get some measures of robustness of a company. In this presentation we introduce a set of modified or new accounting measures that follow the idea of robustness. Contrary to classical figures, robustness figures are more complex and need a pre-calculation. Only some of them are based on classical financial statement analysis. The others use more information from the accounting system or from other sources. We present and discuss the methods to get this robustness figures.

■ WB-43

Wednesday, 10:30-12:00 - Building WE, ground floor, Room 18

DEA and Performance Measurement 4

Stream: DEA and Performance Measurement
Chair: *Sanjeet Singh*

1 - Malmquist index shows post-crisis development in the agrarian sector in the Czech Republic
Helena Brozova, Ivana Bohackova

This contribution aims to show the efficiency of agriculture sector in the regions of the Czech Republic and its development from the year 2008 to 2013. For this the Data Envelopment Analysis models and Malmquist index and its decomposition are used. Each region is characterised by three inputs (agricultural land, annual work units and gross fixed capital formation) and by one output (gross value added). Malmquist indices show significant increasing of efficiency in the 2011 although in other years rather negative development can be seen. Seven possible elements of Malmquist index decomposition support the analysis of the reasons of such development. The regions are evaluated and grouped according to received evaluation at the end.

2 - Efficiency of local government units in Northwestern Philippines as to the attainment of the millennium development goals
Milagros Baldemor

This study determined the performance of the four provinces and eight cities in Region I, Philippines, vis-à-vis their efficiency along the eight goals and 21 targets of the Millennium Development Goals (MDGs) for 2012-2015. Furthermore, it determined the peer groups and weights of the DMUs (Decision Making Units - the different provinces and cities), the virtual inputs/outputs or potential improvements of the DMUs to be in the efficient frontier, the input and output slacks (input excesses and output shortfalls) needed in the different indicators and the best practices to be considered by the inefficient and weak efficient DMUs. The "best practice" in the frontier is the basis to calculate the adjustments necessary for the DMUs. Different indicators showed varied performance levels in the different years but there are best practices from the "efficient" DMUs which could be adapted by the "weak efficient" and "inefficient" ones.

3 - Evaluation of world's largest social welfare scheme: An assessment using non-parametric approach
Sanjeet Singh

Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) is the world's largest social welfare scheme in India for the poverty alleviation through rural employment generation. This paper aims to evaluate the performance of the states in India under MGNREGA. A non-parametric approach, Data Envelopment Analysis (DEA) is used to calculate the overall technical, pure technical, and scale efficiencies of states in India. The results indicate that the main source of inefficiency is both technical and managerial practices adopted. 11 states are overall technically efficient and operate at the optimum scale whereas 18 states are pure technical or managerially efficient. It has been found that for some states it necessary to alter scheme size to perform at par with the best performing states. Our analysis shows that if all inefficient states operate at optimal input and output levels, on an average 17.89% of total expenditures and a total amount of $780million could have been saved in a single year. Most of the inefficient states perform poorly when it comes to the participation of women and disadvantaged sections (SC&ST) in the scheme. In addition, the states are also ranked using the cross efficiency approach and results are analyzed. State of Tamil Nadu occupies the top position followed by Puducherry, Punjab, and Rajasthan in the ranking list. To the best of our knowledge, this is the first pan India level study to evaluate and rank the performance of MGNREGA scheme.

4 - Setting Up Data Staging Areas to ETL Systems
Orlando Belo, António Ribeiro

One of the most relevant elements of an ETL (Extract-Transform-Load) system is the data staging area, which is responsible for providing operational support to all the tasks involved with the populating process of a data warehouse. Basically, it is an area that the ETL system uses to keep all the operational data - data control structures, attributes mapping structures, lookup pointers, surrogate keys, etc. - necessary to sustain its most elementary tasks. All that data is kept in sophisticated data structures organized accordingly to the way we designed the ETL control flows, and structured following the requirements of the ETL tasks. Using as case study a brokerage insurance company, in this paper we present a novel approach for structuring and setting up a data staging area for an ETL system, which provides an alternative design method that allows, whenever necessary, the recovering of a given ETL status during a system failure. This ability is quite relevant when we have small ETL opportunity windows - the time we have to populate a data warehouse - constraining the entire ETL process in terms of processing time and recovering. The method presented and discussed in this work attenuates effectively the effect of an ETL failure, giving a second chance to the ETL system to refresh the data warehouse and therefore to keep updated the information that decision makers use on their daily business activities.

■ WB-47

Wednesday, 10:30-12:00 - Building WE, 1st floor, Room 115

Robust Discrete Optimization and Scheduling

Stream: Robust Optimization
Chair: *Marco Laumanns*

1 - The Min-max Regret Assembly Line Worker Assignment and Balancing Problem
Mariona Vila Bonilla, Jordi Pereira

Assembly line balancing problems aim at assigning the tasks which make up the assembly process into the stations of the line, maximizing the efficiency of the line. Different formulations have been created to better represent different real-life balancing problems. One of such formulations is known as the line worker assignment and balancing problem (ALWABP), which considers both the balancing of the line and the assignment of the line workers to the stations. The heterogeneous nature of the workers is a useful way to model the existing differences among workers and their abilities, but introducing the human factor emphasizes the need to consider non-deterministic processing times for the workers. In this work, we present a min-max regret formulation in which the processing times of each task for each worker can take any value in an interval. The objective is to assign the workers and the tasks to the stations in such a way that the obtained solution remains as close as possible to the optimum solution for any possible scenario. We present a formulation for the problem and we prove that the min-max regret version of this problem extremely difficult to solve, as the original ALWABP problem was already NP-hard. We analyze the effect of studying the robust version of this problem on the quality of the solution, and the results obtained prove that solving the min-max regret ALWABP provides more robust solutions that are capable of withstanding changes on the processing times.

2 - Robust Storage Loading Problems with Stacking Constraints
Thanh Le Xuan, Sigrid Knust

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

3 - Extensions of Gamma-Robustness to Discrete Structures for Robust Optimization
Juan Carlos Espinoza Garcia, Laurent Alfandari

We explore extensions of the Gamma-robustness approach proposed by Bertsimas and Sim. The seminal work considered protection over the worst-case variation, controlled by an uncertainty budget (Gamma), of the parameters in the constraints of a Linear Program. Our work remains in the framework of Gamma-robustness, but we extend this concept to several cases that we consider relevant for practical applications. The first extension deals with a discrete structure of uncertainty based on a set of scenarios associated with a given constraint. Despite this discrete structure, we show using dualization and LP theory that the robust counterpart of this problem is still an LP. We applied this approach to new housing location problems with choice models, where utilities of customers can follow several scenarios, but a most-likely scenario is identified. The second problem considers non-linear impact of the variation of the coefficients in the constraints, which extends the linear case that is generally studied in recent extensions. We study a piece-wise linear approximation of the impact function of the varying coefficient, and show that the subproblem can also be dualized despite the discrete structure of the piece-wise linear function. We study extensions with constant sum requirements, on both right and left-hand-side uncertainty, that better represent certain structures, such as blending problems where coefficients sum over one, and combine row-wise and column-wise uncertainty.

■ WB-48

Wednesday, 10:30-12:00 - Building WE, 1st floor, Room 116

Renewable Energy

Stream: Energy/Environment and Climate
Chair: *James Corbishley*

1 - On the optimal participation in electricity markets of wind power plants with battery energy storage systems
F.-Javier Heredia, Cristina Corchero, Marlyn Dayana Cuadrado Guevara

The recent cost reduction and technologic advances in medium to large scale Battery Energy Storage Systems (BESS) makes these devices a real choice alternative for wind producers operating in electricity markets. The association of a wind power farm with a BESS (the so called Virtual Power Plant VPP) provides utilities with a tool to turn the uncertainty wind power production into a dispatchable technology enabled to operate not only in the spot and adjustment markets (day-ahead and intraday markets) but also in ancillary services markets that, up to now, was forbidden to non-dispatchable technologies. Even more, recent studies have shown that the capital cost investment in BESS can only be recovered through the participation of such a VPP in the ancillary services markets. We present in this study a stochastic programming model to find the optimal participation of a VPP to the day-ahead market and secondary reserve markets (the most relevant ancillary service market) where the uncertainty in wind power generation and markets prices (day-ahead ancillary services) has been considered. A case study with real data from the Iberian Electricity Market is presented.

2 - Using Different Clustering Techniques in Artificial Neural Network for Wind Speed Estimation
Kadriye Ergün, Melike Sultan Karasu Asnaz

In this study, an approach for short-term wind speed forecasting is developed by considering wind speed, wind direction, temperature, pressure, air density and relative humidity data set that are taken at 15-minute intervals from 40th meter of the meteorological station located at the University of Balikesir in Turkey. Artificial neural network is used as the estimation method. Due to difficulties in controlling the variability of meteorological parameters, different clustering techniques are used in the selection of training and test data sets. The obtained sets are evaluated with artificial neural networks, and the results are compared.

3 - Valuing demand responsiveness - using houses as batteries to store electricity
James Corbishley

Increasing demand-side flexibility and responsiveness can have positive impacts on electricity markets. Smart-grid technologies which can automate aggregate consumption patterns are seen as one tool that can contribute to these. The value of this demand side flexibility, however, is unknown.

This paper investigates the gains of optimising electricity heating demand across time given market prices and allowing for market responses. I focus on Finnish heating consumption given that domestic electricity heating consumption is two thirds of total household consumption. I make use of a novel thermodynamic model to track heating consumption and electricity market bid curve data to identify the market responses. I also capture the impacts on suppliers and other consumers given the resulting price changes. I find that consumers gain at the expense of producers.

I find that household gain between EUR 17 and EUR 23 a year, saving approximately 1.8% of annual heating expenditure. The overall welfare gain is EUR 7 million annually when all possible houses optimise their demand. This magnitude is primarily due to relatively constant electricity prices hour to hour.

This is the first paper to attempt to quantify the benefits of optimising electricity consumption while capturing and allowing for market responses.

■ WB-53

Wednesday, 10:30-12:00 - Building PA, Room A

MIP Based Matheuristics

Stream: Metaheuristics
Chair: *M. Grazia Speranza*

1 - Traveling Salesman Problem with Mileage Bands
Maciek Nowak, Mike Hewitt

The trucking industry uses a variety of pricing schemes, typically utilizing rates proportional to distance and weight or volume. One pricing practice that is not as well recognized involves the use of mileage bands. Mileage bands segregate route distances into windows, with the cost per mile (generally) decreasing as the mileage increases. For example, the cost for a route within the band of 500 to 599 miles may be $1.65 per mile, decreasing to $1.60 per mile for a route in the band of 600 to 699 miles. In most TSPs, the cost of a route generally increases linearly with distance. However, with mileage bands a feasible solution must be fully completed in order to determine the per mile cost. Traditional methods through which piecewise linear costs are enforced via constraints cannot be applied to this problem. This research presents an algorithm that iteratively solves a modified version of the TSP to find the route length that results in the lowest cost using mileage bands. Further, an MIP algorithm is proposed to construct mileage bands that maximize profit for a carrier while minimizing the distance traveled. While a shipper may make scheduling adjustments in order to increase the route length to achieve a lower mileage rate, the carrier is interested in applying a set of mileage bands that limit the opportunities for these types of adjustments. The algorithm determines the optimal bands providing an interesting perspective on transportation pricing.

2 - A matheuristic for the stochastic service network design of bike sharing systems
Bruno Albert Neumann Saavedra, Teodor Crainic, Bernard Gendron, Dirk Christian Mattfeld, Michael Römer

We address the bike redistribution problem in station-based bike sharing systems (BSS) with stochastic demands. The aim is to maximize the expected service level, while considering a limited budget of resources. Our time-dependent stochastic service network design formulation (SND) yields the necessary services in order to achieve a high service level. A service is described by a vehicle movement between an origin and destination station, the number of bikes which are moved from the destination station to the vehicle, or vice versa, and a time interval. To cope with stochastic demands, we formulate a two-stage stochastic programming model. The first stage consists in determining the vehicle flow, that is, the design of the service network provided by the vehicle tours. Based on a set of demand scenarios, the second stage determines the scenario-dependent bike flow (both the redistribution flow and the user-induced flow) resulting in time-dependent fill station levels and service levels for each scenario. We propose a neighborhood search-inspired matheuristic to find provably good-quality solutions for SND-BSS instances. Vehicle movement decisions are carefully chosen by means of heuristic search techniques, building thus a neighborhood. The neighborhood is explored with a standard optimization solver, yielding the best services together with the time-dependent fill levels at stations and both user and vehicle bike flows. The matheuristic is tested on a new set of instances.

3 - A Large Neighborhood Search based Matheuristic for the Tourist Cruises Itinerary Planning
Simona Mancini, Giuseppe Stecca

The process of ship itinerary planning for tourist cruises must take into account several and particular constraints related to different considerations such as fuel consumption, port costs, and point of interests to be inserted in each tour. The present work modeled the tour planning problem as a variant of rich vehicle routing problem considering several particular features: fixed number of vehicles to be used, not mandatory visits all nodes, multiple time windows, possibility to choose among different travel speed values. The resulting mathematical formulation lead to a complex model for which commercial solver fails to solve large instances in a reasonable time. We propose a Large Neighborhood Search (LNS) based Matheuristic in which several neighborhoods, generated by ad-hoc defined destroy operators, have been implemented. The Large Neighborhood Search is exploited directly by the model. In this way, it is possible to obtain the local minimum with respect to the considered neighborhood, within a very small computational time. Real time performance analysis of the destroy operators let to dynamically tune their selection criteria. Test analysis and comparison have been made on real time instances showing the effectiveness of the proposed approach.

4 - A Genetic Algorithm for Flexible Job Shop Production Scheduling in a Cosmetic Industry
Genett Jimenez, Fabricio Niebles, Edgar Macias

This work considers the problem of scheduling a given set of jobs in a Flexible Jobshop in a cosmetic industry, located in Bogotá (Colombia). Taking into account the natural complexity of the process and the large amount of variables involved, this problem is considered as NP-hard in strong sense. Therefore, it is possible to find an optimal solution in a reasonable computational time only for small instances, which in general, does not reflect the industrial reality. For that reason, it is proposed the use of Metaheuristics as an alternative approach in this problem with the aim to determine, with a low computational effort, the best assignation of the tasks in order to minimize the number of tardy jobs. This optimization objective will allow to company to improve their customer service. A Genetic Algorithm (GA) is proposed. Computational experiments are carried out comparing the proposed approach versus exact methods. Results show the efficiency of our GA algorithm.

■ WB-54

Wednesday, 10:30-12:00 - Building PA, Room B

First order methods for convex optimization problems

Stream: Convex Optimization
Chair: *Martin Takac*

1 - Distributed Optimization with Arbitrary Local Solvers
Martin Takac, Chenxin Ma, Jakub Konecny, Martin Jaggi, Virginia Smith, Michael Jordan, Peter Richtarik

With the growth of data and necessity for distributed optimization methods, solvers that work well on a single machine must be redesigned to leverage distributed computation. Recent work in this area has been limited by focusing heavily on developing highly specific methods for the distributed environment. These special-purpose methods are often unable to fully leverage the competitive performance of their well-tuned and customized single machine counterparts. Further, they are unable to easily integrate improvements that continue to be made to single machine methods. To this end, we present a framework for distributed optimization that both allows the flexibility of arbitrary solvers to be used on each (single) machine locally, and yet maintains competitive performance against other state-of-the-art special-purpose distributed methods. We give strong primal-dual convergence rate guarantees for our framework that hold for arbitrary local solvers. We demonstrate the impact of local solver selection both theoretically and in an extensive experimental comparison. Finally, we provide thorough implementation details for our framework, highlighting areas for practical performance gains.

2 - Complexity of first order inexact Lagrangian and penalty methods for conic convex programming
Ion Necoara, Andrei Patrascu, François Glineur

In this talk we present a complete iteration complexity analysis of first order Lagrangian and penalty methods for solving general cone constrained convex problems having bounded or unbounded optimal Lagrange multipliers. In the first part we assume bounded optimal Lagrange multipliers and study primal-dual first order methods based on inexact information and augmented Lagrangian smoothing or Nesterov type smoothing. For inexact (fast) gradient augmented Lagrangian methods we derive overall computational complexity measured in terms of projections onto a simple primal set in order to attain an approximate solution of the conic convex problem. For the inexact fast gradient method combined with Nesterov type smoothing we also derive overall computational complexity, which in general is worse than the one corresponding to fast gradient augmented Lagrangian method. Then, we assume possibly unbounded optimal Lagrange multipliers for the cone constrained convex problem, and analyze the fast gradient method for solving penalty re-formulations of the problem. For the fast gradient method combined with penalty framework we also derive overall computational complexity measured in terms of projections onto the same simple primal set to attain an approximate solution for the original problem with unbounded optimal Lagrange multipliers. Thus, our results cover the particular case when Slater condition does not hold or it is difficult to check for large-scale conic convex problems.

3 - Primal-dual coordinate descent: application to joint quantile regression
Olivier Fercoq, Pascal Bianchi, Maxime Sangnier

We introduce a randomized coordinate descent version of the Vu-Condat algorithm. By coordinate descent, we mean that only a subset of the coordinates of the primal and dual iterates is updated at each iteration, the other coordinates being maintained to their past value. Our method allows us to solve optimization problems with a combination of differentiable functions, constraints as well as non-separable and non-differentiable regularizers.

We show that the sequences generated by our algorithm converge to a saddle point of the problem at stake, for a wider range of parameter values than previous methods. In particular, the condition on the step-sizes depends on the coordinate-wise Lipschitz constant of the differentiable function's gradient, which is a major feature allowing classical coordinate descent to perform so well when it is applicable.

We then apply the method to the joint quantile regression problem. The goal is to estimate several conditional quantiles. As we would like to preserve the fact that quantiles are monotone, solving the quantiles problems jointly is necessary. This problem can be solved as a quadratic program with a combination of bound constraints and linear constraints, similar to the dual of support vector machines but with one bias term per quantile. Our numerical experiments support the efficiency of primal-dual coordinate descent for joint quantile regression, especially on large scale problems.

■ WB-56

Wednesday, 10:30-12:00 - Building CW, 1st floor, Room 122

Doing Theory and Practice: own reflection

Stream: Workshops and roundtable
Chair: *Joaquim Gromicho*

1 - Doing Theory and Practice: own reflection
Joaquim Gromicho

I have spent all my conscious life learning, teaching and applying my learnings which - in turn - teaches me a lot. The last 30 years mostly in Operations Research. In a brief lecture I explain why I believe that the gap between theory and practice can be very narrow. Afterwards, I will ask your participation to advocate and to oppose a small list of propositions and help ignite a vivid discussion. Do you envision yourself developing both the theoretical and practical sides of the profession? Then this workshop is the place to be.

■ WB-58

Wednesday, 10:30-12:00 - Building CW, Room 024

Mentoring Session 3

Stream: Mentoring Sessions

1 - Mentoring Session 3
Galina Andreeva

Have you ever thought of talking to someone outside your normal circle of work colleagues and friends for help with solving a problem? The mentoring session is the perfect opportunity to do just that. EURO2016 mentoring enables you to sign up for a 20 minute one-to-one session with an experienced OR professional. It is designed to help you with the issues you might be facing in your practice, career or development. You may use it to gain valuable advice; to help you identify the skills and expertise you need, and where to go for information; to see new perspectives; and to build your network. You must sign up in advance to talk to a specific mentor. Details of how to do this, and the latest mentor line-up, can be found on the EURO2016 website, at: http://www.euro2016.poznan.pl/mentoring/ To get the most from the session, please prepare in advance: what is the problem you'd like help and advice on, what would you like to know from your mentor. Be ready to ask the questions!

Wednesday, 12:30-14:00

■ WC-01

Wednesday, 12:30-14:00 - Building CW, AULA MAGNA

Keynote Giovanni Rinaldi

Stream: Plenary, Keynote and Tutorial Sessions
Chair: *Gerhard-Wilhelm Weber*

1 - Maximum Weight Cuts in Graphs and Extensions
Giovanni Rinaldi

Max-Cut, i.e., the problem of finding a cut of maximum weight in a weighted graph, is one on the most studied and best known hard optimization problems on graphs. Max-Cut is also known to be equivalent to Unconstrained Quadratic Binary Optimization, i.e., to the problem of minimizing a quadratic form in binary variables. Because on the its great interest among the optimizers, several approaches, also of a quite diverse nature, have been proposed to find good or provably good solutions, which makes it also very interesting as a benchmark problem for new algorithmic ideas. We review some of the most successful solution methods proposed for this problem and for some extensions where, instead of a quadratic form, we consider a polynomial of degree higher than two.

■ WC-02

Wednesday, 12:30-14:00 - Building CW, 1st floor, Room 7

Algorithms and Computational Design

Stream: Algorithms and Computational Optimization
Chair: *Goran Lesaja*

1 - Break stage-based Scenario Cluster Lagrangean Decomposition for multistage mixed integer-linear stochastic problems with time stochastic dominance risk averse
Aitziber Unzueta, Laureano Fernando Escudero, María Araceli Garín, María Merino

A Multistage Scenario Cluster Lagrangean Decomposition/Relaxation approach is proposed for obtaining strong lower bounds on the solution value of large-scale multistage integer-linear problems with time related stochastic dominance risk averse. The objective function to minimize is a composite function of the expected cost along the time period over the scenarios and the penalization of the expected cost excess on reaching a modeler-driven set of thresholds, subject to a bound on the expected cost excess and a bound on the failure probability of reaching the thresholds. The original problem is represented by a mixture of the splitting representation up to a given stage, so named break stage, and the compact representation for the other stages along the time horizon. The dualization of the nonanticipativity constraints for the variables related to the nodes in the stages to up to the break one and the relaxation of the related cross node constraints results in a model that can be decomposed into a set of independent submodels. The solution of those submodels where the dualized constraints as well as the relaxed ones are factorized by related Lagrange multipliers lead to a lower bound on the solution value of the original model. Three Lagrangean multipliers updating schemes are considered. We have observed in the instances we have experimented with that the smaller the number of clusters, the stronger the lower bound provided for the original model.

2 - Optimal Design of a Large Scale Distribution Network
Jose Antonio Marmolejo, Roman Rodriguez Aguilar, Jonas Velasco

In this work a large scale method to solve the design of a distribution network for a bottled drinks company is presented. The mathematical model was designed based on a real business problem. The distribution network proposed includes three stages: manufacturing centers, consolidation centers using cross-docking and distribution centers. A mixed-integer programming model in the deterministic and single period contexts is formulated. Due to the problem considers several elements in each stage of the distribution network, a direct solution is very complicated and for medium to large instances the problem falls into large scale. For this reason, we proposed a cross decomposition method that allows to explore simultaneously the primal and dual subproblems of the original problem. A comparison between the direct solution with a mixed-integer lineal programming solver versus the cross decomposition is shown for several randomly generated instances. Results show the good performance of the decomposition method proposed.

3 - An integer linear programming approach to find trend-robust run orders of experimental designs
Jose Nunez Ares, Peter Goos

When a factorial experiment is carried out over a period of time, the responses may depend on a time trend. This may be due to, for example, a learning curve of the person in charge of the experiment, or heating up of the equipment over time. Unless the tests of the factorial experiment are conducted in a proper order, the time trend has a negative impact on the precision of the estimates of the main effects, the interaction effects and the quadratic effects. A proper run order, called a trend-robust run order, minimizes the correlation between the effects' estimates and the time trend's linear, quadratic and cubic components. Finding a trend-robust run order is essentially a permutation problem. We develop a sequential approach based on integer programming to find a trend-robust run order for any given design. The sequential nature of our algorithm allows us to prioritize the trend robustness of the main-effect estimates. In the literature, most of the used methods are heuristics and there has been little attention for trend-robust run orders of response surface designs, such as central composite designs, Box-Behnken designs and definitive screening designs. We test our sequential algorithm on 106 different designs, with two up to six factors, and we identify trend-robust run orders for many commonly used experimental designs.

4 - Discrete Optimization of Sample Sizes in Survey Statistics
Ulf Friedrich, Ralf Münnich, Sven de Vries, Matthias Wagner

In stratified random sampling, minimizing the variance of a total estimate leads to the optimal allocation by Neyman and Tschuprow. Classical algorithms for this problem yield real-valued rather than integer-valued solutions.

We present integer-valued optimization algorithms which solve the problem of minimizing a separable convex function with upper and lower boundary conditions. We begin by identifying the polymatroid structure of the feasible region and show that it can be solved by Greedy-type strategies. Subsequently, we develop a polynomial-time algorithm using a binary search based on medians.

As an application, the algorithms are used to solve the German Census 2011 allocation problem, a large-scale optimal allocation problem in stratified random sampling respecting box constraints. Numerical results show the practical relevance of this approach.

■ WC-03

Wednesday, 12:30-14:00 - Building CW, 1st floor, Room 13

Operations/Marketing Interface

Stream: Operations/Marketing Interface
Chair: *Kathryn E. Stecke*

1 - The First Review Effect
Jinhong Xie, Sungsik Park, Woochoel Shin

Online shoppers now witness an excessive amount of user-generated information illuminating other shoppers' experience with products and services. In such an information-rich environment, will a single consumer review have any significant influence over the fate of a given product? In this paper, we develop a theoretical model to demonstrate the powerful impact of a unique single consumer review, i.e. the very first one, on the product's word-of mouth (WOM) and market performance. Our empirical study based on vacuum cleaner data supports our theoretical predictions. First, the first review significantly affects two key metrics of WOM, volume and valence (e.g., compared to products with a positive first review, products with a negative first review suffer more than 50% loss in WOM volume). Second, the first review effect not only persists, but also can intensify over time. Specifically, although the impact of the first review on WOM valence declines over time, a negative (positive) first review leads to a significantly lower (higher) WOM valence even after 36 months since the first review was posted. More strikingly, the first review effect on WOM volume exaggerates rather than diminishes as time goes by. Together, these results underscores the crucial role of a product's very first consumer review. A product starting with a negative first review suffers not only from lower ratings but also from lack of chances to correct the downward bias in the rating.

2 - An investigation of differentiated prescription decision on profitability
Praowpan Tansitpong, W. Art Chaovalitwongse

This study investigates the equity of different medications prescribed to multiple types of patient. As prescription process plays an important role in hospital resource allocation, physicians make decisions in allocations of the prescribed medications based on diagnostic symptoms, however, physicians may not be aware of an inherited influence of medication options or reimbursed amounts which are related to the benefit plans. This empirical study explores Electronic Health Records (EHRs) from local hospital in Thailand on how variety of benefit plans, competition, and amount of dosage of prescriptions were assigned to segmented group of patients. The results suggested that types of patients indicates multiple schemes for prescription profits, moreover, the number of patient types and brand options also have significant impact on hospital profitability on the prescription.

3 - Pricing in competitive multi-channel retail under asymmetric costs: A Game theoretic analysis
Shounak Basak, Balram Avittathur, Preetam Basu, Souymen Sikdar

Today's consumers are exceedingly demanding and gather as much information as possible about the product by checking it through multiple channels. The research and purchase of the product is carried out by the consumer in one channel and the fulfillment of the product is carried out by another channel. The scenario that is becoming quiet prevalent today, involves consumers gathering information about a product from the offline retailer and then purchasing the product online. This is referred to as showrooming. The consumers gather information from traditional retailers and then, decide to purchase the product from an online channel. It has been seen that more and more consumers look at the products at BestBuy (an offline retail store) and then buy at Amazon.com that provides the convenience of buying from home and many times, at a lower price. In this paper, we consider a scenario where consumers tend to utilize the traditional retail chains for gathering information on the product and then purchase it from an online retail store. Our paper studies the effect of showrooming on the traditional retailer, electronic retailer and the wholesaler. We employ game theoretic frameworks to model the strategic dynamics between the different players involved in multi-channel retailing. . Traditional retailers are alert of the showrooming phenomenon and attempt to respond in an optimum way. This makes the phenomenon worth studying to get important insights.

4 - Digital Piracy and Quality Disclosure
Zelong Yi

We investigate how a firm selling digital products is influenced by piracy in terms of pricing, information disclosure policy and profitability. Specifically, we consider a monopolist, the quality of whose products is unknown to customers. It may choose to disclose the quality to the public at a positive cost. We unexpectedly find that, in equilibrium, the firm's profit may strictly decrease with the anti-piracy enforcement given that the quality is not too high. This is because, with stronger enforcement, the firm has more incentives to disclose the quality and customers' rational expectation towards quality when this information is concealed is lowered. The presence of piracy thus allows the firm to manipulate customers' belief about the quality of its product for its own benefit. Hence, contrary to conventional wisdom, we reveal that weak anti-piracy enforcement may increase the legal firm's profit.

■ WC-06

Wednesday, 12:30-14:00 - Building CW, ground floor, Room 2

Non-additive integration in MCDA

Stream: Multiple Criteria Decision Aiding
Chair: *Marta Bottero*

1 - Choquet integral and extension of ELECTRE III for modelling criteria interactions in environmental decision-making processes
Marta Bottero, Valentina Ferretti, José Rui Figueira, Salvatore Greco, Bernard Roy

The objective of the paper is to compare two different decision aid models for supporting environmental related decision processes. Starting from a previous study developed by the authors concerning the application of the extension of the ELECTRE III method with interactions for comparing alternative projects for the requalification of an abandoned quarry, the present research explores the use of the Choquet integral for supporting the same decision problem. The experimentation is based on the results of a focus group with experts which was aimed at defining the numerical values of the capacities and at translating the raw performances of the alternatives into standardized values to be used in the Choquet model. The paper describes the overall evaluation process, paying particular attention to the description of the development of the focus group and to the definition of the potentialities and limits of the proposed approach.

2 - A Choquet integral for pralines comparison based on fat bloom quantification
Valérie Brison, Marc Pirlot

When a chocolate bar or a praline is left for too long inside a cupboard or in a too warm place, we observe white spots that have appeared on their surface. This phenomenon is called fat bloom. In this work, we are concerned with the quantification of fat bloom on pralines. More precisely, some experts quantified fat bloom by answering two questions: "How much of the surface is covered with fat bloom?" and "What is the bloom density of the (worst) bloomed area?" Then, their answers were converted into a score. From these scores, we obtain a ranking of the pralines from the best (least bloomed) to the worst (most bloomed). Our objective is to reconstitute this ranking by using a multiple criteria decision aiding model (applied on the pictures of the pralines). According to the experts, for the same amount of whitish spots, it is preferred to have scattered small white spots than big white spots. Consequently, we propose to apply a model based on the Choquet integral to represent the experts' preferences, since such a model allows to take into account the contiguity of white pixels.

3 - An analysis of criteria interaction phenomenon in multiple-attribute decision making
Ilker Gölcük, Adil Baykasoğlu

A very common assumption in majority of the multiple-attribute decision making methods is the criteria independence. However, criteria interaction is a very natural phenomenon that entails the use of sophisticated and intelligent techniques to deal with it. It is observed that the literature lacks a comprehensive analysis/discussions related to criteria interaction phenomenon. The present study aims to put a step forward in this direction by providing a classification of methods related to criteria interactions. The study covers state of the art methods such as, Analytical Network Process (ANP), Decision-Making Trial and Evaluation Laboratory (DEMATEL), Choquet integral, Interpretive Structural Modeling (ISM), etc. and their particular roles in handling interactions among criteria. Finally, the present study provides review/discussion of the most promising hybrid methods (i.e., DEMATEL and ANP hybridizations) which grab remarkable attention of decision analysis community in recent years.

■ WC-08

Wednesday, 12:30-14:00 - Building CW, 1st floor, Room 9

OR and Real Implementation 2

Stream: OR and Real Implementation
Chair: *Ben Lev*

1 - Planning of multi-product one-to-one pipelines by economic lot scheduling models
Thomas Kirschstein

Pipelines are one of the most efficient modes of transport w.r.t. variable transportation cost. However, building pipelines incurs high investment costs and pipelines can only be used to transport liquefiable products. Hence, pipeline systems are highly inflexible and mostly used to serve unidirectional transport needs with high and steady transport quantities. Commonly, pipelines are designed for one product only. However, in chemical and oil-refining industry also multi-product pipelines can be found frequently for substances which are chemically similar (like different types of gasoline). The operational management of multi-product pipelines is often concerned with scheduling and sizing of product batches under consideration of e.g. storage capacities or order deadlines. Commonly, such scheduling problems are modeled for a discrete number of product orders of varying size resulting in discrete scheduling problems. In this talk a one-to-one pipeline for multiple products with constant demands per time unit is considered as it appears e.g. in chemical industry. It is shown that the optimal sequencing and scheduling of product batches can be obtained by solving an economic lot scheduling problem (ELSP) which must be adapted w.r.t. to the product separation technology of the pipeline system under study. In three case studies the application of the derived ELSP models is illustrated by solving realistically sized problem instances for different separation technologies.

2 - Seamlessly Creating a Plan, Anywhere, Any Device, Together
Chris Kuip

The phrases in this ambitious title require advanced technological support: - Create Plan: best achieved by a tool for developing Decision Support apps - Anywhere: requires the ability to launch and manage apps from within a browser - Any Device: requires data analysis and manipulation in the browser - Together: requires multi-user support In this presentation, we will show how the AIMMS Engine, the AIMMS PRO platform, the AIMMS WebUI, and the new AIMMS Collaborative Data Management library work seamlessly together to achieve the title.

3 - Reliable allocation of sensor measurements in a diagnostic system solved as a variant of the generalized assignment problem
Claudio Sterle, Antonio Sforza, Neto André Cabrita

In this work we tackle a variant of the generalized assignment problem (GAP) arising from a real problem related to the diagnostic system of a tokamak, a magnetic plasma confinement device for producing controlled thermonuclear fusion power. This problem has been referred to as the oPtImal Measurement Probes Allocation problem (PIMPA) and it is aimed at sequentially determining the storage (allocation) of the plasma measurements revealed by the probes, first in the data acquisition components and then in related boards, maximizing the reliability of the diagnostic system against possible failures of one or more of its parts. A GAP consists in determining the maximum profit assignment of n objects to m bins such that each object is assigned to exactly one bin, satisfying the capacity constraints. With reference to the GAP, the objects to be allocated are the measurements and the bins are the acquisition units. The profit to be maximized is represented by a reliability function which depends on the distribution of the signals within the units. An ILP based solution approach will be presented for the PIMPA problem and its variants. Results on real and test cases will be presented to show the effectiveness of the proposed approach. It is important to highlight that, although in this work PIMPA is introduced for the optimal allocation of plasma measurements in a tokamak, it can be easily extended to any diagnostic system.

4 - Clustering of maintenance of maritime assets under different operating modes
Ben Vermeulen, Ayse Sena Eruguz, Tarkan Tan, Geert-Jan van Houtum

In the maritime sector, vessels are typically used under different operating modes with different degradation rates, different maintenance setup and downtime costs, and particular maintenance/ replacement options. Ideally, the mission schedule codetermines the provisional maintenance plan, including the clustering of maintenance activities. However, given requirements of classification societies and own requirements (e.g. placement of research equipment), owners frequently dock their vessels for complete overhauls or schedule extensive maintenance activities, effectively forming clustered maintenance. Given their ignorance of actual failure rates, asset owners therein follow the OEMs' hyper-conservative and hence costly replacement policies. Currently, the first innovative asset owners have started to lobby with classification societies for notations for condition- and usage-based maintenance for certain systems to allow scheduling maintenance activities more rationally. In our research, we provide a dynamic programming model and a proprietary software tool to provisionally as well as adaptively optimize the schedule and clustering of maintenance activities given the mission schedule with or without prefixed dry-docking. Ultimately, we study sensitivity of clustering in the provisionally optimal maintenance schedule for the degradation rates and compare total maintenance costs with the 'rule-of-thumb' scheduling followed by asset owners based on instructions of OEMs.

■ WC-10

Wednesday, 12:30-14:00 - Building CW, ground floor, Room 1

AHP/ANP Integrated Evaluations

Stream: Analytic Hierarchy Process / Analytic Network Process
Chair: *Jana Talasova*

1 - A Hybrid DEMATEL and ANP SWOT Analysis for A Local Case of University, Industry and Government Interactions
V. Alpagut Yavuz

University, industry and government interactions are regarded as the primary source of innovation and growth in knowledge-based economies. Over the years, governments have developed various plans and programs to cultivate and facilitate these interactions. Recently Turkey has implemented a new mechanism to foster university, industry and government interaction at the city level. For this purpose, a planning and development committee has been formed in every city in the country under the supervision of the city governors that includes representatives from related NGOs, government agencies and universities. In this study, a hybrid method of Decision Making Trial and Evaluation Laboratory (DEMATEL), and Analytical Network Process (ANP) has been implemented to the Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis that will help the development of these planning and development committees' strategic and tactical action plans for the cultivation of university, industry, and government interactions. SWOT analysis by itself does not provide information about the dependency among the identified factors and their importance. In order to overcome these shortcomings, Analytical Hierarchy Process (AHP) method is suggested in SWOT analysis. However, AHP method assumes the independency of factors, which is not attainable in most cases. Thus, by using DEMATEL method in conjunction with ANP method, dependencies among the factors can be accounted for more easily.

2 - Mathematical model for evaluating artistic work outcomes
Jana Talasova, Jan Stoklasa, Pavel Holeček

The paper presents the development and the current state of the formal model for the evaluation of creative work outcomes at Czech art colleges. These outcomes are stored in the Registry of Artistic Performance. The results of the model - scores assigned to the outcomes - are used for funds distribution from the Czech state budget among art colleges. For the purpose of the evaluation, the creative work outcomes are classified into categories based on three criteria: significance of the outcome, its extent, and its institutional reception. Three possible levels are distinguished for each criterion; their combinations thus defining 27 distinct categories. These categories are assigned scores by the AHP. Experts in individual fields of artistic production provided the initial information for the construction of Saaty's matrix under the guidance by a team of mathematicians to achieve sufficient consistency. In time the need emerged to decrease the scores of "questionable" categories where a high expert evaluation of significance is not in line with the institutional reception. The scores of categories were modified accordingly and the consistency of the Saaty's matrix used for their calculation was increased in the process. The two required opinions by independent experts were supplemented by an assessment of the outcome by a special board formed for each field of art. The development and successive modifications of the evaluation model are the focus of this paper.

3 - Using ANP - TOPSIS methods for route selection of monorail in Ankara
Mustafa Hamurcu, Tamer Eren

Due to increasing population in Ankara there are many problems. At the beginning of this problems are traffic for urban areas. It is needed a great traffic planning for the solution of this problem. Public transport should be encouraged. The first, it should be made a selection of the kind of public transport for it. It must be at a level to will meet the demands of the transport type selected. A monorail is an alternative transport vehicle for solving this problem in urban areas. The monorail is a single rail serving as a track in urban area. This system is fast and safely. After this stage, the most appropriate route should be determined. Otherwise this system will not help to improve urban transport. Moreover, route selection is influenced by many factors such as construction cost, environment, public mobility, demand level, accessibility, traffic density etc. Thus, there is a need for a multi-criteria evaluation. This study was conducted to choose from eight alternative route for monorail route selection in Ankara by using Analytic Network Process (ANP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS).

■ WC-12
Wednesday, 12:30-14:00 - Building CW, ground floor, Room 029

Demand-based combinatorial optimization

Stream: Combinatorial Optimization
Chair: *Shadi Sharif Azadeh*

1 - A choice-based optimization approach in flexible mobility on demand
Shadi Sharif Azadeh, Michel Bierlaire

One of the main challenges of operation managers is to decide about how to oer a mix of products to the customers at a given time with the objective of maximizing the expected revenue as well as maximizing the customers' satisfaction. The expected revenue from an oer set is dened by the price and the demand of each of the oered products. Smart phones and new applications have revolutionized urban transportation and mobility. For example Uber market share has grown so fast during the last couple of years calling for new challenging optimization models to be solved efficiently. For the first time in this field, we introduce an integrated choice-based optimization model that takes into account the cost of routing for taxis and shared taxis while accounting for customer choice behavior.

2 - Revenue management capacity control optimization with aggregated non-parametric choice behaviour
Thibault Barbier, Miguel Anjos, Fabien Cirinei, Gilles Savard

We consider the revenue management network capacity control problem. Several works have shown the importance to implement customer choice behaviour. When tackling phenomena like "buy-up" or "buy-down", choice-based models generate more accurate and robust solutions. The first choice for behaviour modeling is parametric models such as Multinomial Logit. Such models deal with the probability of buying a product among a set of proposed products. More recently, non-parametric choice behaviour modeling was introduced. It is one of the most flexible and powerful approaches to address the revenue management network capacity control problem. Non-parametric choice behaviour modeling aims to predict customer choice when faced with different options. In this approach, each arriving customer chooses from several alternatives available according to an ordered preference list of products. If the customer's most preferred product is not available, he substitutes it with the next-ranked product in his ordered preference list. We propose a new mathematical programming approach to compute the optimal allocation of resources under an aggregated non-parametric choice model of demand. New methods are proposed to efficiently optimize and simulate large-scale and real-world practical problems.

3 - A new mathematical formulation to integrate supply and demand within a choice-based optimization framework
Meritxell Pacheco Paneque, Shadi Sharif Azadeh, Michel Bierlaire

During the last decade, there has been an increasing trend to combine customer behavior models in optimization, since it provides a better understanding of the preferences of clients to policy makers while planning for their systems. These preferences are formalized with predefined discrete choice models, which are the state-of-the-art for the mathematical modeling of demand. However, their complexity leads to mathematical formulations that are highly non linear and non convex in the variables of interest. On the other hand, we are also interested in discrete optimization models where supply and demand closely interact, which is typically the case in transportation problems. Such models are associated with (mixed) integer optimization problems, whose discrete variables are used to design and configure the supply. In this research we present a general methodology that integrates both supply and demand while keeping the discrete choice model inside the framework of a mixed linear integer problem that is scalable and solvable within reasonable time.

■ WC-13
Wednesday, 12:30-14:00 - Building CW, ground floor, Room 3

VeRoLog: Heuristics for VRP variants 2

Stream: Vehicle Routing and Logistics Optimization
Chair: *Jose Brandao*

1 - Team orienteering problem with time windows and partial scores
Vincent F. Yu, Hsiu-I Ting

We study the team orienteering problem with time windows and partial scores (TOPTWPS), an extension of the well-known team orienteering problem with time windows (TOPTW). One of the applications of TOPTW is the design of tourist trips. In TOPTW, when a participant visits a vertex, the score associated with the vertex is collected by the participant. However, when a tourist is planning a visit to a point of interest (POI), the tourist may not be interested in all the activities or attractions of the POI. In terms of TOPTW, the participant is allowed to collect partial score from a vertex. Therefore, we define TOPTWPS to consider this situation. We develop a mathematical programming model for TOPTWPS and a heuristic algorithm to solve the problem. Results of computational study indicate that the proposed heuristic effectively solves TOPTWPS.

2 - Incorporating Linear Optimization into Routing Problems
Murat Firat, Nico Dellaert, Wim Nuijten

This work introduces a heuristic algorithm for the Vehicle Routing Problem with Time Windows (VRPTW) that greedily constructs a routing plan by employing a master Linear Programming (LP) model as a central optimization mechanism. The objects to select in the LP model are routes that are bi-directionally constructed by a Dynamic Programming (DP) based method. Different from classical depot-to-depot type route construction in the literature, our routes are initialized at certain customers, so called route centers, and they are extended by visiting further customers before and after already visited ones. Here, a route center corresponds to a used vehicles, and a clique in the customer incompatibility graph gives us initial route centers. A complete routing plan, i.e. an integer solution to the master LP model, is obtained by making two type of decisions; customer grouping and introducing a new vehicle. These decisions are made by examining solution properties of the dual our master LP model. We also give a dual interpretation of the master LP model by using the primal-dual method as a base for our decision system. An important feature of our algorithm is that every used vehicle has a fixed-size route set in the master LP model which makes our algorithm to halt in constant time. The efficiency of our algorithm is shown by means of a computational study by using well-known Solomon VRPTW benchmark instances.

3 - Iterated local search algorithm for the vehicle routing problem with backhauls and soft time windows
Jose Brandao

The vehicle routing problem with backhauls and soft time windows (VRPBSTW) contains two distinct sets of customers: those that receive goods from the depot, who are called linehauls, and those that send goods to the depot, named backhauls. In each route the linehauls have to be served before the backhauls. To each customer is associated an interval of time (time window), during which each one should be served. If the time window can be violated it is called soft, but this violation implies an additional cost. We solve the VRPBSTW using iterated local search. The good behaviour of the method devised results, to a great extent, from the perturbations used. The performance of the method is tested using a large set of benchmark problems from the literature.

4 - Neighborhood search approaches for multi-trip vehicle routing problems
Véronique François, Yasemin Arda, Yves Crama, Gilbert Laporte

We introduce two large neighborhood search approaches for solving the multi-trip vehicle routing problem (MTVRP), where each vehicle can perform several routes to serve a set of customers. The problem specifically arises when travel times between customers are short and/or when demands are large. It has been commonly solved in the literature by mixing vehicle routing heuristics and bin packing techniques aimed at assigning routes to vehicles. As an alternative, we propose specific operators that tackle the routing and the assignment aspects of the problem simultaneously. The introduced methods are compared both for the MTVRP and the version with time windows, in which the assignment part of the problem becomes more challenging. In the latter, besides considering a time window at the depot, the working time of each vehicle may not exceed a maximum duration, while its start time is a decision variable. Beyond providing several best known solutions for benchmark instances of the MTVRP, we focus on understanding the behavior of the algorithms. An automatic configuration tool is used, not only to improve the quality of the results, but also as a mean to gain knowledge about algorithm design options and their interactions. We question the impact of several heuristic components and in particular those of the roulette wheel mechanism and of the adaptive memory of routes.

■ WC-14

Wednesday, 12:30-14:00 - Building CW, 1st floor, Room 125

Port operations

Stream: Maritime Transportation
Chair: *Massimo Di Francesco*
Chair: *Paola Zuddas*

1 - A New Random-Key Genetic Algorithm for the Berth Allocation and Quay Crane Assignment Problem
Juan Correcher, Ramon Alvarez-Valdes, Jose Tamarit

In this work we address jointly the dynamic berth allocation problem and the quay crane assignment problem in maritime container terminals. We tackle the integrated version (BACAP) in which the terminal has a continuous quay, that is, vessels can be moored at any point of the quay provided that they do not overlap. Moreover, we consider the time-invariant version of the crane assignment problem, so the number of cranes assigned to each vessel is kept fixed throughout its loading/unloading process. The processing time of each vessel depends on the number of cranes assigned to it, and there are several costs related to waiting and delay times, and the deviation from the desired position at the quay. The objective is to determine for each vessel the number of cranes assigned to it and its berthing time and position, in order to minimize the total assignment cost of all the vessels in the planning horizon.

We propose a new Biased Random-Key Genetic Algorithm (BRKGA) and we include a Local Search to obtain good solutions in short computing times. Computational experiments over several sets of generated instances show that the solutions thus achieved deviate very little from the optimal/best known solutions on instances with up to 60 vessels.

2 - The Regional Port Competition with Different Terminal Competition Intensity
Mingzhu Yu, Chung-Yee Lee

This paper studies the regional container port competition problem which involves two port cities each with its own container terminal. We provide two-level game-theoretic models to characterize several practice-related issues, such as container terminal cooperation situation, and the difference between local in/out and transshipment container throughputs. Numerical experiments are conducted based on the port system in the Pearl River Delta area of China. We find that (1) service differentiation exists in the heterogeneous regional port system, (2) the terminal cooperation will be supported by both the port city governments and the terminal operators, (3) the developed port will gradually dominate the transshipment container business in the system, leaving the developing port to focus its efforts on the local in/out container business instead.

3 - A Novel Integrated Scheduling Model of SP-AS/RS, ALV and Quay Cranes at Automated Container Terminal
Seyed Hamidreza Sadeghian

Integration of various types of handling equipment is one the important ways to increase the efficiency of processes and productivity of a container terminal. Using Automated Lifting Vehicles (ALVs), due to their ability in lifting a container from the ground by themselves, can decrease the delay of loading and unloading tasks in automatic container terminals. Also in recent years a new storage system called Split-Platform Automated Storage/Retrieval System (SP-AS/RS) with the capability of using stacking area efficiently, has been introduced in the literature. In this paper, a novel mixed-integer programming model, which considers the integration of ALVs, Quay Cranes (QCs) and SP-AS/RS at automated container terminals with limited buffer spaces, is developed. This model minimizes the makespan of all the loading and unloading tasks for a pre-defined set of cranes in a scheduling problem.

4 - An optimization model for the short-term manpower planning problem in transhipment container terminals
Massimo Di Francesco, Paola Zuddas, Nuria Dìaz-Maroto Llorente, Simone Zanda

We investigate the short-term manpower planning problem for transhipment container terminals. It consists of determining shifts, tasks and activities of the terminals' manpower, in order to serve vessels in time intervals, which typically do not overlap with personnel shifts. This complex problem is modelled by an integer linear programming formulation. The optimal solutions of the model are compared to the decisions made according to the manpower policy adopted by a real transhipment container terminal. The experimentation sheds light on when its policy is effective or there is room for optimization. The computational tests show that the model can be optimally solved even in the case of huge transhipment container terminals.

■ WC-15

Wednesday, 12:30-14:00 - Building CW, 1st floor, Room 126

Uncertainty and robustness

Stream: Supply Chain Management
Chair: *Christian Ruf*

1 - Optimal Supply Chain Strategy and Postponement Degree with 3D Printing
Daniel Ramon Lumbierres, Asier Muguruza, Robert Gimeno Feu, Ping Guo, Mary Hamilton, Kiron Shastry, Sunny Webb, Joaquim Minguella, F.-Javier Heredia

In this contribution we would like to present the results of a research project developed by Accenture and BarcelonaTech aiming at studying the advantages of ultra-postponement with 3D printing using the analytical tools of operational research. In this project a new two-stage stochastic programming decision model has been developed to assess (a) the convenience of the introduction of 3D printing in any generic supply chain and (b) the optimal degree of postponement, the so called Customer Order Decoupling Point (CODP), assuming uncertainty in demand for multiple markets. To this end we propose the formulation of a generic supply chain through an oriented graph that represents all the alternative technologies that can be deployed, defined through a set of operations for manufacturing, assembly and distribution, each one characterized by a lead time and cost parameters. Based on this graph we develop a mixed integer two-stage stochastic program that finds the optimal manufacturing technology to meet the demand of each market, the optimal production quantity for each operation and the optimal CODP for each technology. The results obtained with several case studies from real manufacturing companies are presented and analyzed.

2 - Rolling Planning for the Sourcing Problem with Local Content Constraints
Christian Ruf

In a global manufacturing environment companies have access to low-priced sources of supply. At the same time they are often committed or commit themselves to a minimum level of local content. In a dynamic environment sourcing decisions can be subject to short term changes. Therefore it is necessary to generate sourcing plans that are insensitive to such changes so as to minimize costs while not violating the local content requirements. In this paper a formulation for the Sourcing Problem with Local Content Constraints is presented. The model is solved heuristically in a rolling planning fashion. The results of the computational study suggest the applicability of the developed approach.

3 - Spare Parts Quantity Problem, Interval Loss Matrix and Uncertainty with Unknown Probabilities
Helena Gaspars-Wieloch

The spare parts quantity problem (SPQP) plays a central role in service parts management. The goal of SPQP is to ensure the right number of extra (spare, service) parts at the right place (where the broken part is) at the right time. SPQP may be analyzed in the context of repairable or non-repairable service parts. Here, we focus on the second case. In the literature, spare parts optimization is regarded as a stochastic problem since the demand for extra parts is treated as a random variable with a known distribution. Hence, the optimal stock quantity minimizes the expected loss resulting from buying a given number of parts before potential failures. However, in the author's opinion, SPQP may also be a strategic problem, i.e. an uncertain problem with unknown probabilities. Such a situation occurs e.g. for totally new devices with no historical data about previous failures. Therefore, we present a novel approach, based on a hybrid of Hurwicz and Bayes decision rules. It takes into account the decision maker's attitude towards risk (measured by coefficients of optimism and pessimism) and the dispersion (asymmetry, range, frequency of extreme values) of losses connected with particular stock quantities. Additionally, we assume that the future unit purchase cost of a service part bought after the breakdown is also uncertain, which leads to decision making on the basis of a loss matrix with interval values.Financed by: National Science Center, Poland (2014/15/D/HS4/00771).

■ WC-16

Wednesday, 12:30-14:00 - Building CW, 1st floor, Room 128

Emergency Department Modeling and Optimization

Stream: Healthcare Logistics
Chair: *Shahrooz Shahparvari*

1 - Optimization of patient scheduling in emergency department
Marwa Harzi, Issam Nouaouri, Jean-François Condotta, Saoussen Krichen

Since the last two decades, hospitals, particularly Emergency Departments, are facing mutation imposed by medical and economic constraints. The pressure of the stream and the number of patients, the limited number of available resources, and the proliferation of unexpected situations, make the management of the daily service very difficult. This change should push decision-makers towards developing a more efficient organization to construct an objective and rigorous management.The scheduling of patients in emergency departments is one of the most tackled problems in real-world situations. In the literature review, some works were interested in scheduling of patients and medical staff.The main focus of this paper is to seeka suitable scheduling that minimizes the overall wait time of patients in queues of treatment process. In this context, we propose a mixed integer linear programming that minimizes the average total patients wait time from the arrival of patients in the ED until their hospitalization.The system was tested on a set of real instances from an emergency department. Our findings indicate that the proposed procedure outperforms results of the current situation by reducing the total wait time of patients in queues.

2 - Optimization of Emergency Department under uncertainties
Issam Nouaouri, Dorsaf Daldoul, Hanen Bouchriha, Hamid Allaoui

The Emergency care is critically important to the health of population. Worldwide, Emergency Department (ED) visits are steadily increasing, with 30% in France from 2002 to 2012 (Rapport ARS 2012). The ED is often saturated by a continuous flow of patients, the waiting rooms are always full, and representing an excessive wait time for the patients (Meah 2008). The EDs are operating with limited resources and high levels of stochastic demands. In this paper, an ED of a public hospital was studied to analyze the current system and its performance. The main focus of this paper is to analyze the bottlenecks and improve the patient flow through the ED by managing efficiently the allocated resources (physicians, nurses and beds). In this context, we propose a stochastic mixed-integer linear programming that minimizes the average total patients wait time from the arrival of patients in the ED until their hospitalization. Most of studies published in the literature focus on scheduling and assigning of patients. Some works were interested in scheduling of medical staff and sizing of healthcare resources. These works do not consider all levels of the process in the ED. In this work, we consider six patient queues that represent the six main activities: the triage of patients, general assessment, surgical assessment, auxiliary exams (X-rays and/or clinical lab tests), life-threatening emergencies and affectation to a bed.

3 - Vehicle Routing and Scheduling for Bushfire Emergency Evacuation
Shahrooz Shahparvari, Babak Abbasi, Prem Chhetri

Quick response to evacuate evacuees within a short-notice bushfire situation through efficient emergency logistics distribution is essential to the mitigation of disaster impact in the concerned areas, which remains challenging in the logistics related areas.Therefore, this study aims to model the emergency evacuation process in bushfire scenarios. The objective is set to transfer utmost late evacuees from the local assembly points to the safer places in the minimal amount of time and resource usage, by routing and scheduling a fleet of homogeneous and capacitated vehicles. The contribution of this study is to propose a dynamic evacuation routing approach that incorporates time-dependent evacuation times considering multiple pick up points, destinations, and vehicles and under roads disruptions. Also, a novel heuristic approach is developed to cope with the complex nature of VRP based problems. To evaluate the effectiveness of proposed procedure, the model is conducted in a real case study from Australia.

■ WC-18

Wednesday, 12:30-14:00 - Building CW, ground floor, Room 023

Computing and OR - Emerging Applications 3

Stream: Computing
Chair: *Ioannis Tsiligkaridis*
Chair: *Omer Melih Gul*

1 - Data Mining Methods for Server Decision Processes in Wireless Mobile Computing
Ioannis Tsiligkaridis

The problem of server performance in a contemporary, rapidly developed and multi-discipline environment is examined. A huge number of users request services in a very short time increasing this way the number of connections and pushing the server to the limit. Nowadays, data driven knowledge acquisition and decision making are increasingly important for any type of application domain. The administration of the data sources or repositories during the execution of the query plan becomes primary interest especially for starting the query server. In this approach, based on group and query mobility, new material for server dependency using Data Mining techniques is presented. A tree composed method (TCM) can guarantee the acceleration of the distributed query execution and the expedition of the data prefetching operation. TCM, apart from the ability to generate rules, can also provide data replication schemes. Depending on the domain the query needs to work in and the accuracy values of the path for each group and query mobility, new rules can be created in order to minimize the query execution time. For external queries, metrics are also introduced that can estimate the dependency among servers for various mobility schemes. Depending on the opportunity to hold the "hot" data, the time period and the location of events, the offered services and the purpose of each server, more rules can be produced.

2 - Enabling Cloud Service Consolidation with Minimal Interference
Yue Jin, Jennifer Ryan

As Cloud computing becomes more pervasive, the number of services running in Cloud is constantly increasing. Cloud operators are consolidating services in order to increase the utilization of resources and control operating costs. This consolidation puts multiple services onto the same physical infrastructure. Inevitably, the services contend for resources and consequently suffer from performance degradation. In this work, we propose and validate an analytical model for this type of interference between services. We develop the model based on queuing theory. We design and implement an experiment to test the validity of the model. We fit the model to the experimental data and achieve a 85% accuracy. Moreover, we develop an optimization model to place services on physical resources with minimal interference. Our analysis of the optimization model enables us to calculate the service utilizations efficiently for a given placement. We propose a greedy algorithm to find the optimal placement efficiently.

3 - A risk-based decision making approach for maintenance strategy selection using fuzzy AHP: A case study for the petrochemical industry
Mohammadreza Vasili

The effective use of the maintenance strategies has recently been one of the most critical and challenging tasks for the decision makers in industries. The selection of an appropriate is vital in order to increase the availability and the reliability levels of production facilities at reasonable costs. In this study, an integrated approach of risk analysis and fuzzy analytical hierarchy process (FAHP) has been proposed to select a proper maintenance strategy. The risk priority matrix has been made for five different risk levels, including desirable, acceptable, tolerable, undesirable, and vital. With FAHP technique, four possible alternatives have been analyzed: emergency maintenance (EM), preventive maintenance (PM), condition based maintenance (CBM), and improvement maintenance (IM). In order to characterize each of the above-mentioned maintenance strategies, four criteria including reliability, availability, maintainability, have been considered as part of the MCDM model. The proposed method has been used for selecting the best maintenance strategy for an important Iranian petrochemical plant. Results show that for the desirable risk level, the emergency maintenance strategy has been selected, while for the risk levels of acceptable, tolerable, and undesirable, preventive maintenance strategy has been more appropriate. Likewise, condition-based maintenance has been recognized as the proper strategy for vital risk level.

■ WC-19

Wednesday, 12:30-14:00 - Building CW, ground floor, Room 021

Simulation-Optimization in Logistics and Transportation

Stream: Transportation and Logistics
Chair: *Guido Perboli*

1 - Optimization for Networked Data in Environmental Urban Waste Collection: the ONDE-UWC project
Guido Perboli, Edoardo Fadda, Luca Gobbato, Mariangela Rosano, Roberto Tadei

The Optimization for Networked Data in Environmental Urban Waste Collection project (ONDE-UWC) is the first work applying the Internet of Things paradigm to the solid waste collection. Sensors installed on dumpsters and vehicles share data as number of users' accesses and waste weight and volume. Thanks to these data, and differently from the approaches in the literature, we schedule the weekly waste collection activities without imposing periodic routes [1]. In particular, given historical data, we estimate the demand at each dumpster day by day. Then, we use this estimation to plan operations (i.e. scheduling, dumpster-vehicle assignment, and routing) by minimizing their costs. Because of the high number of dumpsters, we propose a heuristic algorithm that aggregates dumpsters in clusters and solves a mixed integer linear program of the aggregate problem. A post-optimization phase then builds the actual routes by considering the single dumpster in each cluster. The results show as the vehicle capacity usage increases more than 10%, while dumpsters are emptied when their load is closed to 80% of their capacity. These benefits have been certified by the company, which shows a decrement of its operational costs of 20%.

References

[1] G. Ghiani, D. Laganà, E. Manni, R. Musmanno, D. Vigo. "Operations research in solid waste management: A survey of strategic and tactical issues". Computers & Operations Research. 44:22-32, 2014.

2 - An integrated multi-agent/system dynamics model for the assessment of City Logistics project
Giovanni Zenezini, Alberto De Marco

Urban distribution is one of the most expensive and impacting portion of a supply chain, with several stakeholders operating with different objectives and scope of actions. In this context, City Logistics (CL) projects aim at optimizing urban logistics activities by reducing the related social and environmental impacts, but are often discarded due to divergent objectives between the stakeholders or lack of economic feasibility. Current inefficiencies and the barriers to the implementation of innovative projects are both due to the distributed decision-making by heterogeneous stakeholders. Agent-based modelling (ABM) enables to approach the problem of distributed decision-making by modelling each of the stakeholders of the urban environment as an autonomous agent. Moreover, integrating ABM with System Dynamics (SD) can prove to be beneficial for reducing the complexity of the model. Therefore, the objective of this research is to develop an integrated agent based/system dynamics simulation model to assess the impacts of CL projects on the stakeholders' activities in order to evaluate their long-term sustainability. Each agent takes decision based on the benefits offered by the project and its utility function, designed with the features that compose each agent's business model. Decision-making processes are also affected by feedback loops, which are modelled via System dynamics (SD). SD is in fact the proper tool to simulate these processes at the agent level.

3 - Container-Level Simulation of Quay-Side Crane Operations
Karolina Glowacka, Yuen Ying Avis Lam

In this research we study container port operations with focus on quay-side crane activities. The majority of existing port simulation models consider vessel workload simply as the total number of container moves or lifts that need to be performed on that ship. In contrast, we generate the number of moves for each cargo bay on a vessel, in order to more accurately model crane operations. This allows us to represent more realistic ship-to-shore quay crane operations, where no more than one crane can work simultaneously on one or two bays. This is an important consideration, as the workload on a vessel per bay may vary greatly. It is particularly critical in variable-in-time crane assignment models, where crane allocation per vessel can change during the operation. We model container ships as three-level hierarchical entities with the levels representing containers, cargo bays, and vessels respectively. We implement the simulation in Simio and combine it with Simio crane object library to demonstrate loading and discharging operations on vessels of various sizes. We also discuss statistical properties of vessels, including total moves and moves per bay, based on data obtained from one of the large port operators in Hong Kong.

4 - Multiple criteria evaluation of alternative international/global supply systems
Barbara Galinska, Jacek Zak

In this paper the authors consider the problem of a multiple criteria evaluation and ranking of different options of supplying finished products in a garment industry. The transported assortments are clothes. These goods are manufactured in China, then transferred to a central warehouse (corporate headquarter), located in the central part of Poland (near Lodz). The considered decision problem consists in selecting the most desirable option of transporting goods. Solving the problem is the responsibility of the top management of an international company (acts as a Decision Maker DM), that manufactures and distributes the clothes. The decision problem is formulated as a multiple criteria ranking problem. Thus, the authors design alternative global supply corridors between China and Central Europe (Poland) based on a single mode and multimodal transportation. As a result they define 8 alternatives of delivering goods. They evaluate them by a consistent family of criteria. The authors model the DM's preferences and carry out a series of computational experiments with the application of selected MCDM/A ranking methods. As a result they generate final rankings of transportation options. Using statistical methods the authors compare the rankings generated by different computational algorithms and draw final conclusions regarding their stability. Finally, they recommend the best option of transporting clothes.

■ WC-20

Wednesday, 12:30-14:00 - Building CW, ground floor, Room 022

Cutting and Packing 4

Stream: Cutting and Packing
Chair: *A. Miguel Gomes*

1 - Lower bounds for a bin-packing problem with linear usage costs
Roland Braune

In this contribution, we address a special kind of a bin packing problem. Contrary to the standard case, which is about minimizing the number of allocated bins, we focus on the usage cost of bins. The cost of placing an item into a bin depends on its load and the bin number or index, where the bin-dependent usage cost linearly increases with the bin index. The motivation for analyzing this kind of model is a real-world multiprocessor scheduling problem, in which we seek to shape the utilization profile of discretely divisible resources in a right-skewed fashion, that is, preferring higher utilization in earlier time periods.

The methodological core of our contribution is the proposal, comparison and analysis of lower bounding schemes for the considered bin packing problem. First, we present adaptations of bounds L2 (Martello and Toth, 1990) and L3 (Labbe et al., 1991) for the linear usage cost objective. Second, we devise two new lower bounds, one based on a relaxation of a bin covering problem and the other one based on a multiple choice knapsack problem. We conduct a theoretical and experimental worst-case performance analysis for some of the proposed bounds and compare them to Lagrangean relaxation approaches as well as recently published adaptations of network flow and column generation-based bounds for a slightly more general objective (Cambazard et al., 2013). Final computational experience is based on a broad range of randomly generated instances of varying size.

2 - On the computational complexity of the Cover Printing Problem

Arnaud Vandaele, Daniel Tuyttens

The Cover Printing Problem (CPP) is a combinatorial optimization problem arising mostly in printing factories and can be considered as a variation of the famous Cutting Stock Problem. The problem consists in producing book covers with the use of several templates. A template can be considered as a large plate which can accommodate different covers.

More formally, given a set of demands (each corresponding to a number of copies of a book cover to produce), the CPP consists in (1) determining the number of templates to use, (2) finding an assignment of the book covers to the slots of each template and, (3) determining the number of printings of each template. The objective is to minimize the total cost while producing the required number of copies of each cover.

The CPP has been studied for a long time but very few works focused on its difficulty. In the first part of this work, we describe special cases for which there are polynomial time algorithms. In a second time, we show the CPP is strongly NP-hard in general.

3 - A Mathematical programming approach for 1.5-Dimensional Cutting Stock Problem

SueJeong Kwon, Jinil Han, Kyungsik Lee

In this paper we consider 1.5-dimensional cutting stock problem which arises in paper industry. In the classical 1-dimensional problem, each input roll is allowed to be cut only horizontally under the assumption that each item is characterized by its width only. In 1.5-dimensional problem, each item is characterized by its length that is usually larger than the length of input rolls as well as its width, thereby having to cut input rolls vertically as well as horizontally. We present mixed integer programs for the 1.5-dimensional problem and compare their strength. We also propose decomposition approaches for the problem based on cutting patterns. Preliminary computational results also will be given.

■ WC-21

Wednesday, 12:30-14:00 - Building CW, ground floor, Room 025

Methodology of Societal Complexity and Sustainable Development

Stream: Methodology of Societal Complexity
Chair: *Dorien DeTombe*

1 - Optimizing Public Governance. Requirements for Handling Complex Societal Problems

Antoinette Muntjewerff

Good governance is an indeterminate term used in international development literature to describe various normative accounts of how public institutions ought to conduct public affairs and manage public resources. Countries and their governments are confronted with local, national, continent wide and global problems. These problems are referred to by DeTombe as Complex Societal Problems (see, for instance, DeTombe, 2015). These problems require government and inter-government interventions. In our article optimization is defined as a methodology of making something (as a design, system, or decision) as fully perfect, functional, or effective as possible. The theory of the methodology of societal complexity and the COMPRAM methodology based on it are ways to optimize the handling of complex societal problems through governance (DeTombe, 2015). She pleads for governments to be stimulated to establish a democratic socially based society (DeTombe, 2015, p. 338). Over the last decades efforts have been made to assess and measure the quality of governance. The Worldwide Governance Index (WGI) has been developed with the following indicators: peace and security, rule of law, human rights and participation, sustainable development and human development. The COMPRAM methodology is specifically developed to support governments in handling complex societal problems. In this article we want to make a link between the COMPRAM methodology and the requirements of good governance

2 - COMPRAM Methodology of Societal Complexity Approaching and Analytical Enhancing the Human & Social Peace and Security Capabilities by 'Science-Religion Dialogue'

Nicolae Bulz, Eliza-Cristina Bulz, Dorien DeTombe

The study considers on three research stages: - The experience on the beyond time approach to complexity by the Roman philosopher Boetius' Consolation of Philosophy 523 AD, and Professor Dorien DeTombe's COMPRAM Methodology; - The Knowledge Transfer from the structural nexus within COMPRAM Methodology toward the contemporary (re-)structuring of the 'Science-Religion Dialogue'; - The Knowledge Transfer from the above two research stages to the analytical enhancing the Human & Social Peace and Security Capabilities.

3 - The Refugee Problem in Europe: A Complex Societal Problem

Dorien DeTombe

The refugee problem in Europe is a complex societal problem which can have many unexpected effects. Since 2014 many refugees and asylum seekers, coming from the African and Arabic countries enter Europe. Thousands of people enter Europe without visa or permission. Mostly young men but also families. They enter often by sea in vulnerable boots to Greece and Italy in order to continue over land by foot, train or car to the Northern states of Europe where there is a high standard of living. These refugees and asylum seekers provoke much emotion to politicians, and to European citizens. Although the Schengen contract dismissed the interior borders in Europe, now borders are being closed by several European countries to prevent refugees to enter. Politicians are confronted with thousands of illegal refugees, mostly with a Muslim religion, who want to have houses, social security, money, food, healthcare and a job. Some European citizens are protesting, some welcoming the refugees. Some states (Germany in 2015) welcome the refugees, some states refuse the refugees (Romania). It is time that politicians stop making emotional and ad hock decisions and take the time to analyze the problem seriously as well as the consequences on the long run. How the Field of Methodology of Societal Complexity handles this problem using the Compram methodology dealing with the knowledge, power and emotional aspects of the refugee problem will be described in this article.

4 - The Complexity of Human Communication: Order Out of Chaos

Cor van Dijkum, Niek Lam

We developed a model for feedback loops in the exchange of information between two actors, for example a GP and his patient, or a teacher and a student. Feedback loops were constructed in that model, according to hypotheses about positive and negative feedback between the actors. For the actors themselves we supposed entangled 'inner' feedback loops between the information task and related psycho-social and control processes. Those processes were modeled with non-linear differential equations of logistic growth. In a number of simulation studies, using STELLA and Madonna, we proved at face value that this complex model fit patterns we found in video observations of the interaction between a patient and his GP as it was put in SPSS data (Dijkum et al 2008). To explore the model in a more methodological and fundamental way we reprogrammed the model in Matlab as an extension of a model that was explored earlier by Savi (2007). We did some experiments with the model in which we explored the interaction between the different components of the model, being in states of order and chaos (Dijkum & Lam 2010). The leading questions of the exploration for this paper are: (1) can a system of which the components are all in a state of chaos produce order; (2) how can this be interpreted for our model of human communication?

■ WC-22

Wednesday, 12:30-14:00 - Building CW, ground floor, Room 027

Advances in multilevel optimization

Stream: Combinatorial Optimization
Chair: *Michele Monaci*

1 - Intersection Cuts for Mixed-Integer Bilevel Linear Programs
Ivana Ljubic, Matteo Fischetti, Michele Monaci, Markus Sinnl

Bilevel optimization is commonly used to model situations in which two non-cooperative actors take decision according to different objectives. We consider the case in which both problems are described by linear objective function and constraints, and some variables are required to take integer values. We present new ideas and algorithms to solve to proven optimality a generic Mixed-Integer Bilevel Linear Program (MIBLP), and describe a general-purpose approach that, under mild assumptions, can be applied to a general MIBLP, rather than ad-hoc methods for specific cases. In particular, we introduce intersection cuts based on different feasible-free convex sets to be embedded into a branch-and-cut framework. We present an extensive computational study on different classes of test problems from the literature, in which we demonstrate that our approach outperforms alternative state-of-the-art methods from the literature.

2 - An improved branch-and-cut algorithm for mixed-integer bilevel linear programs
Michele Monaci, Matteo Fischetti, Ivana Ljubic, Markus Sinnl

We present an improved branch-and-cut algorithm for generic Mixed-Integer Bilevel Linear Programs (MIBLPs). Building on our recent work on intersection cuts for bilevel optimization, we introduce new classes of linear inequalities to be embedded in a branch-and-cut framework, as well as a preprocessing procedure. A very extensive computational study is presented, where we evaluate the performance of various solution methods on a common testbed of more than 800 instances from the literature. The results show that our improved general purpose bilevel solver is able to solve to optimality hundreds of instances unsolved even by recent specialized codes.

3 - Decomposition Approaches for Interdiction Problems
Markus Sinnl, Matteo Fischetti, Ivana Ljubic, Michele Monaci

In many real world problems, there is no single decision-maker, but different parties with conflicting goals. This leads to a natural extension of single-level to multi-level optimization problems.

In this work, we focus on interdiction problems, which are a special case of bi-level problems. In interdiction problems, we have a leader and a follower. The follower solves a maximization problem and the goal of the leader is to interdict a subset of the available items of the follower in such a way, that the objective of the follower is minimized. If an item is interdicted, the follower cannot use it. The leader has an interdiction budget constraint and thus cannot interdict all items. Interdiction problems have been mainly studied for polynomially-solvable network problems as follower problem. We consider more general follower problems, with a focus on knapsack problems.

We present a integer programming framework based on decomposition. In the master problem, the interdicted items are chosen, and the follower problem is then solved subject to the interdicted items, to produce optimality cuts. Optimality cuts are produced in generic and problem specific ways. Note that unlike to Benders decomposition, using duality theory usually does not provide valid optimality cuts. We show how to lift the obtained optimality cuts and describe further valid inequalities. A computational study on interdiction instances from literature is done to assess the efficiency of our approach.

4 - Multilevel Approaches for the Robust Critical Node Problem
Andrea Baggio, Andrea Lodi, Andrea Tramontani, Margarida Carvalho

In recent years, a lot of effort has been dedicated to develop strategies to defend networks against possible cascade failures or malicious viral attacks. In particular, many results rely on two different viewpoints. On the one hand, network safety is investigated from a preventive perspective. In this paradigm, for a given network, the goal is to modify its structure, in order to minimize its capacity to propagate failures. On the other hand, blocking models have been proposed for scenarios where the attack has already taken place. In this case, a harmful spreading agent is assumed to propagate through the network with particular dynamics, allowing some time for an effective defensive reaction. In this work we combine these two different perspectives. More precisely, following the framework of the Defender-Attacker-Defender model, as introduced by Brown et al., we consider a model of defense, attack, and operation of an infrastructure system using a three-stage, sequential game. Thus, we assume the defender not only to be able to adopt preventive strategies but also to defend the network after an attack takes place. Supposing the attacker will act in the most clever way, we want to provide a robust approach for network design under these circumstances. Our contribution consists of looking at this problem as a trilevel Mixed-Integer Linear Program and design an algorithm for it based on recent tools developed for bilevel programming.

■ WC-23

Wednesday, 12:30-14:00 - Building CW, ground floor, Room 028

Green Routing

Stream: Green Logistics
Chair: *Jan Fabian Ehmke*

1 - Online electric taxi dispatching and charging as the assignment problem
Michal Maciejewski, Joschka Bischoff

Out of many initiatives regarding e-mobility, electric taxis seem to be one of the niches where electric vehicles (EV) can successfully replace conventional ones despite their limited range: (1) higher concentration of chargers in urban areas, and (2) many relatively short trips interleaved with idle periods. When dispatching a fleet of e-taxis, we need not only to find optimal assignments of vehicles to incoming requests, but also to schedule battery recharging in such a way that the quality of assignments is as close as possible to that of conventional taxis.

To efficiently solve this problem, we propose an online e-taxi dispatching strategy that is based on the linear assignment problem, where at each decision epoch, each available (idle or busy) taxi can be assigned to an open request or idle/"soon idle" charger, or remain unassigned. In order to model all possible assignments, sets of dummy vehicles, request and chargers have to be added to the problem formulation. We analyse and evaluate various functions representing costs of assignments (including non-revenue mileage, passenger wait time, or waiting at chargers).

The assignment-based strategy was tested by means of the MATSim simulator and compared w simple rule-based strategies (e.g. nearest taxi/nearest charger). The impact of battery charging was estimated by comparing the results obtained with the assignment-based strategy for both electric and conventional taxi fleets.

2 - Green Same Day Package Delivery Service with Real-time Demand

Jane Lin, Wei Zhou, Lili Du

In light of the rapid development in the e-commerce sector and the increasingly popular demand for same day delivery, this study evaluates a green same day delivery (green-SDDS) paradigm for its cost performance by comparing the total costs of three delivery paradigms - hub-and-spoke, green-SDDS with a commercial fleet, and green-SDDS by crowdsourcing. The cost performance of green-SDDS is quantified by a cost model that finds an optimal green-SDDS strategy with the minimal sum of travel time cost, fuel cost, and emission cost. An emission-based heuristic algorithm is presented to efficiently solve a large scale green-SDDS problem. Our emission-based algorithm is shown to be computationally efficient. Among the three service paradigms compared, hub-and-spoke proves to be cost-effective for the traditional distribution service provided by commercial carriers but ill suited for providing same day delivery service. Commercial carriers are facing tremendous pressure in the era when same-day delivery service is increasingly expected. Crowdsourcing seems like a promising solution to providing low cost same day delivery service. Lastly, regardless of the delivery paradigm, the cost goes down as the economy of scale increases; and green-SDDS by crowdsourcing would become even more competitive when the demand ratio is very high; however, its fuel consumption and emissions tend to go up due to the additional vehicle detours to accommodate real time demand.

3 - The impact of mixed fleets on minimizing emissions in urban routing

Jan Fabian Ehmke, Ann Campbell, Barrett Thomas

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

4 - The selective travelling salesman problem with emission allocation rules

Christian Bierwirth, Thomas Kirschstein

In addition to cost- and time-orientation, greenhouse gas emission has become a further command variable for planning processes in the transportation industry. But in contrast to transport rates and service levels, the allocation of GHG emission to shipments cannot be negotiated freely between carriers and shippers. As currently under political discussion, emission allocation presumably will soon be regulated by a European law, see proposal EN 16 258. Hence, the incorporation of emission allocation and declaration standards will become a future issue in transportation planning. For planning transport processes from a customer perspective with focus on environmental impact, this means to estimate the total process' total emission and to apply an emission allocation scheme to calculate the emission declarations for each transport request served. In this talk, we formulate a selective travelling salesman problem with emission allocation rules (sTSP-EA). The model seeks to select and route a (sub-)set of transport request such that the emissions allocated to a particular transport order are minimized. Additionally for the selected requests served in the route, a legal emission allocation rule has to be selected. For the sTSP-EA valid inequalities are derived. To tackle large-scaled problem instances a LNS heuristic is proposed. The performance of the valid inequalities and the proposed heuristic is evaluated by computational experiments.

■ WC-24

Wednesday, 12:30-14:00 - Building BM, 1st floor, Room 119

Energy-Aware Scheduling 2

Stream: Project Management and Scheduling
Chair: *Jan Weglarz*
Chair: *Joanna Józefowska*

1 - Minimizing Energy Costs in Data Centers with Variable Energy Prices and the Use of Renewable Energy Sources

Ariel Oleksiak

Data centers consume large amounts of energy. In parallel, power grid operators are struggling with reduction of peak energy demands. To cope with this problem automated demand response (ADR) techniques are developed. As data centers are precisely monitored and controlled they are well suited to the participation in ADR programmes. However, shapes of loads in data centres may be variable and not fitting the energy supply. We propose to apply ADR to data centers by adequate scheduling of workloads and the partial use of renewable energy sources (RES) during peak hours. We assign priorities to jobs to limit impact of ADR actions on required performance. As the energy produced by renewable sources may be very variable we investigate the use of energy storage. We present a model, heuristics that minimise overall energy cost, and experimental results. We discuss profits for data centers that may come from participation in the demand response programme and the use of renewables energy sources.

2 - Improving Energy Efficiency Trough Software Aided Liquid Cooling Management of a Supercomputer

Radosław Januszewski

Moving from traditional air cooled computing systems grants by itself significant benefits in terms of energy consomption reduction. In addition, thanks to more flexible environmental confditions that are acceptable by liquid cooled supercomputer, it is possible to reap additional reduction of consumed power by the means of tight collaboration between computers resource managment system (queue system) and cooling loop managment system. Furthermore, thanks to coupling job scheduling algorithms with cooing infrastructure state and specifications one can reduce both capex and opex of an whole computing infrastructure. We are going to present results gathered from long term usage of a prototype system together with recent results of large scale production system.

3 - Data Center Workload and Resource Management Simulator Extensions for Energy Efficient Modelling and Experiments

Krzysztof Kurowski

The predicted performance of high-end supercomputers will reach the exascale through the advent of core counts in billions, but with limited power constraints. In fact, many applications have to change even now by redesigning algorithms and data structures respectively to take the advantage of recent improvements in energy efficiency of heterogeneous computing, memory, I/O and storage hardware. Unfortunately, future parallel applications will have to deal with different energy costs attached to heterogeneous computing units. Furthermore, applications will have to be aware of deep memory and disk hierarchies taking into account energy costs in moving data off-chip. As various new energy consumption constraints on memory bandwidth, interconnects and computing will play a key role in High Performance Computing (HPC), more sophisticated and dynamic scheduling techniques are needed at both application and system levels. To address this need, new modelling tools have been successfully developed to allow researchers to design and run simulations to discover the overall efficiency and power usage of various supercomputers under different workloads. We will introduce new capabilities in Data Center Workload and Resource Management Simulator (DCworms) for both compute-intensive and data-intensive applications based on new energy estimation plugins for heterogeneous HPC hardware building blocks.

4 - A New Algorithm for Discrete-Continuous Scheduling Problem with Makespan Criterion
Mateusz Gorczyca

A discrete-continuous scheduling problem with makespan criterion and identical parallel processors is considered. Task processing is described by means of a dynamic model, i.e., an instantaneous rate of task processing depends on the amount of an additional resource allocated to the task. An upper bound on the available resource is given. Such a problem appears in computer systems with variable speed processors, where the current rate of program execution depends on the amount of power supplied to the processor. This problem was extensively analyzed in the literature, since methodology for solving it can be used for other problems after minor modification. The exact algorithm is computationally expensive. It consists in complete enumeration of all task sequences on processors (discrete part of solution) and finding an optimal resource allocation for each sequence (continuous part of solution) by solving particular convex optimization problem. Other methods are faster, but quality of the obtained solution is unknown. To fill this gap, a new approach is proposed. The new method does not enumerate all task sequences, but it generates only one sequence based on a solution of the relaxed convex optimization problem instead. For the found sequence, the procedure simply approximates a resource allocation. It is proved that the method quickly gives a solution no more than two to three times worse than the optimal one, where exact ratio depends on the number of processors.

■ WC-25

Wednesday, 12:30-14:00 - Building BM, ground floor, Room 19

Mining Biological Data

Stream: Computational Biology, Bioinformatics and Medicine
Chair: *Marta Kasprzak*

1 - Processing, Integration and Mining of Biological Data
Maciej Miłostan, Jakub Wiedemann

Tremendous amount of biologically related data are produced each year and stored in various databases. During the presentation various kinds of available data will be shown along with possible scenarios of data integration and storage possibilities. The computational challenges will be highlighted. Additionally some remarks on applicability of modern big data technologies (e.g. based on map-reduce) and classical OR techniques will be provided.

2 - Tight Lower Bounds and a Hybrid Heuristic for a Problem of Selecting Features
Amir Salehipour, Pablo Moscato

In this study we develop a very tight lower bound and an upper bound for the (a, b)-k-Feature Set Problem. The problem has applications in data mining. We consider an application of the problem in Bioinformatics, more precisely, in clustering healthy and disease samples. The hybrid algorithm derives a lower bound and an upper bound. Iteratively, it improves the upper bound by introducing valid inequalities into the relaxed formulation of the problem. Further improvement of the upper bound is obtained by a greedy removal heuristic. We ran the algorithm on six real-world biological datasets (ranging from 73 to 17099 features, and 83 to 1219 samples) and compared the outcome with the CPLEX, an advanced mixed-integer programming commercial solver as well as with the only available heuristic for the problem. The computational results are very promising and show that the proposed hybrid algorithm finds proven optimal solutions in 4 out of 6 instances while for the remaining two problems, the worst optimality gap is around 0.8%.

3 - Applications of Coalescence Computations for Large Samples
Andrzej Polanski

Coalescence theory is a basic approach for statistical inference on genetic structures and parameters of evolving populations. The standard model represents the past history of an n-sample of DNA sequences taken at present, where the coalescences are events of DNA replications seen in the reverse time. The emergence of large datasets resulting from contemporary sequencing technologies motivates developing results in the coalescence theory towards the case of large sample sizes. The aim of the presentation is to overview some of the methodologies concerning coalescence computations for large sample sizes and to present some applications. We present approaches for computing expected allele frequencies based on combinatorial identities and on methods of summing hypergeometric series and methods for computing distributions of times in the coalescence tree based on combining transformations of coalescence time scale with integral transforms. We present applications: studies on estimating population size histories from observed allele frequencies, comparisons of deterministic versus Gaussian large scale approximations of times in the coalescence tree and expected allele frequencies and comparisons of accuracies of computing expected allele frequencies with the use of different approaches.

4 - Clustering of Biological Datasets
Marek Blazewicz, Giovanni Felici, Aleksandra Swiercz, Daniele Santoni, Marcin Jaroszewski, Agnieszka Zmienko, Marta Kasprzak

In the last decades the need for robust and efficient algorithms to analyze outcomes of biological experiments is constantly growing. Thanks to the capabilities of the Internet, scientists are able to share the results of their experiments, giving rise to the fact that the information is no longer a bottleneck in the research process. Now the limitation is insufficient number of domain experts analyzing huge amount of information and looking for some recognizable patterns, often across data of different kinds. In our work we have focused on optimizing the process of automatic recognition of knowledge present in biological networks. As the main goal of the analysis we have taken finding the groups of functionally related genes. The information is derived from several datasets, including outcomes of microarray experiments, protein-protein interaction networks and Gene Ontology. However, our algorithm is not limited to these datasets.

■ WC-26

Wednesday, 12:30-14:00 - Building BM, 1st floor, Room 109D

Business Analytics

Stream: Business Analytics and Intelligent Optimization
Chair: *Dries Benoit*
Chair: *Wouter Verbeke*
Chair: *Kristof Coussement*

1 - Multi label learning for churn prediction in online research communities
Steven Debaere, Kristof Coussement, Tom De Ruyck

As firms recognize an online research community (RC) as a valuable resource for integrating external consumer knowledge into innovation processes, they increasingly ignore temporal interaction borders and support long-term collaborations. However, in the pursuit of a long-term RC, moderators face enormous challenges, especially due to member churn. Churn, whether in the form of passive participation and/or passive contributions, produces a shallow community with minimal activity and rotten community with inferior content, respectively. Because either or both churn types can occur, members can be associated with multiple labels simultaneously. Following this consideration, the paradigm of multi label learning naturally emerges, which associates each observation of interest with a set of labels instead of a single label, as known to traditional supervised learning. This study explores state-of-the-art multi-label algorithms (e.g. MLkNN, BPMLL) and compares it to their traditional single label learning counterpart (e.g. kNN, BPNN) to obtain better churn predictions. The results advance literature by indicating the effectiveness of the multi label learning methodology to predict churn at the individual community member level in RCs and provide useful insights for moderators to implement these tactics within their own community.

2 - A Survey on Cost-sensitive Learning for Large Binary Imbalanced Datasets Using Decision Trees and Ensembles

George Petrides, Wouter Verbeke

The task of Predictive Analytics is given a set of recorded observations and their outcomes to predict as accurately as possible the outcome of new observations. Of particular interest are binary classifiers which deal with cases where only two classes of outcomes are considered, such as fraudulent and legitimate credit card transactions, responders and non-responders to a marketing campaign, and defaulting and repaying debtors to name a few. In most of these cases, one of the classes is a small minority and consequently traditional classifiers may classify all of its members as belonging to the majority class without any significant overall accuracy loss.

A remedy to the undesirable situation just described, known as the class-imbalance problem, are classifiers which instead of accuracy take misclassification costs into account and are thus termed cost-sensitive. We illustrate this idea in the credit card fraud detection framework: accepting all fraudulent transactions as legitimate incurs costs equal to the sum of their amounts. Conversely, requiring additional security checks for all transactions (such as contacting the card owner) incurs overhead costs. A cost-sensitive classifier finds a cost-minimising balance between overhead costs and fraud costs.

In this work, we survey existing decision tree and ensemble based cost-sensitive techniques and compare their performance using 3 large imbalanced datasets: on direct marketing, credit scoring and credit-card fraud.

3 - Value-Centric Uplift Modelling for Customer Retention

Floris Devriendt, Darie Moldovan, Thomas Verbraken, Wouter Verbeke

For years traditional response models have been used to identify customers that are most likely to respond to a direct marketing campaign. The goal of these models is to increase the returns of a campaign by targeting the most probable responders. One major drawback of this approach is that these also include those who would have responded positively on their own accord, i.e. without the campaign. A marketing campaign can even cause adverse reactions among the customers such as churn when they realise their contract is about to end because of the retention campaign.

Uplift modelling has recently gained increased attention as its objective function is more focused on maximising the incremental impact of a marketing campaign. Uplift modelling allows to target the customers whom will be most affected by the campaign, and to exclude those that would already respond favourably. However, little research has been done so far on this topic. This paper attempts to fill this gap and presents the state-of-the-art techniques and methodologies in the field of uplifting modelling. The techniques are benchmarked on several private and public datasets, representing both cross/up-selling and retention campaigns. In addition, a new value-centric approach is suggested which takes into account the costs and expected benefits of a marketing campaign in order to target the most beneficial customers.

4 - Customer lifetime value prediction in the banking industry: A comparison of approaches

Sam Verboven, Wouter Verbeke

In times where competition among banks has arguably risen to an all-time high, a better understanding of a bank's customer base, and hence its most valuable customers, is paramount in order to ensure long-term survival. Notably, banks are in possession of an unparalleled richness of data, which has partly remained untapped as of today. Firstly, this work provides a brief overview of Customer Lifetime Value (CLV) applications with special attention for the retail banking industry. Furthermore, using data from a retail bank, this study aims to empirically test and evaluate competing modeling and prediction approaches, using regression and machine learning techniques alike, in both single-product and multi-product settings. Additionally, one of the goals of this study is to introduce new, sector-specific factors to CLV-modeling, which are vital to garner a profound understanding of customer behaviour in this context. Profit margins are, where applicable, customer-specific and determined in consultation with product-experts.

■ WC-27

Wednesday, 12:30-14:00 - Building BM, ground floor, Room 20

OR for Development and Developing Countries 2

Stream: OR for Development and Developing Countries
Chair: *Elise del Rosario*
Chair: *Gerhard-Wilhelm Weber*
Chair: *Sadia Samar Ali*

1 - Programming Air Freight Subject to Conditions - Airstrips and Airplanes to Humanitarian Logistics in a Natural Disaster

Fernando Crespo

The current study proposes a Mixed Integer Linear Programming Model to air travel for humanitarian logistics in natural disasters. This condition to supply end zones via areas has been proposed by the competent national authorities considering the geographical conditions of Chile and availability of runways and landing. The model reflects restrictions regarding aircraft runways and landing, operating hours, fuel plus cargo landing conditions, shift and crew availability. The model was tested under the conditions of real scenario with respect to an far Southern city of Chile. The results allow to reduce air planning developed by a human operator from 24 hours to less than 2 hours including possible check list and manual modifies, considering that the opportunity of moving freight could be on target at 48 hours after the disaster.

Co-authors: Carlos Belmar, Major Chilean Air Force (cabefi@hotmail.com), Carlos Seitz, Major Chilean Air Force (cseitz78@hotmail.com)

■ WC-29

Wednesday, 12:30-14:00 - Building BM, ground floor, Room 7

Assessment and Conference Scheduling

Stream: Timetabling
Chair: *Frits Spieksma*

1 - A matheuristic for short-term planning of assessment centers

Tom Rihm, Norbert Trautmann

The planning situation we deal with has been reported to us by a Swiss service provider which organizes assessment centers for companies. In an assessment center, candidates for job positions perform a series of tasks and are thereby observed and evaluated by assessors (e.g., managers or psychologists). The planning situation consists of scheduling the tasks and assigning some assessors to the tasks subject to specific assessor-assignment constraints such that the total assessment-center duration is minimized. We propose a matheuristic which iteratively repeats three phases. In the first phase, the tasks are scheduled without assigning any assessors to the tasks. In the second phase, the assessors are assigned to the tasks based on this schedule. However, due to the assessor-assignment constraints, the resulting solution is not necessarily feasible. In the third phase, in order to attain feasibility, some tasks are shifted in time. The schedule obtained is then used as initial solution for the subsequent execution of the first phase. In a computational study, we analyze the performance of the matheuristic on four real-world instances and a set of 240 instances derived from real-world data. The results indicate that our matheuristic outperforms state-of-the-art methods, and optimal or near-optimal solutions are obtained for all instances within short computational time.

2 - Conference Room Distribution Planning at EURO 2015 and EURO 2016
Thomas Stidsen, Daniele Vigo, David Pisinger

Scheduling the program of major conferences is a challenging task with many competing objectives.

In this talk we will briefly describe the Mixed Integer Model applied to the room planning problem at EURO 2015 in Glasgow and EURO 2016 in Poznan. To optimize the planning, a Mixed Integer Programming model is formulated, which assigns Areas and streams to timeslots, rooms and buildings.

As opposed to many other conference planning models, the main objective is to respect the hierarchical logic of the EURO conferences. Streams should be scheduled in consecutive time slots, preferably in the same room, and related streams and areas areas should be scheduled close to each other.

To allow flexibility to the stream organizers, sessions in a stream are anonymous, allowing the stream organizer to adjust the detailed planning to satisfy various wishes.

The model attempts to satisfy the seat demand for the sessions, maximize the allocation of related areas in the same buildings and minimize the number of different rooms allocated to a stream.

At the talk, we will describe the model in detail and also describe which simplifications and tricks were necessary in order solve the model.

3 - Conference Scheduling - A Personalized Approach
Bart Vangerven, Annette Ficker, Dries Goossens, Ward Passchyn, Frits Spieksma, Gerhard J. Woeginger

Scientific conferences are an essential part of academic research, as they allow researchers to present their work and receive feedback, as well as learn from attending presentations. Attending a conference requires considerable effort in terms of time and money from a participant. Thus, it falls upon the organizers to develop a schedule that allows the participants to attend the presentations of their interest. We present a combined approach of assigning presentations to rooms and time slots, grouping presentations into sessions, and deciding on an optimal itinerary for each participant. We use a hierarchical optimization approach. Our goal in the first level is, given attendance profiles for participants, to maximize attendance by selecting which presentations are scheduled at the same moment in time, a finer granularity than sessions. In the second level, our goal is to minimize the common practice of session hopping by creating so-called blocks. Session hopping can be seen as an indication of participants being confronted with a schedule which is not optimal given their preferences and is typically experienced as disturbing by presenters and audiences. In the third level, we accommodate presenters' availabilities and minimize the number of availability violations. This method has been successfully applied to construct the schedule of the MAPSP 2015 conference, a medium-sized event with about 120 participants and 88 presentations.

■ WC-30

Wednesday, 12:30-14:00 - Building BM, 1st floor, Room 110

Control Theory in Economics

Stream: Optimal Control Applications
Chair: *Bruno Viscolani*

1 - Manufacturing high-tech products subject to rapid obsolescence
Bruno Viscolani, Luca Grosset

We formulate a production problem in high-tech industry as a free final time optimal control problem. The instance with linear production cost is equivalent to a problem proposed by Pangburn and Sundaresan. The instance with quadratic production cost allows us to find a solution which is closer to what is seen in the real world. In the latter instance the optimal production rate is strictly decreasing in a neighbourhood of the final time.

2 - On a non-standard payoff function in a differential game with random time horizon
Anastasiya Malakhova, Ekaterina Gromova, Dmitry Gromov

We consider cooperative differential games with random time horizon. For such class of games, three optimal control problems related to the optimization of the expected value, the variance, and the second moment of the payoff function are described in detail. These problems are related to the optimization of risk and deviation measures. The results are illustrated by a numerical example. When considering problems with elements of randomness, the control action is typically to minimize the uncertainty resulting from the random nature of the problem. The most obvious measure of the uncertainty is the variance of the payoff function which can be classified as a deviation measure. In this paper we formulate the problem of variance minimization as an optimal control problem and discuss in detail the related aspects. In particular, it is shown that the solution of the corresponding two-point boundary value problem can be rather involved since it involves solving an associated fixed-point problem. Therefore it was proposed to consider the second moment as an alternative characteristic. In contrast to the variance, the second moment constitutes a risk measure and cannot therefore be considered as a substitution for the variance. On the other hand, this measure bears other properties which can be useful when estimating the performance of the process.

3 - Non existence of optimal programs in continuous time
Silvia Faggian, Giuseppe Freni, Giorgio Fabbri

For undiscounted convex models of optimal growth, it is well known that existence of optimal (in the sense of overtaking) solutions cannot be proved in general if the utility function is not strictly concave. However, for concave utility functions, Brock (1970) introduced a weaker optimality criterion know as maximality (or weak overtaking optimality), and proved existence of maximal solutions under the mild assumption of a unique maximal steady state, presenting an example of a maximal steady state that is not optimal. Peleg (1973) pointed out that the same example can be used to prove the non-existence of optimal paths, implying that, without additional assumptions, it is not possible to strength Brock's existence theorem.

To the best of our knowledge there are only three published examples of nonexistence: the Brock-Peleg one, one reported in Khan and Piazza (2010) and one provided in a paper by Fabbri, Faggian and Freni (2015), among which only the last is in continuous time (and with an infinite dimensional state space). We here report a new example showing that in continuous time the minimum dimension is 2, thus confirming a conjecture in Brock and Haurie (1976).

■ WC-31

Wednesday, 12:30-14:00 - Building BM, 1st floor, Room 111

Coordination in Humanitarian Networks

Stream: Humanitarian Operations
Chair: *Ala Pazirandeh*
Chair: *Diego Vega*

1 - Improving forecasting performance in the humanitarian context through time-series clustering
Erwin van der Laan, Jan van Dalen, Kim van West

Next to short-term emergency relief many humanitarian aid organizations provide longer term aid. Quite similar to commercial operations these longer-term projects require regular demand planning. Faced with a product portfolio that runs into the thousands, humanitarian organizations could seriously benefit from statistical forecasting methods to support demand planning, but practice is often hampered by lack of historical data and poor access to IT infrastructure and appropriate forecasting methods. Hence, analyzing standardized consumption data of the Operational Center Amsterdam of Médecins Sans Frontières (MSF-OCA) regarding more than 2000 medical items spanning a time period of three years, we show how forecast accuracy of humanitarian organizations can be improved by identifying patterns through clustering of short time-series of consumption data.

2 - Robust optimization for inventory routing problems in humanitarian relief chains
Mohammadmehdi Hakimifar, Najmesadat Nazemi, S. Ali Torabi

Quick response to a disastrous event is of vital importance. Logistics operations can play a pivotal role in alleviating disaster impact in aected areas. Mathematical modeling can provide insights for managers to make appropriate decisions. Inventory allocation and vehicle routing are two important decisions of logistics operations in disaster management which are closely related to each other. Integrating these two problems is known as the inventory routing problem. In this paper, a multi-period, multi-commodity model is developed to coordinate emergency relief distribution and evacuation operations. Besides, the complex nature and dynamics of the relationships among the different actors in a relief chain imply an important degree of uncertainty in relief chain planning decisions. To deal with this inherent uncertainty of disastrous situations, we applied robust optimization. Finally, the results of deterministic and uncertain approaches are shown via computational experiments to demonstrate the applicability and usefulness of the proposed model and its solution method.

3 - Making sense of humanitarian operations
Diego Vega, Mauricio Rodriguez

In August 4th 1949, a fire caused the dead of 13 firefighters in what is better known as the Mann Gulch disaster. The case depicts the downfall of Sensemaking (Weick 1993), a continuous retrospective process that searches for plausible explanations that give sense of actions. Multiple actions presented throughout the incident led the crew to misunderstand the situation, and loose the sense of the actions taken and recommendations given by the first-in-command, leading to a panic stage and finally to perish. All proportions guarded, the characteristics of the Mann Gulch disaster can resemble to those found in humanitarian operations, as lack of coordination amongst different parties and lack of information sharing lead to problems in the execution of an effective response. The purpose of this paper is to explore the concept of Sensemaking as a coordination mechanism for humanitarian operations. Through a content analysis of official documentation on the 2010 Pakistan floods emergency response, this research shows that the events occurred during the first year of operations correspond to the 7 features of Sensemaking and thus, this concept can be used as a mechanism for ensuring coordination of humanitarian operations. Based on the different cues that illustrate specific events in the disaster response timeline, a model of relationship among enactment, coordination and sensemaking is proposed using Weick's (1979) ESR (ecological change, selection and retrospective) sequence.

■ WC-33

Wednesday, 12:30-14:00 - Building BM, 1st floor, Room 113

Logistics Scheduling

Stream: Scheduling, Sequencing, and Applications
Chair: *Nils Boysen*

1 - The Berth Allocation Problem as a Maximum Flow Problem
Flávia Barbosa, Priscila Rampazzo, Akebo Yamakami

The increasing demand of transport by vessels is one of the biggest problems faced by marine terminals around the world. The heavy flow of vessels and containers in ports has generated a search for a logistics that optimize port operations, making it interesting to analyze questions about the Berth Allocation Problem. It is possible to address different models and formulations for the problem and propose different methods for their treatment or optimization. Modeling it as a Scheduling Problem in Parallel Machines, the BAP may be solved by formulating a Maximum Flow Problem, in which berths are represented by machines and vessels are represented by jobs. Each job has a processing time, a release time and a due time. The proposal is to find a schedule of this jobs, allowing interruption, so that they are processed into the respective time windows and the maximum delay is minimized. A directed graph is constructed with a set of nodes for the jobs and a set of nodes for intervals, in addition to a source node and a destination node. A given task being processed in a certain interval is represented by a flow through the arc connecting the respective nodes. This maximum flow problem is linear, it can be easily solved. However, heuristic methods are needed to treat this solution and fix interruptions in processing.

2 - Optimizing automated sorting in warehouses: The minimum order spread sequencing problem
Stefan Fedtke, Nils Boysen

Order consolidation processes are inevitable whenever picking orders are assembled under a zoning and/or batching policy. In our specific warehouse setting, bins containing partial orders picked under a zoning and batching policy are intermediately stored in an automated storage/retrieval system (ASRS) and, afterwards, released on a conveyor system supplying the consolidation area. Here, a fully-automated sorter merges partial orders belonging to the same customer in packing stations where, finally, the customers' cardboard boxes are packed. For sequencing the release of bins from the ASRS we derive an elementary optimization problem which aims to minimize the spread of orders in the release sequence, so that picking orders are quickly assembled at their packing stations. The resulting problem is formalized, computational complexity is proven and effi cient solution procedures are provided. Additionally, managerial aspects are addressed with the help of a comprehensive simulation study.

3 - Beyond the chaos: How to store items in the warehouse of an online retailer
Felix Weidinger, Nils Boysen

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

4 - Optimal layouts of a parking lot
Konrad Stephan, Nils Boysen

The talk examines optimal arrangements of parking spaces on a parking lot of given size and shape that allow for a direct access to all parking spaces. Considering typical dimensions of cars as well as the widths of traffic lanes we aim at maximizing the number of parking spaces without overlapping each other. After presenting a basic MIP-model and some relevant extensions for practical requirements (easy access to all parking spaces, parking parallel and at right angle to the traffic lanes, modelling different sizes of parking spaces, avoiding dead end streets, considering the space consumption in bends, separating the entrance and the exit, applying a system of one-way streets, regulating the traffic flow) we develop a branch and bound algorithm for the basic problem, which can be easily extended for most of the aforementioned extensions.

■ WC-34

Wednesday, 12:30-14:00 - Building BM, 1st floor, Room 116

Flow Shop Scheduling

Stream: Scheduling Theory and Applications
Chair: *Patrick De Causmaecker*

1 - Comparison of CDS, Genetic Algorithm and GRASP for Permutation Flow Shop Scheduling Problem
Fatma Demircan Keskin, Ural Gokay Cicekli, Murat Kocamaz

The permutation flow shop scheduling problem encountered in many industries, such as steel, food processing and pharmaceutical, has attracted a great deal of attention in the literature. In this problem there are n jobs simultaneously available at time zero and to be processed by m machines. In this environment machines are arranged in series with unlimited storage in between them and all jobs have to follow the same route in the same order throughout the machines. We assume that processing times of all jobs are known with certainty and constant setup times that are included in processing times. In flow shop problems in the case of two machines, optimal job sequence can be obtained by employing Johnson's Rule. To solve three or more machines flow shop scheduling problems that are NP- hard, some heuristic procedures have been developed . One of the most well known heuristics is Campbell, Dudek, and Smith (CDS) heuristic that is an extention of Johnson's algorithm to more than two machines. Many metaheuristics are also used to solve permutation flow shop scheduling problems This paper intends to solve permutation flow shop scheduling problem including 7 machines with 8 jobs and 10 jobs in order to minimize makespan. For each case we'll derive 25 samples. To solve these problems, in addition to CDS heuristic, we'll apply genetic algorithm and GRASP metaheuristics. We will compare their performances with the optimum results obtained by brute -force

2 - Improved Bounded Dynamic Programming Algorithm for Solving the Flow Shop Problem
Ansis Ozolins

In this paper, a flow shop scheduling problem is inspected. Many heuristics have been developed for solving the blocking flow shop problem with a makespan criterion. However, only few exact methods have been proposed. One such approach is the bounded dynamic programming method which is further developed in this paper. Different lower bounds are used proving that the two machine based lower bound with time lags are the best. Computational results show that the presented algorithm works on practice solving moderate benchmark instances in a reasonable time limit. The optimality is proven for several benchmark instances which have been open before.

3 - Assembly Flow Shop Scheduling
Uttarayan Bagchi

We consider flow shops with two or three stages. The first stage can be viewed as a fabrication stage with multiple non-identical processors working in parallel. Both the second and third stages have a single processor. The second stage is conveniently viewed as an assembly stage. The third stage could be a testing stage. Each customer order requires processing in one or more stages. The primary scheduling objective is to minimize makespan across multiple customer orders. For the two-stage problem, we generalize extant results in the literature. The generalizations concern provisions for zero processing times and non-permutation schedules. New results include dominance conditions and heuristic performance guarantees. We then present extensions of the two-stage results to the three-stage problem.

■ WC-35

Wednesday, 12:30-14:00 - Building BM, ground floor, Room 17

Graphs and Networks in Bioinformatics

Stream: Computational Biology, Bioinformatics and Medicine
Chair: *Piotr Formanowicz*

1 - Evaluating Disease Control Interventions in Networks of Injection Drug Users: A Model-Based Analysis
Margaret L. Brandeau

Injection drug users (IDUs) are at high risk of acquiring and spreading various blood-borne infections including human immunodeficiency virus (HIV), hepatitis C virus (HCV), hepatitis B virus (HBV) and a number of sexually transmitted infections. These infections can spread among IDUs via risky sexual and needle-sharing contacts. We develop a bi-layer network model that captures both types of risky contacts. We present methodology for inferring important model parameters, such as those governing network structure and dynamics, from readily available data sources (e.g., epidemiological surveys). Such a model can be used to evaluate the efficacy of various programs that aim to combat drug addiction and contain blood-borne diseases among IDUs. We instantiate the model with data from a network of IDUs collected by a needle and syringe program in Chicago. We use the model to evaluate the potential effects of various targeted and untargeted programs aimed at reducing risk of HIV transmission in the population.

2 - Bilevel Clustering of Biomedical Knowledge Combining Ontology, Euclidean and Graph-based Distances
Marek Ostaszewski, Emmanuel Kieffer, Piotr Gawron, Gregoire Danoy, Pascal Bouvry

Complex biomedical knowledge is often visualized as diagrams called molecular interaction maps that depict mechanisms of human health and disease. With constant growth of biomedical knowledge, these diagrams are updated and expanded. Their size often exceeds thousands of elements and interactions, requiring a high-level overview to facilitate exploration and use. As the content and layout of molecular interaction maps are updated locally and asynchronously, it becomes challenging to keep a contextualized high-level overview of the diagram. We analyzed the contents of Parkinson's disease (PD) map, a large biomedical knowledge repository using clustering approaches and three distance metrics: Euclidean, graph-based and ontology-based. Using these metrics we investigated the possibility of obtaining clusters of varying size that represent concepts of different granularity describing detailed mechanisms of PD map. In order to improve the clustering we combined distance metrics using bi-level approach, where metrics represent objectives in each level. The resulting optimization problem is solved with hybrid genetic algorithm. As a result we obtained a set of clustering schemes describing contents of the PD map. The combination of distance metrics via bi-level approach with GA provided improved results over hierarchical clustering and offered knowledge gain according to expert evaluation. Our results offer improvement in contextualized, visual knowledge exploration.

3 - Algorithms for Construction of Graphs with Predefined Vertex Degrees
Alexander Antkowiak, Piotr Formanowicz

We consider a problem of a construction of graphs with given vertex degrees. In the basic version of this problem the input data consist of a sequence of positive integers and the solution is a simple graph with degrees of vertices equal to the numbers from the sequence. It is a well-known problem in graph theory and some algorithms have been already proposed for solving it. However, we consider some extensions of the basic problem. Among others, we assume that instead of a sequence of positive integers a sequence of sets of such numbers is given. The numbers from each of these sets correspond to possible degrees of a vertex in the graph which should be constructed. Moreover, we also allow parallel edges, i.e., in such a case a multigraph is constructed. Such extensions correspond to a problem of a construction of a structural formula of a chemical compound on the basis of the information about the number of atoms of various elements composing the target molecule and their possible valencies, what is one of our motivations for considering the problems. Such data may come from mass spectrometry experiments when relatively small molecules (e.g. metabolites) are investigated. We propose algorithms solving different variants of the problem, both the ones corresponding to the biochemical problem and also some more general ones.

4 - Methods for Comparison of Petri Nets
Bartłomiej Szawulak, Piotr Formanowicz

Petri nets are a well-known formalism widely used in many areas of computer science to model and analyze concurrent processes. In recent years nets of this type are also used to model complex biological systems. Here models of metabolic networks are the main area of research but regulatory and signaling networks are also considered. Since biological systems have their own specificity methods of analysis of their Petri net based models are still being developed. However, many interesting biological results have been already obtained. One of the important still not well-solved problems in this area is a comparison of Petri net based models of some possibly related biological processes. An effective method for such a comparison would allow to determine common structures occuring in different biological systems what may have a great impact on understanding their functions. Such comparisons are tried to be performed in the case of more classical models of metabolic networks (e.g., the ones expressed as systems of linear equations). However, since Petri nets are especially promising as a tool for modeling and analyzing biological systems it is important to develop an effective method for comparison of such nets. We have modified and extended some ideas of comparison of metabolic networks and proposed algorithms for comparison of Petri nets which can be applied to models of various biological systems expressed as nets of this type.

■ WC-38

Wednesday, 12:30-14:00 - Building BM, 1st floor, Room 109M

Scheduling with Resource Constraints IV

Stream: Scheduling with Resource Constraints
Chair: *Jean-Charles Billaut*

1 - An Algorithm for a Bi-objective Parallel Machine Problem with Eligibility, Release Dates and Delivery Times of the Jobs
Jacques Teghem, Manuel Mateo, Daniel Tuyttens, Daniel Tuyttens

We present a model with three different parallel machines called as high, medium and low level respectively. The set of jobs to be scheduled on these three parallel machines are also distributed among these three levels: one job from a level can be manufactured in a machine of the same or higher level. But a penalty appears when a job is manufactured in a machine different of the higher level. Besides, there are release dates and delivery times associated to each job. The tackled problem is bi-objective with the criteria: minimization of the final date and minimization of the total penalty generated by the jobs. In a first step we revisited possible heuristic to minimize the final date on a single machine. In a second step a heuristic is proposed to approximate the Pareto front of the bi-objective problem. All the algorithms are experimented on various instances.

2 - The New Method of Sub-Neighborhood Generation in Discrete Optimization Problems
Mieczysław Wodecki, Wojciech Bożejko

Nowadays in the best applied metaheuristic algorithms of solving NP-hard discrete optimization problems based on the local search idea, such as tabu search, iterated dynasearch, etc., the most time-consuming is the process of generating and searching of neighborhood for the best move, or a composition of moves (in exponential-size neighborhoods). In the paper we propose the new method of generating of sub-neighborhoods (i.e. a part of a neighborhood with exception of not promising moves) containing all the improving moves of a full neighborhood. For this, we use the so-called patterns, i.e. optimal solutions of subproblems of much smaller size. If in any solution of the considered problem one can show a part identical to a part of a pattern, therefore any change of this part does not generate solution with better value of the criterial function. Thanks to this during neighborhood generation we can omit such solutions because they does not improve criterial function value. We will present the application of patterns on the example of scheduling problems which solutions are represented by permutations (e.g. cyclic flow shop problem with setup times) or binary sequences (e.g. two-machine flexible cyclic scheduling problem). Preliminary computational experiments indicate high efficiency of the proposed approach.

3 - A robust approach for an integrated production scheduling and delivery routing problem
Jean-Charles Billaut, Azeddine Cheref, Christian Artigues

In this paper, we incorporate the delivery plan of a single vehicle into a single machine scheduling problem, representing a single manufacturing facility. We assume that the data are known with uncertainty and the objective is to find a schedule and a delivery plan so that a robustness criteria is minimized, under a scenario-based uncertainty modeling. In contrast with standard robust optimization approaches for scheduling, we do not propose a single complete solution to the problem, that has to be feasible, but we adopt a recoverable robustness framework, that considers first-stage decisions and second-stage recovery options. We propose for the first-stage a set of solutions by using the concept of groups of permutable jobs. At second stage, a greedy and online recovery algorithm exploits the revealed information about the jobs available to be scheduled or to be delivered at decision time. We propose two tabu search algorithms and compare them on a set of randomly generated problem instances.

■ WC-40

Wednesday, 12:30-14:00 - Building WE, 1st floor, Room 108

Power Systems

Stream: Computational Methods in Finance
Chair: *Marcus Hildmann*
Chair: *Dejan Stokic*

1 - An Investigation on Behavior of Power Generation Companies in the Electricity Market under Different Market-Clearing Mechanisms
Danial EsmaeiliAliabadi, Murat Kaya, Guvenc Sahin

As a result of liberalization in the early 1990's, deregulated electricity markets were formed to provide affordable electricity for consumers through promoting competition. Although the new structure is believed to serve this purpose, the results do not always fulfill the expectations. The regulator's market-clearing mechanism is a strategic choice that may affect the level of competition in the market. We conceive of the market-clearing mechanism as composed of two components: pricing rules and dispatch policies. We investigate the strategic behavior of Power Generation Companies (GenCos) under different market-clearing mechanisms by an agent-based simulation model which integrates a game-theoretical understanding of the auction mechanism in the electricity market and GenCos learning mechanism. We present results of our simulation experiments using various cases representing different market settings. In particular, (1) We observe the market in our simulations to converge to a Nash equilibrium of the stage game to or a similar state under most parameter combinations; (2) We find the market to be the most competitive under uniform pricing and random dispatch policy of the ISO.

2 - Optimal investment planning in a competitive electricity market with distributed generation
Fernando Gontijo Bernardes Junior

The changes in the Brazilian legislation and the advent of new technologies propitiated the competition in power generation through the market desverticalization and favoring the creation of smaller power plants. Today distribution companies get energy to supply their customers through auctions, where the energy is commercialized from several generating agents distributed in the mesh. This paper proposes a method that allows distribution companies to evaluate the best strategy to be adopted to optimize energy purchase by agreement of auctions and the desired goals. Payoff matrices are constructed representing the strategy of each bidder. In the proposed method these matrices are evaluated using the Nash equilibrium. To outline the prices of batches of energy is used a neural network that performs the price prediction for the next month using historical series of energy market prices and historical rainfall for the period. It is proposed a prediction quality index using the technical analysis tools bollinger bands and moving averages. The method is applied in three scenarios with the following objectives: maximizing profits, minimizing electrical losses and hydroelectric energy pricing. Using the method, it was possible to determine the expected value of the results achieved for each decision maker, which in turn, considered the use of optimal strategies against your opponents.

3 - Study of the Bidding Strategy of a Wind Power Producer in Electricity Markets
Eduardo Ramos, Pablo Frias, Camila Fernandes

Nowadays, Renewable Energy Sources-Electricity, RES-E, have to deal with a change in the regulation paradigm in which support schemes have been removed. Thus, RES-E have to establish new strategies to maximize their profits trading in short-term markets. In Spain, they are day-ahead (DA), intraday (ID) and balancing markets. In order to reproduce the strategic decisions of a Wind Power Producer (WPP) in a short-term horizon, a stochastic model with different scenarios according to the markets is formulated. Arbitrage between different markets could be done to benefit from the differences in prices and closure times. IDs and balancing markets are volatile and liquid markets, in which the volume of energy traded is lower than in the DA. However, ID and balancing bids are constrained to the 10% of the rated capacity of the WPP, in order not to affect the market clearing price so as not to change the strategy followed by competitors. This assumption is realistic assuming that the RES-E is a marginal player in the markets. We control the risk in the operation of the WPP not allowing to bid more energy than the upper bound established by the expected forecast. Non-anticipativity constraints are introduced to drive the WPP to follow the time structure of the short-term electricity markets. We have done several runs to analyze the bidding strategy results evaluating the influence of the market prices, output forecasts, risk assumed and imbalances on the RES-E decisions.

■ WC-41

Wednesday, 12:30-14:00 - Building WE, 2nd floor, Room 209

OR in Clinical Decision Support 2

Stream: OR in Clinical Decision Support
Chair: *Szymon Wilk*

1 - Performance-based Contracts to Promote Quality Provision in Breast Cancer Treatment
Salar Ghamat, Greg Zaric, Hubert Pun

As health care payment systems are undergoing a swift reform in order to better control the healthcare costs, the growing number of expensive testing technologies and a general trend towards increased use of personalized medicine suggests a need to include them in future funding models. We design performance-based payment contracts to promote use of an optional diagnostic test for newly diagnosed breast cancer patients. We model the interaction between two parties, a healthcare payer and an oncologist, with both adverse selection and moral hazard. First, the payer does not know all the characteristics of the patients. Second, the payer does not know whether the optimal course of action is used by the oncologist. We show that, in the presence of information asymmetry, the payer will never offer a contract in which all patients are tested, even when the test is available for free. In our analysis we obtain the counterintuitive finding that there are cases for which the payer benefits from an increase in reputational concerns by the oncologist. Finally, even in the presence of asymmetric information, the payer can still design a contract such that the provider's profit is not affected by the characteristics of the patients.

2 - Combining Patient Therapy Adherence and Preference Models for Patient-centered Therapy Evaluation
Szymon Wilk, Dympna O'Sullivan, Martin Michalowski, Wojtek Michalowski, Marc Carrier, Hugh O'Sullivan

Patient-centered medicine postulates considering patient preferences when developing management plans. Given that adherence to therapy is considered one of the key factors in patient management, we claim that it should also be considered as part of patient-centered care. In this work we combine patient adherence and preference models for a comprehensive evaluation of therapies comprising a management plan. Both these models include criteria describing therapies and represent preferences as value functions. Adherence models use criteria reflecting high level factors that impact therapy adherence, e.g., treatment complexity. Preference models use patient-specific subjective criteria, e.g., perceived trade-off between the risks of potential adverse events. Preference models are elicited from the patients using the Generalized Regression with Intensities of Preference (GRIP) method. Using population-level data we identify groups of patients sharing similar characteristics. For each group we construct a representative patient profile, called a persona (e.g. a poor-adherence persona), and use GRIP to develop an adherence model for this persona. To select the most appropriate therapy for a given patient, the appropriate adherence model is combined with their preference model to provide a comprehensive perspective of the patient's view about their management plan. We illustrate our approach using a clinical scenario describing patients managed for atrial fibrillation.

3 - Development of Models for Endometrial Cancer Patients Classification by Surgery Type and Surgical Output
Pavel Andreev, Behnam Alimohammadi, Wojtek Michalowski

There are three surgical treatments for endometrial cancers. Although minimally invasive surgeries - standard or robotic laparoscopy are usually preferred, however, due to different postoperative outcomes not every patient is a good candidate for these types of surgery, and the laparotomy is suggested for some patients. In this study, we develop models that help in decision making on the classification of patients by surgery type and according to surgical output. Prediction models constructed from data using machine learning techniques will be evaluated in two phases to; first, to select the best performing model that classifies patients into a surgery type; and second, to choose the best model that classifies surgical patients into a surgical outcome. A retrospective review of all endometrial cancers patients treated by the division of gynecologic oncology at the Ottawa Hospital from January 1, 2012, to March 31, 2015, will be carried out in two phases. In phase 1, preoperative features of patients will be used to construct, evaluate different decision models, and to choose the best model that classifies patients into a type of surgery approach. In phase 2, based on the perioperative features, decision models will be constructed and evaluated. The best model will be identified to classify surgical patients into a surgical outcome.

■ WC-42

Wednesday, 12:30-14:00 - Building WE, 1st floor, Room 120

Predicting Distress

Stream: Operational Research in Financial and Management Accounting
Chair: *Matthias Amen*

1 - Performance Evaluation of Dynamic Methodologies for Predicting Distress under Multiple Criteria
Mohammad Mahdi Mousavi, Jamal Ouenniche

Continuous assessment and monitoring of companies is of crucial importance to a wide range of stakeholders and decision makers. In practice, such assessment and monitoring process is assisted with a variety of tools including models to predict distress. With the huge number of distress prediction models, a considerable number of studies have focused on answering the question that which of these models are superior in performance. However, in practice, the relative performance evaluation of competing prediction models remain an exercise that is mono-criterion in nature. Further, very limited number of criteria and measure have been employed to compare the performance of competing prediction models. In this research, we explore dynamic modelling and prediction frameworks of corporate distress and propose new ones. A multi-criteria framework is also proposed to assess the relative performance of these dynamic models in predicting corporate distress for UK firms listed on the London Stock Exchange (LSE).

2 - Predicting US banks bankruptcy: logit versus Canonical Discriminant analysis
Zeineb Affes, Rania Hentati-Kaffel

Using a large panel of US banks over the period 2008-2013, this paper proposes an early-warning framework to identify bank leading to bankruptcy. We conduct a comparative analysis based on both Canonical Discriminant Analysis and Logit models to examine and to determine the most accurate of these models. Moreover, we analyze and improve suitability of models by comparing different optimal cut-off score (ROC curve vs theoretical value). The main conclusions are: i) Results vary with cut-off value of score ii) the logistic regression using 0.5 as critical cut-off value outperforms DA model with an average of correct classification equal to 96.22%. However, it produces the highest error type 1 rate 42.67% iii) ROC curve validation improves the quality of the model by minimizing the error of misclassification of bankrupt banks: only 4.42% in average and exhibiting 0% in both 2012 and 2013. Also, it emphasizes better prediction of failure of banks because it delivers in mean the highest error type II 8.43 %.

3 - Forecast bankruptcy using a blend of clustering and MARS model - Case of US banks
Rania Hentati-Kaffel, Zeineb Affes

In this paper, we tested three nonparametric methods of classification to compare the performance of Regression Trees (CART), k-means and the newly Multivariate Adaptive Regression Splines (MARS) models for forecasting bankruptcy. Models are implemented on a large universe of US banks over the period spanning 2008 to 2013 and running under a K-Fold Cross validation. We propose also an empirical validation of hybrid system which combines K-means clustering and MARS to perform results in term of bankruptcy prediction. Our findings highlight that i) Either in training or in the testing sample, MARS provide better correct classification than CART model in average (96,06%-94,37% versus 94,76%-94,07%) ii) Hybrid approach enhanced the classification accuracy by 3% for the training sample and 2,55% for the testing one iii) In term of prediction MARS underperform according to the miscl ssification rate notably in 2008 and 2009 iv) according to the Receiver Operating Characteristic Curve we observe a slightly difference in the training and the testing sample results of MARS except for 2013 .

■ WC-43

Wednesday, 12:30-14:00 - Building WE, ground floor, Room 18

DEA and Performance Measurement 5

Stream: DEA and Performance Measurement
Chair: *Katarzyna Bijak*

1 - The extensive network DEA model for economic efficiency assessment of port cities
Wendi Ouyang

With the development of world economy, global commodity business has become the blood for supporting the world economy. As the cornerstone of the global commodity business, international shipping has a pivotal position in the world economy. Port cities are trading hubs and important pivot points in international shipping. Thus, measuring port-cities economic efficiency is not only a valuable reference to local economic development but also a key indicator of national or world economic health. Port-city economic system has a complicated structure. It has several input factors, several output factors, and several function components. Thus, decision makers will face many problems in the evaluation of port-city economic efficiency. SBM-DEA seems like a good method to measure port-city economic efficiency. In 2013, Kaoru Tone and Miki Tsutsui proposed "Dynamic SBM-DEA with network structure", and applied it to the dataset of US electric utilities. It evidences the possibility of using DEA model to measure dynamic complex-structure system. In 2015, Orla A. Murphy, Ping Wang, Sunny X. Wang, and Greg Tkacz used SBM-DEA model to evaluated economic efficiency at Ghana. Now, this research will introduce Dynamic SBM-DEA into port-city economic efficiency evaluation. Meanwhile this research considers a more complex system structure than any research before based on network flow.

2 - Financial Inclusion in Colombia 2014 Study on Efficiency
Gloria Rodriguez Lozano

Financial inclusion is a process of integration of financial services to everyday economic activities of the population, which can contribute significantly to economic growth to the extent that would allow effectively reduce financing costs, insurance and management resources, both people and businesses. In countries developing financial inclusion has four key dimensions: i) access, which refers to the available financial infrastructure to provide financial products and services; ii) use on the number of people available to financial products; iii) financial education, and iv) consumer protection. This research addresses measure efficiency; by using data envelopment analysis (DEA), with the main actors in the Colombian financial means manage their resources to achieve financial inclusion of the Colombian population. DEA is a methodology advanced by double linear programming optimization process generates efficiency and productivity indicators.

3 - The quantitative analysis of the Research Excellence Framework effectiveness in evaluating the British universities' third mission
Katarzyna Bijak, Marta Degl'Innocenti

Since 1986 the performance of the UK Higher Education Institutions (HEIs), including all British universities, has been evaluated using the Research Assessment Exercise (RAE) or the Research Excellence Framework (REF), the latter since 2014. Such evaluations are the foundation of performance-based research funding systems, and this has been the case in the UK. This research focuses on the effectiveness of REF 2014 in evaluating the HEIs' third mission, i.e. the level of knowledge and technology transfer. We build two models that share the same inputs, but have different outputs. The inputs include variables that represent key information on the HEI, such as the numbers of academic staff and students. The output of the first model is based on the REF scores of the HEI as assigned by the REF expert panels. The output of the second model is based on a number of variables that describe the level of engagement of the HEI's staff in the third mission activities. Subsequently, we compare the performance of the two models to analyse how effectively the REF evaluates the level of knowledge and technology transfer. The data used in this research comes from the

Higher Education Information Database for Institutions (HEIDI) and covers the period from 2007 to 2013. We also use the REF 2014 results provided by the Higher Education Funding Council for England (HEFCE).

■ WC-47

Wednesday, 12:30-14:00 - Building WE, 1st floor, Room 115

Endogenous and Distributional Uncertainty

Stream: Robust Optimization
Chair: *Marco Laumanns*

1 - Robust Multi-Product Pricing Optimization with Experiments
Cong Cheng

We study the multi-product pricing problem using pricing experiments. In particular, we develop a data driven approach to this problem using the theory of marginal distribution. We show that the pricing problem is convex for a large class of discrete choice models, including the classical logit and nested logit model. In fact, our model remains convex as long as the marginal distribution is log-concave. More importantly, by fitting data to optimise the selection of choice model, we develop an LP based approach to the non-parametric version of the pricing problem. Preliminary tests using a set of automobile data show that this approach provides near optimal solution, even with random coefficient logit model.

2 - Integration of Robust Optimization and Monte Carlo Simulation for Maximum Capability Evaluation of Gas Transmission Network under Disruptions
Trung Hieu Tran, Simon French, Rhys Ashman, Edward Kent, Steven Hopkins

In the recent years, demand for flexible use of the gas transmission network has increased requiring reliable and available assets (e.g., compressors) to satisfy customers' requirements. In the worst case, all assets in the network are required to be operational with maximum performance to meet the customers' requirements. A compressor station consists of a number of compressor units that can operate in parallel, series, or both to obtain its maximum capacity. If some of compressor units fail to operate due to the impact of any unexpected disruption, network capability may not be able to satisfy the customers' demand. In this paper, we consider random disruptions the probability of which may be known or unknown. Monte Carlo simulation is used to handle the disruption when the probability of operational failure is known, while robust optimization is applied for other disruption. A mathematical model integrating Monte Carlo simulation and robust optimization to evaluate the impact of the disruptions to network capability is developed. The model can be deployed for overall network as well as individual zones. For the evaluation of maximum capability on individual zones, pressure loss equations along pipelines are considered. A linearization technique is constructed to deal with the non-linear equations. Computational experiments were carried out on a case study in National Grid to demonstrate the performance of the integrated model.

3 - Scenario Aggregation using Binary Decision Diagrams for Stochastic Programs with Endogenous Uncertainty
Utz-Uwe Haus, Marco Laumanns, Carla Michini

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

4 - Inventory Decisions with Dependent Demand Using Simulation
Sang-Won Kim

When a firm sells similar items at different prices, the demand for any given class depends on the demand for the other classes. Customers will substitute for a product that is out of stock by buying a similar product or the same product at a later point in time, which is known as inventory-driven substitution. Substitution has a considerable profit implication. We develop an Excel-based simulation model for this situaltion and heuristic model with efficient algorithms to reduce computation time.

■ WC-48

Wednesday, 12:30-14:00 - Building WE, 1st floor, Room 116

Environmental Management

Stream: Energy/Environment and Climate
Chair: *Maurizio Tomasella*

1 - The organic fraction of untreated waste streams and his environmental potential
Florian Gehring, Eva Knüpffer, Christian Peter Brandstetter, Stefan Albrecht

Large proportions of the organic part of the European municipal solid waste are still not treated in an adequate manner. Commonly the organic fraction is landfilled, mechanical biological treated or incinerated. These technology approaches allow only an energetic or a low economic resource recycling. In case of resource depletion a generation of valuable materials is desirable. To tackle this challenge an innovative technology approach was developed within the EU FP7 funded project Waste2Go. The approach makes the organic fraction accessible for especially developed enzymes and converts the organics in basic chemicals which could be used as a feedstock in the chemical industry. On the one hand it is desirable to replace fossil based basic chemicals. But on the other hand it has to be investigated if the technology would have an environmental benefit compared to the actual treatment and production routes at all. To analyse this a life cycle assessment (LCA) was implemented in accordance to ISO 14040/44 standards. During the project two waste streams (dry mixed recycling and paper/cardboard) were defined and investigated. The scope of the LCA covers specific settings to the approach and possible output materials. Furthermore the state of the art technologies (landfill, incineration) and the fossil based production of the replaceable feedstock materials were considered in parallel to the development of Waste2Go. The final results show important environmental drivers.

2 - A Study on the Structural Relation of Green Purchase Behavior
Jusik Park, Nguyen Huyen

Vietnam seems to be among the countries most directly threatened by the consequences of climate change. This makes it imperative to change habits and practices with regard to fishery, farming and environmental protection. Using green products is also required to protect environment. Globally, using green products is indeed becoming a trend and has been in the developed world. Nowadays, in the developing countries, environmental product use is indeed up, but not nearly as high as awareness is. This research is to understand green consumer behavior in Vietnam and suggests a structural model of green purchase behavior, focusing on the moderating effect of affordability. Based on the literature review, a research model of behavior of buying green products was proposed and tested empirically using the field study. To examine the proposed research model, the reliability and validity verifications on measurement items were carried out and then the structural equation model analysis was applied to test the model.

3 - Product Greening under Government Regulations
Debabrata Ghosh

In this paper we explore a firm's pricing and greening decisions under government regulations and increasing costs. We also analyze their impact on consumers. Through this problem we address the emerging challenges that firms face in the presence of regulations. Our key contribution lies in modeling government regulations and decision making under demand expansion effects while analyzing the resulting decisions of product greening and pricing. This research lays the platform for future work in the area of green product design, pricing and study of impact of environmental regulations on firms.

4 - The ReCCEL toolbox: a response to carbon reduction challenges in the UK construction industry
Maurizio Tomasella, Roberto Rossi, Belen Martin-Barragan

The ReCCEL project analyses the feasibility of low-carbon delivery on major infrastructure projects, particularly through more widespread adoption of telematics and telemetry technologies and services. The project is led by Costain, one of UK's leaders in construction engineering solutions. The project team also features the University of Edinburgh and Cenex, the UK's Centre of Excellence for Low Carbon and Fuel Cell Technologies. By focusing on a portfolio of Costain's major infrastructure projects currently ongoing in the UK, the ReCCEL team mapped current construction processes and elicited existing barriers to the fully integrated, low-carbon construction supply chain. The aim of this talk is to illustrate open challenges that have been identified in the course of the project. We will be focusing on the suite of Operational Research decision support tools that the project team are currently developing to leverage live information feeds from telematics/telemetry systems, available on construction plant and vehicle fleets normally deployed in construction sites and quarries, into enhanced decision making. Particular insight will be given to the stochastic aspects of our optimisation problems, models and solution algorithms. Above all, we will quantify their significant value in the delivery of business outcomes for the integrated construction supply chain in real world major construction and infrastructure projects.

■ WC-54

Wednesday, 12:30-14:00 - Building PA, Room B

Efficient algorithms for mathematical imaging applications

Stream: Convex Optimization
Chair: *Kristian Bredies*

1 - An inexact variable metric line-search algorithm for convex and non-convex optimization
Ignace Loris

A novel iterative algorithm for the solution of convex or non-convex optimization problems is presented. We assume that the objective function is the sum of a differentiable (possibly non-convex) function plus a convex (possibly non-differentiable) function. The algorithm is based on inexact knowledge of the proximal operator of the non-smooth part and uses a variable metric in combination with an Armijo line-search rule. In general we prove that all limit points of the iterates are stationary, while in the special case of a convex objective function we prove the convergence of the whole sequence to a minimizer, under the assumption that a minimizer exists. Moreover, verifiable criteria for the inexact computation of the proximal operator are given in some cases of practical interest. Finally, the algorithms are applied to various image reconstruction tasks.

This presentation is based on joint work with S. Bonettini, F. Porta, M. Prato and S. Rebegoldi.

2 - Convergence and stability of Inertial Forward-Backward
Charles Dossal

The Forward Backward algorithm (FB) has been designed to minimize the sum F of to convex lsc proper functions f an g such that f is differentiable and such that the proximal operator associated to g can be computed. FB consists in applying alternatively a gradient descent on f and a proximal descent on g. An acceleration of this algorithm named FISTA has been proposed by Beck and Teboulle in 2009. FISTA introduces an inertial term to build the minimizing sequence (x_n). FISTA is faster than FB but is less stable to perturbations, when the gradient of f or the proximal operator of g are approximately computed. In this talk I will present recent results on the convergence and the stability of a class of inertial FB including FISTA publish in JOTA with JF Aujol. I will give conditions ensuring the convergence of such algorithms and show that when there are perturbations, some inertial FB different from FISTA may be better than both FB and FISTA. I will present theoretical results and numerical experiments.

3 - A globalized semismooth Newton method for nonsmooth problems
Andre Milzarek, Michael Ulbrich

We propose a globalized semismooth Newton framework for solving optimization problems involving smooth nonconvex and nonsmooth convex terms in the objective function. The class of problems we consider comprises a large variety of applications such as l1-regularized or group sparse problems and minimization problems arising in machine learning or image processing. A prox-type fixed point equation representing the optimality or stationarity conditions forms the basis of the approach. The algorithmic framework we investigate uses semismooth Newton steps for the fixed point equation to accelerate an underlying globally convergent descent method. A multidimensional filter mechanism is utilized to control the acceptance of the Newton steps. We present both global and local convergence results and provide numerical experiments illustrating the efficiency of the proposed method.

■ WC-56

Wednesday, 12:30-14:00 - Building CW, 1st floor, Room 122

O.R. for the Public Good: A Workshop on Volunteering and O.R.

Stream: Workshops and roundtable
Chair: *Ruth Kaufman*
Chair: *Howard Turner*

1 - O.R. for the Public Good: A Workshop on Volunteering and O.R.
Ruth Kaufman, Howard Turner

For the last 3-4 years, the UK's OR Society has run a 'Pro Bono OR' scheme, identifying potential OR projects in charities and other 'third sector' organisations, and putting the organisations in touch with suitably skilled volunteers to undertake the project. The aim of this workshop is to share experience of Pro Bono, to help spread and improve outcomes, both at an individual level and a community/national level. We will describe the Pro Bono O.R. scheme, and discuss: • at the individual level, volunteer benefits, barriers to volunteering, what is different about doing Pro Bono OR for a charity, and practical ways of being more effective; and • at the community level, community benefits, practical challenges, potential cultural differences between communities and how they may affect what is done. This workshop is for you if you are: an existing or past volunteer, in the UK or elsewhere, willing to share/exchange experiences; a practitioner/academic who might be interested personally in undertaking voluntary work; or a practitioner/academic who is interested in starting or developing a pro bono scheme locally.

Wednesday, 14:30-15:30

■ WD-01

Wednesday, 14:30-15:30 - Building CW, AULA MAGNA

Plenary Rolf Möhring

Stream: Plenary, Keynote and Tutorial Sessions
Chair: *Jan Weglarz*

1 - Optimizing the Kiel Canal - Integrating Dynamic Network Flows and Scheduling
Rolf Möhring

We introduce, discuss, and solve a hard practical optimization problem that deals with routing bidirectional traffic on the Kiel Canal, which is the world's busiest artificial waterway with more passages than the Panama and Suez Canal together. The problem arises from scarce resources (locations) at which large ships can only pass each other in opposing directions.

This is a prototype problem for traffic management and routing in logistic systems. One wants to utilize the available street or logistic network in such a way that the network "load" is minimized or the "throughput" is maximized. The aspects of "time" and "congestion" play a crucial role in these problems and require new techniques that need to integrate dynamic network flows and scheduling.

The lecture will illustrate recent developments in this direction on the example of the Kiel Canal problem, which which was a project with the German Federal Waterways and Shipping Administration. Here certain ships must wait in sidings to let opposing traffic pass. This requires to decisions on who should wait for whom (scheduling), in which siding to wait (packing) and when and how far to steer a ship between sidings (routing), and all this for online arriving ships at both sides of the canal.

The combination of routing and scheduling (without the packing) leads to a new class of scheduling problems dealing with scheduling bidirected traffic on a path, and we will address recent complexity and approximation results for this class.

For the full problem, we need a feasible assignment of parking slots within sidings over time that is consistent with the scheduling decisions between the sidings and the routing. To that end, we used a routing algorithm that we had developed earlier for routing automated guided vehicles in a container terminals (cooperation with HHLA). We will explain details of this algorithm and show how to combine it with a rolling horizon technique for the scheduling and packing decisions in the canal. This provides a unified view of routing and scheduling that blends simultaneous (global) and sequential (local) solution approaches to allocate scarce network resources to a stream of online arriving vehicles in a collision-free manner.

Computational experiments on real traffic data with results obtained by human expert planners show that our combinatorial algorithm improves upon manual planning by 25%. It was subsequently used to identify bottlenecks in the canal and to make suggestions for enlarging the capacity of critical sections of the canal to make it suitable for future traffic demands.

Wednesday, 16:00-17:45

■ WE-01

Wednesday, 16:00-17:45 - Building CW, AULA MAGNA

Closing Session

Stream: Opening and Closing sessions
Chair: *Daniele Vigo*

1 - Closing Session
Daniele Vigo, Joanna Józefowska

Closing session of the EURO 2016 Conference.

STREAMS

Advances in Revenue Management

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Track(s): 39

Algorithms and Computational Optimization

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Track(s): 2

Analytic Hierarchy Process / Analytic Network Process

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Track(s): 10

Behavioural Operational Research

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Track(s): 25

Biomass-Based Supply Chains

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Track(s): 39

Business Analytics and Intelligent Optimization

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Track(s): 26

Case Studies in OR

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Track(s): 27

Combinatorial Optimization

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Track(s): 12 22

Computational Biology, Bioinformatics and Medicine

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Track(s): 25 35

Computational Methods in Finance

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Track(s): 40

Computational Statistics

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Track(s): 33

Computing

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Track(s): 18

Convex Optimization

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Track(s): 54

Convex, Semi-Infinite and Semidefinite Optimization

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Track(s): 52

Customer Based Services and Knowledge in Organizations

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Track(s): 8

Cutting and Packing

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Track(s): 20

Data Science in Optimisation

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Track(s): 27

DEA and Performance Measurement

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Track(s): 43

Decision Making Modeling and Risk Assessment in the Financial Sector

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Track(s): 48

Decision Support Systems

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Track(s): 39

Defence and Security

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Track(s): 24

Demand and Supply Management in Retail and Consumer Goods

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Track(s): 17

Discrete and Global Optimization

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Track(s): 11

Discrete Optimization under Uncertainty

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Track(s): 16

Dynamic Models in Game Theory

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Track(s): 42

Dynamic Programming

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Track(s): 27

Dynamical Models in Sustainable Development

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Track(s): 26

Dynamical Systems and Mathematical Modelling in OR

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Track(s): 27

Emerging Applications in Portfolio Selection and Management Science

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Track(s): 9

Energy/Environment and Climate

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Track(s): 48

Engineering Optimization

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Track(s): 15

Environmental Sustainability in Supply Chains

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EURO Awards and Journals

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Track(s): 7 10

Evolutionary Multiobjective Optimization

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Financial and Commodities Modeling

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Track(s): 39

Financial Engineering and Optimization

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Financial Mathematics and OR

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Track(s): 41

Fuzzy Optimization - Systems, Networks and Applications

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Track(s): 11

Game Theory and Operations Management

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Track(s): 40

Game Theory, Solutions and Structures

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Track(s): 42

Global Optimization

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Track(s): 52

Graph Searching

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Track(s): 19

Graphs and Networks

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Track(s): 23

Green Logistics

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Track(s): 23

Health Care Emergency Management

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Health Care Management

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Track(s): 38

Healthcare Logistics

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Track(s): 16

How OR found its way into Universities

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Track(s): 20

Humanitarian Operations

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Track(s): 31

IBM Research Applications

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Track(s): 8

Information and Intelligent Systems

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Track(s): 36

Initiatives for OR Education

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Track(s): 53

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Track(s): 20

Long Term Financial Decisions

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Track(s): 48

Long Term Planning in Energy, Environment and Climate

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Track(s): 42

Lot Sizing, Lot Scheduling and Production Planning

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Track(s): 19

Maritime Transportation

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Track(s): 14

Mathematical Models in Macro- and Microeconomics

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Track(s): 40

Mathematical Programming

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Track(s): 51

Mathematical Programming Software

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Track(s): 9

Memorial Session

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Track(s): 7

Mentoring Sessions

Track(s): 58

Metaheuristics

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Track(s): 53

Methodology of Societal Complexity

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Track(s): 21

Mixed-Integer Linear and Nonlinear Programming

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Track(s): 14

Multiobjective Optimization

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Track(s): 5

Multiple Criteria Decision Aiding

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Track(s): 6 8

Multiple Criteria Decision Analysis

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Track(s): 3

Nonsmooth Optimization

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Track(s): 51

Numerical and Simulation Methods in Finance

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Track(s): 47

Opening and Closing sessions

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Track(s): 1

Operational Research for Health and Social Care

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Track(s): 30

Operational Research in Financial and Management Accounting

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Track(s): 42

Operations Research and Combinatorial Optimization in Web Engineering

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Track(s): 4

Operations/Marketing Interface

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Track(s): 3

Optimal Control Applications

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Track(s): 30

Optimization for Sustainable Development

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Track(s): 38

Optimization in Renewable Energy Systems

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Track(s): 43

Optimization of Gas Networks

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Track(s): 15

OR and Ethics

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Track(s): 10

OR and Real Implementation

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Track(s): 8

OR and the Arts

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Track(s): 9

OR Applications in Industry

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Track(s): 9

OR for Development and Developing Countries

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Track(s): 27

OR for Sustainable Development

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OR in Agriculture, Forestry and Fisheries

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Track(s): 41

OR in Clinical Decision Support

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OR in Quality Management

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Track(s): 4

OR in Sports

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Track(s): 31

OR Methods in Consumer Behavior Research

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Track(s): 9

Plenary, Keynote and Tutorial Sessions

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Preference Learning

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Track(s): 3

Probabilistic Models

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Track(s): 11

Production and Operations Management

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Track(s): 18

Project Management and Scheduling

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Track(s): 24

Public Transportation

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Recent Advances in Dynamics of Variational Inequalities and Equilibrum Problems

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Recent Developments on Optimization and Some Results on Game Theory

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Risk, Uncertainty, and Decision

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Robust Optimization

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Rough Sets in Decision

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Track(s): 2

Scheduling in Healthcare

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Track(s): 36

Scheduling Theory and Applications

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Track(s): 34

Scheduling with Resource Constraints

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Track(s): 38

Scheduling, Sequencing, and Applications

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Track(s): 33

Simulation in Management Accounting and Management Control

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Track(s): 48

Soft OR and Problem Structuring Methods

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Track(s): 29

Spatial Risk Analysis

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Track(s): 7

Stochastic Modeling and Simulation in Engineering, Management and Science

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Track(s): 47

Stochastic Models in Renewably Generated Electricity

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Supply Chain Management

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Track(s): 15

Supply Chain Scheduling and Logistics

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Track(s): 34

Sustainable Supply Chains

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System Dynamics Modeling and Simulation

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Teaching OR/MS

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Track(s): 8

Telecommunications and Network Optimization

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Timetabling

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Track(s): 29

Transportation

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Transportation and Logistics

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Track(s): 19

Vector and Set-Valued Optimization

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Track(s): 52

Vehicle Routing and Logistics Optimization

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