



23rd International Conference
on Multiple Criteria
Decision Making

2nd–7th August 2015 · Hamburg · Germany



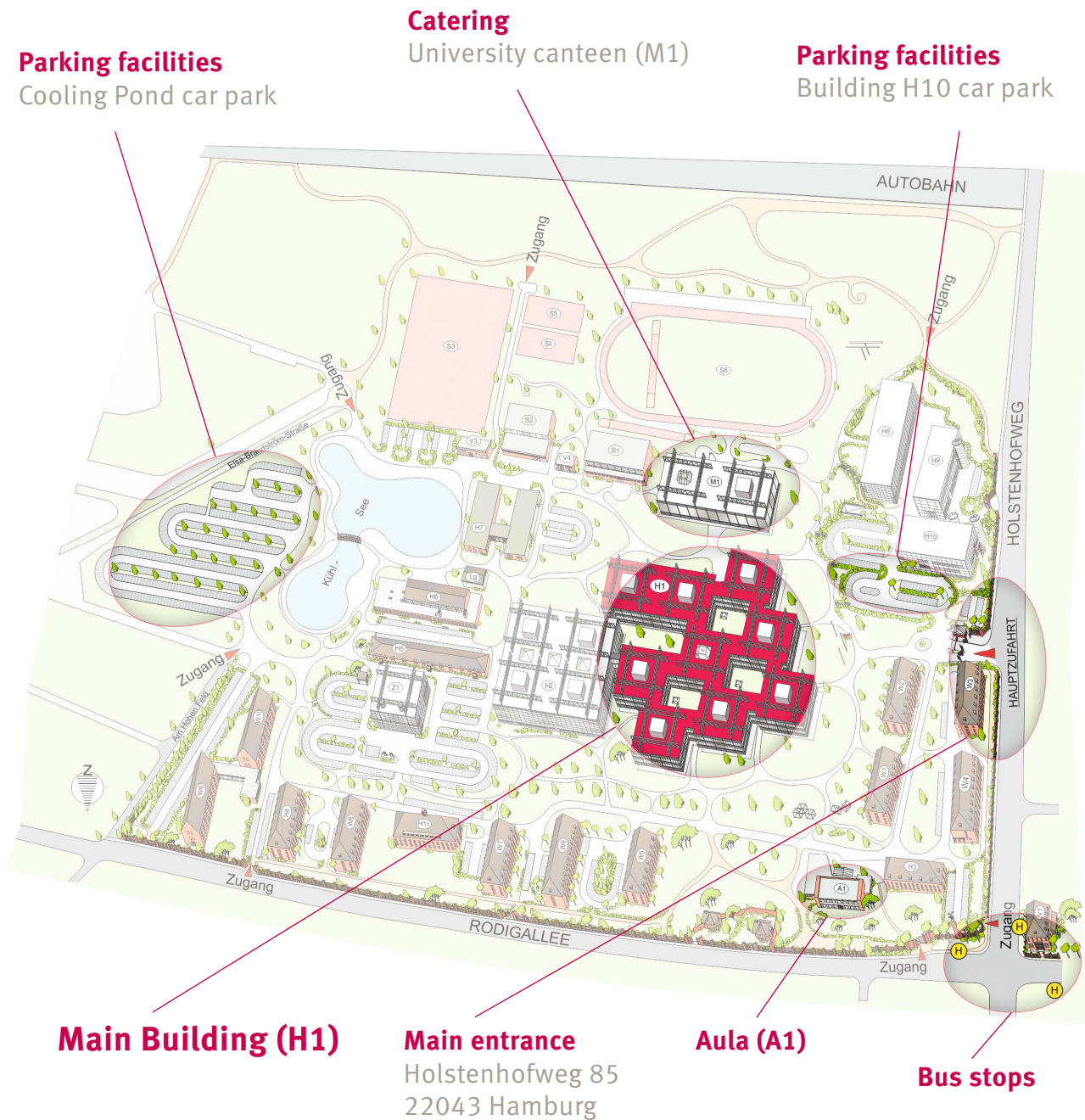
MCDM 2015 – BRIDGING DISCIPLINES

BOOK OF ABSTRACTS



Helmut Schmidt University/University of the Federal Armed Forces Hamburg
Holstenhofweg 85 · 22043 Hamburg · Germany

Campus Plan

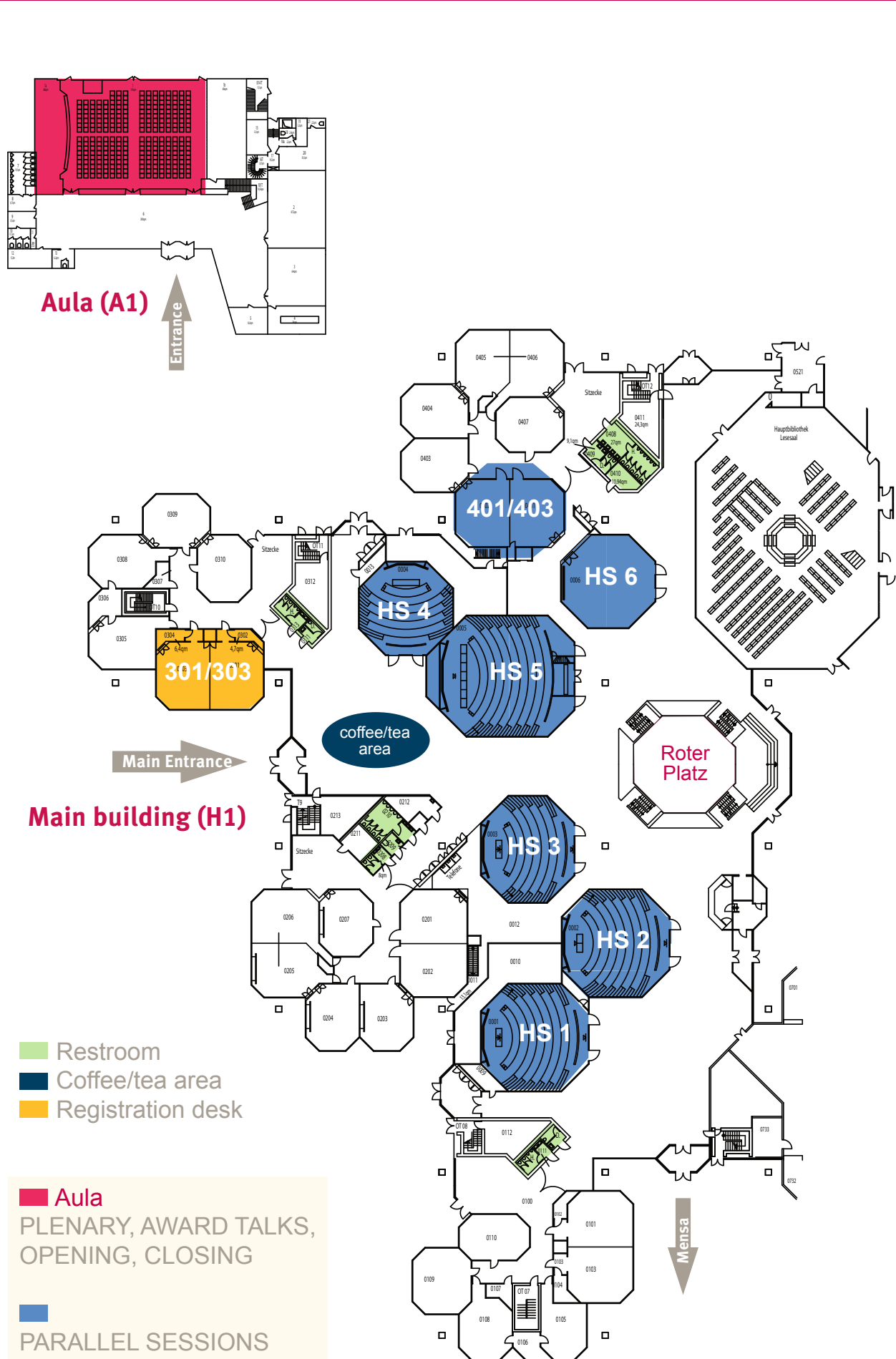


Sponsors



SCIENTIFIC PROGRAM

TIME	SUNDAY AUGUST 2 ND	MONDAY AUGUST 3 RD	TUESDAY AUGUST 4 TH	WEDNESDAY AUGUST 5 TH	THURSDAY AUGUST 6 TH	FRIDAY AUGUST 7 TH
08:00–08:10		Registration				
08:10–08:20						
08:20–08:30						
08:30–08:40			Registration	Registration	Registration	Registration
08:40–08:50						
08:50–09:00						
09:00–09:10		MO-1	TU-1	WE-1	TH-1	
09:10–09:20						
09:20–09:30						
09:30–09:40						
09:40–09:50						
09:50–10:00						
10:00–10:10		MO-2	Group photo		Coffee/tea	FR-1
10:10–10:20			Coffee/tea			
10:20–10:30						
10:30–10:40						
10:40–10:50						
10:50–11:00				Coffee/tea		
11:00–11:10		Coffee/tea	TU-2		TH-2	Coffee/tea
11:10–11:20						
11:20–11:30						
11:30–11:40						
11:40–11:50						
11:50–12:00				WE-2		
12:00–12:10		MO-3				FR-2
12:10–12:20						
12:20–12:30						
12:30–12:40						
12:40–12:50						
12:50–13:00			Lunch		Lunch	
13:00–13:10				Lunch		
13:10–13:20						
13:20–13:30						
13:30–13:40						
13:40–13:50						
13:50–14:00		Lunch				Lunch
14:00–14:10			TU-3		TH-3	
14:10–14:20						
14:20–14:30						
14:30–14:40						
14:40–14:50						
14:50–15:00				WE-3		FR-3
15:00–15:10		MO-4				
15:10–15:20						
15:20–15:30						
15:30–15:40						
15:40–15:50						
15:50–16:00						
16:00–16:10					TH-4	
16:10–16:20						
16:20–16:30						
16:30–16:40						
16:40–16:50						
16:50–17:00					Business meeting	
17:00–17:10		MO-5		Outing		
17:10–17:20						
17:20–17:30						
17:30–17:40						
17:40–17:50						
17:50–18:00						
18:00–18:10	Get-together				Banquet	
18:10–18:20						
Late Evening						



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1 Welcome Messages

University President Prof. Dr. rer. nat. Wilfried Seidel



Dear participants,

I am delighted to welcome you to the conference on Multiple Criteria Decision Making and to your conference site - the Helmut Schmidt University / University of the Armed Forces Hamburg. Our University is an institution beyond compare. We offer a broad set of study programs for the future leaders of the German Armed Forces. About 100 professors, plus 300 research assistants provide 2,200 students with an excellent university education in an accelerated timeline. This takes place on a notable compact University campus, which is clearly an asset for realizing innovative interdisciplinary research.

For many years now, the field of Logistics and Operations Research is one of the outstanding research areas of our University. To welcome such a renowned international conference is an honor we are especially proud of.

I warmly invite you to discover all the inspiring places this campus has to offer. Due to its harbor Hamburg has a deeply rooted tradition of welcoming people from all parts of the world, of being a place where ideas are interchanged, horizons get broadened and new friends are made. The University will put all its efforts into making this conference your success.

Professor Dr. rer. nat. Wilfried Seidel
President of the Helmut-Schmidt-University / University of
the Armed Forces Hamburg



**International Society on
Multiple Criteria Decision Making**

Welcome to MCDM2015!

Dear participants of the MCDM2015 conference,

I am very happy to wish you warmly welcome to the main scientific event of the International Society on Multiple Criteria Decision Making (MCDM, <http://www.mcdmsociety.org>). Our conference series has a long history and this conference in Hamburg is the 23rd International Conference on Multiple Criteria Decision Making. The conferences are organized every two years and the location of the next conference will be decided and announced during this conference.

I hope that you will find this conference fruitful and will also attend future conferences of our Society and encourage your colleagues and students to attend as well. The conferences in this series are not too big in size so that it is possible to find colleagues to discuss but still you get a versatile view of the state of the art in multiple criteria decision making, different approaches, theories and applications. Here you have an excellent opportunity to meet old and make new friends, exchange ideas, receive feedback and get inspired.

The purposes of the International Society on MCDM are to develop, test, evaluate and apply methodologies for solving MCDM problems, to foster interaction and research in the scientific field of MCDM, and to cooperate with other organizations in this. This conference is an excellent forum to advance on all these objectives.

I invite all members of the society to attend the business meeting of the Society. In this meeting, the final decision of updating the bylaws of the Society will be made and information about future events and elections will be given.

If you are not yet a member, you can join by filling the form at <http://mcdmsociety.org/members/?page=signup>. Please note that our society does not have any membership fees.

Have a memorable conference and enjoy both the scientific and social program!

Kaisa Miettinen

President of the International Society on Multiple Criteria Decision Making
and Program Chair of MCDM2015

Professor and Vice-rector of the University of Jyväskylä, Finland

Email: president@mcdmsociety.org

Martin Josef Geiger – General Chair of the MCDM 2015



Moin!

With this typical greeting from Hamburg, I am welcoming you to the *23rd International Conference on Multiple Criteria Decision Making (MCDM 2015)*. We at the *Helmut-Schmidt-University/ University of the Federal Armed Forces Hamburg (HSU)* are proud to host such an important scientific event, and we can report that the MCDM 2015 will welcome more participants than any other preceding MCDM congress: 361 colleagues hailing from 49 countries demonstrate that our field is growing, and we are happily contributing to this development. The topic of this years conference has been chosen as “bridging disciplines”, and the conference will once again, like many preceding before, demonstrate that MCDM is indeed an inter-disciplinarian field. Besides, the city of Hamburg will allow you to cross more bridges than any other city in the world.

The scientific program is particularly rich. It will feature 306 talks in a little bit above 6 parallel sessions, 22 invited streams/ sessions, three plenary talks, and, of course, the three award talks of the International Society on Multiple Criteria Decision Making. It is also excellent to see that the *International MCDM Doctoral Dissertation Award* will be handed over once again, and we welcome all finalists of this prestigious competition. As a matter of fact, the conference attracted a significant number of PhD-students and young researchers, another indication that MCDM is looking into a bright future indeed.

We also did work hard on an attractive social program. Following the traditions of the *International Society on Multiple Criteria Decision Making*, an excursion will take place on Wednesday, taking you around the beautiful city of Hamburg, and refreshing you with a dinner close to the harbour (“Landungsbrücken”). The conference banquet will then feature a maritime experience, combining a cruise on the river Elbe with typical local food and drinks.

Organizing such a conference would not have been possible without the help of many people and organizations. I would like to express my thanks to our sponsors, the *International Society on MCDM*, but also to my local university: it was the *HSU Hamburg* who granted us free access to all facilities, and contributed significantly to the acquisition of the students helping during this event. It is satisfying indeed to see that we have a scientific institution with professional staff devoted to research and teaching.

I would also express my sincere thanks to two young researchers who worked

tremendously and untiring during the organization: Sandra Huber and Sandra Zajac. You certainly have heard their names before, and I am sure you will meet them in the near future at other meetings where they will continue making an impact in science.

Martin Josef Geiger
General Chair of the MCDM 2015

2 Venue

The conference will take place at the Faculty of Business Administration, especially Logistics Management at the Helmut-Schmidt-University, University of the Federal Armed Forces. It is located close to the center and the recommended hotels.

Address: Helmut-Schmidt-University, Holstenhofweg 85, 22043 Hamburg

2.1 Provided Public Transportation Ticket

For using public transportation you do not need to buy a ticket during the event. The conference organizers provide for regular / student registrations a ticket for unlimited travel:

- valid from **Saturday, 1st** until **Saturday, 8th, 06:00 a.m.**
- Fare zone: **A / B**. The city center and the conference venue are definitely included in this fare zone. For further travel information download the HVV app on your mobile phone or see http://www.hvv.de/pdf/tarifplaene/hvv_tarifplan_usar.pdf.

The accompanying person receives a “HVV – Hamburg Card: Greater Hamburg Area (Fare zone AB)”

- valid from **Monday, August 3rd** to **Saturday, August 8th, 06:00 a.m.**

With this Hamburg Card you have access to public transportation and in addition you have special offers for museums, harbour cruises, restaurants etc. For further information see

http://www.hvv.de/pdf/tarif/hvv_flyer_hamburgcard.pdf.

The tickets will be send to you via *mail*. In order to use them, you have to *print the tickets* and take them with you for using the public transportation network. Make sure that you always have your *ID card* with you since the ticket is personalized.

In case you arrive earlier or leave later than the dates above, an additional ticket must be bought!

2.2 How to Reach the Campus

- By car:
 - Take the BAB 24 (A24; motorway 24) direction: Hamburg Horn
 - Take the motorway exit Hamburg Jenfeld
 - Turn right on Schiffbeker Weg
 - At the big crossing “Schiffbeker Weg / Rodigallee” turn left (3rd street)
 - At the next big crossing “Rodigallee / Holstenhofweg” please turn left
 - The main entrance will appear after about 200 meters on your left hand

- For parking lots, please look at the Helmut-Schmidt-University map

Please, keep in mind to register at the guard, before you enter the campus by car. Otherwise the gate will not open.

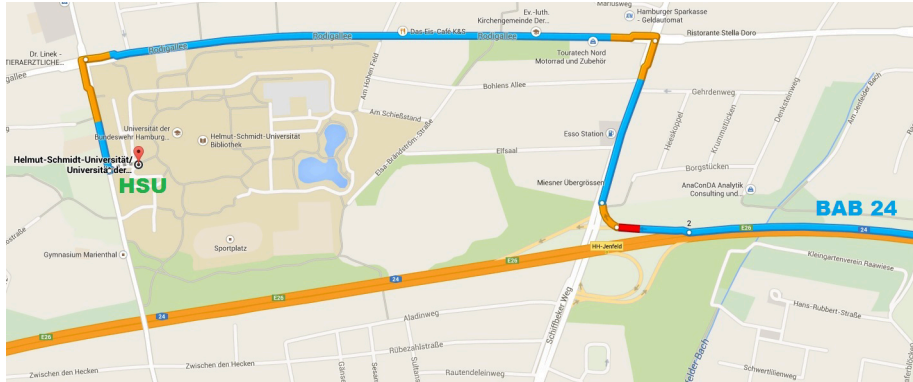


Figure 1: BAB 24 to Helmut-Schmidt-University

- From Hamburg Main Station by public transportation:
 - Alternative A: Take the bus no. 35 (direction Sorenkoppel) to busstop “Universität der Bundeswehr” (about 28 minutes)
 - Alternative B: Take the underground U1 (blue line) to Wandsbek Markt, change for bus no. 10, 261 or 263 to busstop “Universität der Bundeswehr” (29 minutes)
- From Hamburg Airport by public transportation:
 - Alternative A: Take the suburban train S1 to “Wandsbeker Chaussee”, change for bus no. 261 (direction U Horner Rennbahn) or bus no. 35 (direction Sorenkoppel) to busstop “Universität der Bundeswehr” (about 36 minutes)
 - Alternative B: Take the bus No. 39 (direction U Wandsbek Markt) to Wandsbek Markt, change for bus no. 10, 261 or 263 to busstop “Universität der Bundeswehr” (about 45 minutes)

If, for any reason, you need more tickets you find a brief overview here:

- Single Ticket (Einzelkarte)
EURO 2,10 valid for 1 trip and 1 person.
- All-day Ticket (Ganztageskarte)
EURO 7,50 valid for unlimited travel by 1 adult and 3 children (6-14 years inclusive) on the date of issue, all day until 06:00 a.m. the following day. This ticket is transferable.
- 9 am Day Ticket (9-Uhr-Tageskarte)
EURO 6,00 valid for unlimited travel on the date of issue by 1 adult and 3 children (6-14 years inclusive) Mon-Fri from midnight – 06:00 a.m. and from 09:00 a.m. until 06:00 a.m. the following day, all day on Sat and Sun. This ticket is transferable.
- 9 am Group Ticket (9-Uhr-Gruppenkarte) EURO 11.20 valid on the date of issue for unlimited travel by up to 5 persons, Mon-Fri from

midnight–06:00 a.m. and from 09:00 a.m. until 06:00 a.m. the following day, all day on Sat, Sun or public holidays. This ticket is transferable.

A 9 am Day Ticket can often make sense for just two trips on the day you select, the 9 am Group Ticket even when only two of you are travelling.

Buy Single and Day Tickets from any bus driver or ticket vending machine.

For further information visit: “<http://www.hvv.de/en/tickets/>”

- By Taxi:
 - from Airport about EURO 30 (about 20 minutes)
 - from Hamburg Main Station about EURO 25 (about 13 minutes)

2.3 Registration Desk

The registration desk will be located in H1, Room 301 / 303. We recommend picking up your registration material as soon as you arrive on Sunday at the get-together to avoid queues on Monday morning.

Opening hours of the registration desk:

- Sunday, August 2nd: 18:00 at the get-together
- Monday, August 3rd: 08:00 – 18:20
- Tuesday, August 4th: 08:00 – 17:20
- Wednesday, August 5th: 08:00 – 15:00
- Thursday, August 6th: 08:00 – 17:00
- Friday, August 7th: 08:00 – 09:00

2.4 Registration Fee, Badges

Registration is required for all participants. Registered participants will receive a badge giving them access to the get-together, conference venue, outing and banquet.

Note that the badges of the local organizing committee have a **green color**. If you have any questions, please do not hesitate to contact them.

The regular or student registration covers the following:

- Get-together on Sunday, August 2nd, 2015
- Outing on Wednesday, August 5th, 2015
- Banquet on Thursday, August 6th, 2015
- Access to all rooms, talks, facilities

- Printed and electronic conference material (book of abstracts, program, etc.)
- Conference bag and usual material
- Lunches and coffee/tea breaks during the conference
- Hamburg public transport ticket for the week of the conference. More specifically, the ticket is valid from **Saturday, 1st until Saturday, 8th, 06:00 a. m..**

Regular registrations contribute with no less than 25 USD to the International Society on Multiple Criteria Decision Making.

The accompanying person registration covers the following:

- Get-together on Sunday, August 2nd, 2015
- Outing on Wednesday, August 5th, 2015
- Banquet on Thursday, August 6th, 2015
- HVV – Hamburg Card from **Monday, August 3rd to Saturday, August 8th, 06:00 a. m.**
- Guided sightseeing tour of Hamburg

2.5 Internet Access

During the conference, free Wi-Fi connection will be available throughout the campus. It will be provided from August 1st to August 9th. In order to use this free Wi-Fi connection, you have to follow these steps:

1. Receive your Eventcamp Ticket at the registration desk
2. Connect to the wireless network named “HS”
3. Visit “www.internet.hsu-hh.de”
4. Type in the 8 digit code

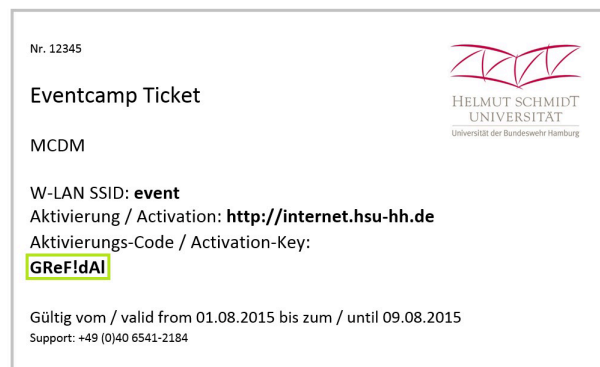


Figure 2: Eventcamp Ticket example

Alternatively, you can connect your PC via Eduroam to the internet.

2.6 Lunch and Coffee / Tea Breaks

Lunches are included in the conference fee and will be served from Monday to Friday in the canteen. Tickets are required for lunch. These can be found in your conference bags.

Please select one option in each category, such as starter, main course and dessert. Every day you have different side options. Note that hot and cold beverages are also included in the lunch.

Find an overview of the menu for each day below:

- Monday, August 3rd:
 - **Starter:** 1) Salad 2) Clear soup with vegetables and noodles
 - **Main course:** 1) Spring roll with chicken in Asian sauce 2) Meat with sauce 3) Rice pudding with apple and cherry sauce
 - **Dessert:** 1) Lemon mousse 2) Fruits
- Tuesday, August 4th:
 - **Starter:** 1) Salad 2) Potato cream soup 3) Pasta squares filled with meat and spinach
 - **Main course:** 1) Fish cake with herb sauce 2) Goulash 3) Vegetarian stuffed cabbage with tomato sauce
 - **Dessert:** 1) Pastry with apples 2) Rice pudding with fruits 3) Fruits
- Wednesday, August 5th:
 - **Starter:** 1) Salad 2) Chicken soup with noodles
 - **Main course:** 1) “Schnitzel” in cheese crust with sauce 2) Roast Beef with sauce 3) Broccoli-potato-gratin with vegetable sauce
 - **Dessert:** 1) Strawberry cream 2) Fruits
- Thursday, August 6th:
 - **Starter:** 1) Salad 2) Onion soup 3) Marinated herring snack
 - **Main course:** 1) Chicken meatball with spicy sauce 2) Cauliflower and cheese-medallion with curry sauce 3) Beef
 - **Dessert:** 1) Fruits
- Friday, August 7th:
 - **Starter:** 1) Salad 2) Ćevapčići with Sambal Olek dip
 - **Main course:** 1) Sausage with curry sauce 2) Cheese pizza 3) Potato pancakes with apple sauce
 - **Dessert:** 1) Cherry cream 2) Fruits

During the Coffee / Tea Breaks hot coffee, tea, water, biscuits and e. g. “Franzbrötchen”, a German speciality, will be served close to the registration desk. Please check the scheduled times for lunches and coffee breaks in the conference program.

2.7 Language

The language of the conference is English.

2.8 Meeting Room

We have booked several meeting rooms for you. The room is available for participants who want to have a private meeting. Please contact the registration desk in order to make a reservation.

2.9 About Hamburg

Hamburg, officially “Freie und Hansestadt Hamburg” (Free and Hanseatic City of Hamburg), is the second largest city in Germany and the eighth largest city in the European Union. It is also the thirteenth largest German state and located in the North of Germany. Its population is over 1.8 million people. The port of Hamburg, on the river Elbe, is the second largest port in Europe (after the Port of Rotterdam) and tenth largest worldwide.

The official name reflects its history as a member of the medieval Hanseatic League, as a free imperial city of the Holy Roman Empire, a city-state, and one of the 16 states of Germany. Before the 1871 Unification of Germany, it was a fully sovereign state. Prior to the constitutional changes in 1919, the stringent civic republic was ruled by a class of hereditary grand burghers or Hanseaten.

Hamburg is a major transport hub and is one of the most affluent cities in Europe. It has become a media and industrial center, with plants and facilities belonging to Airbus, Blohm+Voss and Aurubis. The radio and television broadcaster Norddeutscher Rundfunk and publishers such as Gruner+Jahr and Spiegel-Verlag are pillars of the important media industry in Hamburg. Hamburg has been an important financial centre for centuries, and is the seat of the world's second oldest bank, Berenberg Bank. There are more than 120,000 enterprises.

The city is a notable tourist destination for both domestic and overseas visitors; it ranked 17th in the world for livability in 2012.

To find more information please visit section 5.4.

2.10 About HSU

The Helmut-Schmidt-University is one of the two universities in Germany that serve the scientific study and the academic education of armed forces' officers. It increases the attractiveness of the profession and is pulse generator and service provider for the Federal Armed Forces. With its research infrastructure it strengthens the city of Hamburg as a center of knowledge.

It develops the courses of study and further training offer according to the state of the sciences as well as for further needs of military, economics and society. It stresses and develops the possibilities of multidisciplinary in research and teaching between social, natural, economical and engineering sciences, in order to sharpen the profile of the graduates in national and international competition and to improve their future prospects. That applies at least by promoting junior scientists.

For further information please visit the HSU's web page: “www.hsu-hh.de”

3 The 23rd International Conference On Multiple Criteria Decision Making, MCDM 2015

3.1 Committees

Local Organizing Team:

- Claudia Fantapié Altobelli
- Andreas Fink
- Martin Josef Geiger
(General Chair)
- Sebastian Grötschel
- Sandra Huber
- Johannes Siebert
- Christian Stürck
- Ulrich Tüshaus
- Sandra Zajac

Scientific Program Committee:

- Kalyanmoy Deb
- Jim Dyer
- Matthias Ehrgott
- José Rui Figueira
- Martin Josef Geiger
- Jutta Geldermann
- Salvatore Greco
- Birsen Karpak
- Kathrin Klamroth
- Murat Köksalan
- Kaisa Miettinen
(Program Chair)
- Carlos Romero
- Francisco Ruiz
- Heike-Yasmin Schenk-
Mathes
- Johannes Siebert
- Roman Słowiński
- Jaap Spronk
- Theodor Stewart
- Jyrki Wallenius

3.2 Awards

MCDM Society Awards

Since 1992 the Society on Multiple Criteria Decision Making has honoured individuals with the following awards:

- **The MCDM Gold Medal**
“This is the highest honor that the International Society on Multiple Criteria Decision Making bestows upon a scholar who, over a distinguished career, has devoted much of his/her talent, time, and energy to advancing the field of MCDM, and who has markedly contributed to the theory, methodology, and practice of MCDM” (see <http://www.mcdmsociety.org/intro.html>).
- **The MCDM Edgeworth-Pareto Award**
“As the highest distinction that the International Society on Multiple Criteria Decision Making bestows upon a researcher who, over his/her career, has established a record of creativity to the extent that the field of MCDM would not exist in its current form without the far-reaching contributions from this distinguished scholar” (see <http://www.mcdmsociety.org/intro.html>).
- **The Georg Cantor Award**
“As the highest form of recognition that the International Society on Multiple Criteria Decision Making bestows upon a researcher who, over his/her distinguished career, has personified the spirit of independent inquiry and whose many innovative ideas and achievements are decidedly reflected in the theory, methodology, and current practices of MCDM” (see <http://www.mcdmsociety.org/intro.html>).

These awards will be presented at the 23rd MCDM 2015 conference in Hamburg, Germany. The names of the awardees will be made public at the banquet on August 6th, 2015. Their talks will be held on Friday morning (FR-1).

MCDM Doctoral Dissertation Awards

The International Society on Multiple Criteria Decision Making will honor young researchers who recently completed their PhD in the area of Multiple Criteria Decision Making and / or related research fields at the 23rd MCDM conference in Hamburg, Germany.

The finalists for this year are:

- **Kerstin Daechert**
Generating discrete representations for continuous tricriteria optimization problems by adaptive parametric algorithms
- **Sebastiaan Breedveld**
Towards Automated Treatment Planning in Radiotherapy
- **Gokhan Kirlik**
Exact And Representation Methods For Multiobjective Optimization Problems

Their talks will be given on Monday from 16:40 – 18:20 in Room 401 (MO-5- π -R401). The final decision is made after the talks and the result is also presented at the banquet.

3.3 Invited Plenary Speakers

All invited plenary talks will take place in the Aula. The following three distinguished speakers have agreed to give an invited plenary talk at the MCDM 2015:

- **Monday, 10:00 – 11:00; Aula (MO-2):**
Margaret M. Wiecek, Clemson University, USA
Polysemy of Robustness in Multiobjective Optimization
- **Tuesday, 09:00 – 10:00; Aula (TU-1):**
Roman Słowiński, Poznań University of Technology, Poland
Decision Aiding with Multiple Criteria Hierarchy Process
- **Thursday, 09:00 – 10:00; Aula (TH-1):**
Carlos M. Fonseca, University of Coimbra, Portugal
Subset Selection in Evolutionary Multiobjective Optimization

Besides, some other plenary sessions have been added to the program:

- **Opening Session:** First session on Monday from 9:00 – 10:00 (MO-1).
- **Business Meeting:** The Business meeting of the International Society on MCDM is scheduled on Thursday from 16:30 – 17:00. President of the Society, Prof. Kaisa Miettinen, is chairing the meeting.
- **Award Talks:** On Friday the awardees deliver their talks from 09:00 – 11:00 (FR-1).
- **Closing Session:** Last session on Friday from 14:30 – 15:20 (FR-3).

3.4 Parallel Sessions

300 presentations in 82 parallel sessions are included and the MCDM 2015 scientific program covers, but is not limited to, the following topics:

- Advances in MCDM Theory
- AHP, ANP
- Behavioral Issues in Decision Making
- Compromise Programming
- Computing and Software for MCDM
- Data Envelopment Analysis
- Environmental Decision Making
- Evolutionary Algorithms and MCDM
- Fuzzy Multiple Criteria Decision Making
- Goal Programming
- Group Decision Making, Negotiations
- Multiattribute Utility or Value Theory
- Multiobjective Optimization

- Multiple Criteria Classification, Ranking, and Sorting
- Multiple Criteria Decision Aiding
- Multiple Objective Combinatorial Optimization
- Multiple Objective Metaheuristics
- New Approaches and Decision Support Systems
- New Areas where MCDM is Applied Outranking Methods
- Practical Applications of MCDM
- Preference Modelling Risk and Uncertainty
- Teaching MCDM

Session identifier

Every parallel session is identified by a 7/8 character code which means the following:

- The first two characters correspond to the day of the week when the talk takes place: MO, TU, WE, TH and FR.
- The third character displays the time slot of the day. For example, MO-5 means that all sessions with this identifier are assigned to the fifth time slot on Monday.
- The fourth character is representing the stream of the session which is represented by a Greek symbol. The following symbols are possible:
 - α : Behavioral Aspects, Group Decision Making, Negotiations, Interactive Methods, Software
 - β : Decision Aiding
 - γ : Model Building
 - δ : Industry and Business Applications
 - κ : AHP/ANP
 - λ : Fuzzy Approaches, Decision Making under Fuzziness
 - σ : Multi Objective Optimization
 - χ : Environment, Infrastructure & Emerging Applications
 - π : Special Sessions
- The last characters represent the room where the session takes place. The possible options are:
 - Room HS 1
 - Room HS 2
 - Room HS 3
 - Room HS 4
 - Room HS 5
 - Room HS 6
 - Room 401

Invited Sessions

225 out of 300 presentations are contributed and 75 talks are assigned to the following invited sessions:

- **IS-AHP-TA:** Theory and Applications of the AHP/ANP
(organizers: *Magda Gabriela Sava, Luis G. Vargas*)
- **IS-AUTOMAT:** Automating decision-making
(organizer: *Sebastiaan Breedveld*)
- **IS-CPL-MCDA:** Constructive Preference Learning in MCDA
(organizers: *Miłosz Kadziński, Salvatore Corrente*)
- **IS-EMO:** Evolutionary Multiobjective Optimization (EMO)
(organizers: *Dimo Brockhoff, Joshua Knowles, Boris Naujoks, Karthik Sindhya*)
- **IS-INFRA:** MCDA for Infrastructure Planning and Environmental Management
(organizers: *Valentin Bertsch, Lisa Scholten, Judit Lienert, Jutta Geldermann*)
- **IS-INTEG:** Integrated MCDM Applications
(organizers: *Ilker Topcu, Ozgur Kabak*)
- **IS-INTER-SOFT:** Multiobjective Optimization software for Supporting Interactive Decision Making
(organizers: *Karthik Sindhya, Silvia Poles, Jussi Hakanen*)
- **IS-MB-PMI:** Building MCDA Models: Practical and Methodological Issues
(organizers: *Luciana Hazin Alencar and Adiel Teixeira de Almeida*)
- **IS-MB-RISK-MAINT:** MCDA Models in Risk, Reliability and Maintenance Contexts
(organizers: *Cristiano Alexandre V. Cavalcante and Marcelo Hazin Alencar*)
- **IS-MB-SERVSYST:** Building MCDA Models in Service Systems
(organizers: *Caroline Maria de Miranda Mota and Suzana Daher*)
- **IS-MCDM-LATAM:** New Developments and Applications of MCDM in Latin America
(organizers: *Luiz F. Autran M. Gomes, Juan Carlos Leyva Lopez*)
- **IS-MIPA:** Methodological Issues for Practical Applications of MCDA Models
(organizers: *Danielle Costa Moraes, Ana Paula C. S. Costa*)
- **IS-MOO-CIVIL:** Metaheuristic Algorithms in Multi-Objective Optimization of Civil Engineering Problems
(organizers: *Tom Schanz, Gebrail Bekdas, Sinan Melih Nigdeli*)
- **IS-SMART:** MCDM for smart and sustainable communities
(organizers: *Marta Bottero, Valentina Ferretti*)

- **IS-SUST:** Use of MCDM to support sustainability evaluations: a way forward in multidisciplinary research
(organizers: *Marco Cinelli, Stuart R. Coles, Kerry Kirwan*)
- Behavioural MCDM – Biases and Scales
(organizer: *Johannes Siebert*)

3.5 Important Instructions for the Preparation of your Presentation

Many talks have been scheduled during the conference which are on a tight schedule. Please take into account the following instructions:

- Your presentation should be no longer than **20 minutes**. Moreover, **5 minutes** are reserved for the discussion.
- The slides should be in English.
- Please, bring your presentation on a USB memory stick.
- Please, save your slides as a PDF or Powerpoint.
- Every room is equipped with a projector, computer, screen and a presenter.
- Find your room and meet the Session Chair before your oral presentation. Also make sure that you upload your slides on the computer before the session starts.

3.6 Post-Conference Publications

Participants of the MCDM 2015 conference will be given the opportunity to submit full papers to a number of special journal issues. Submission deadlines are typically after the MCDM 2015, and announced here, during the conference, and on the dedicated journal websites.

The calls can be downloaded on the MCDM 2015 homepage under “Post-conference submissions”: <http://www2.hsu-hh.de/logistik/MCDM-2015/>.

- Special issue of the Journal of Multi-Criteria Decision Analysis
 - Special Issue on MCDA Practice
 - Special editors: Johannes Siebert and Theodor Stewart
 - Deadline for submission: September 30th 2015
 - Submission system: <http://mc.manuscriptcentral.com/mcda>
- Special Issue of the Computers & Operations Research journal
 - Special issue on “Evolutionary Multiobjective Optimization”
 - Guest editors: Dimo Brockhoff, INRIA Lille - Nord Europe, France
Joshua Knowles, University of Manchester, UK
Boris Naujoks, Cologne University of Applied Sciences, Germany
Karthik Sindhya, University of Jyväskylä, Finland
 - Deadline for submission: September 30th 2015
 - Submission system: <http://ees.elsevier.com/cor/>

- IMA Journal of Management and Mathematics
 - Special issue on Decision Analysis and Multicriteria Decision Methods for Mathematical Modelling of Decisions
 - Guest editors:
Adiel Teixeira de Almeida, Universidade Federal de Pernambuco, Brazil
Martin Josef Geiger, Helmut Schmidt University, Germany
Danielle Morais, Universidade Federal de Pernambuco, Brazil
 - Deadline for submission: September 30th 2015
 - Submission system: <http://mc.manuscriptcentral.com/imaman>
- Mathematical Problems in Engineering
 - Special Issue on Building Mathematical Models for Multicriteria and Multiobjective Applications
 - Lead guest editor:
Adiel Teixeira de Almeida, Department of Management Engineering, Universidade Federal de Pernambuco, Recife, Brazil
 - Guest editors:
Love Ekenberg, International Institute for Applied Systems Analysis (IIASA) - Schlossplatz 1 - A-2361 Laxenburg, Austria
Martin J. Geiger, Logistics Management Department, University of the Federal Armed Forces Hamburg, Germany
Juan Carlos Leyva, Department of Economic and Management Sciences, University of Occident, Culiacán, Mexico
Danielle Morais, Department of Management Engineering, Universidade Federal de Pernambuco, Recife, Brazil
 - Deadline for submission: December 25th 2015

3.7 Social Program

Our social program will introduce you to the beauty of the harbor city Hamburg and take you on a culinary journey. Please, be sure to always wear your conference badge.

Get-Together

On Sunday 2nd of August evening, we are looking forward to welcoming you in the *Officers' Mess* (abbreviated as *OHG* in German) of the Helmut-Schmidt-University in Hamburg.

- **Day of the get-together:** Sunday August 2nd
- **Location:** Officers' Mess, Helmut-Schmidt-University
- **Starting time:**
 - Registration desk: 18:00
 - Champagne Reception: 18:00
 - Barbecue: 19:00

The OHG is founded by the German officer corps with the legal status of a registered association. In the OHG, the comradeship is strengthened with the help of various social and cultural events. Traditionally, it serves as a dining and common room. Furthermore you can discover a fireplace room, a poolroom and a salon.

The get-together starts at 18:00 at the OHG, which is located directly next to the bus station *Universität der Bundeswehr*. After you receive your personal conference bag including the book of abstracts, the conference program and further materials, we will enjoy a welcome champagne in the garden of the OHG. Around 19:00 we will do what all Germans love to do – barbecue. For the meat-lovers among us, the barbecue includes marinated pork neck and turkey steak, German Thuringian sausage and ham sausage. This is accompanied by grilled cheese, cabbage salad, coleslaw, potato salad as well as fresh baguette and buns. Together with your meal, you are invited to have a taste of our good German beer or other beverages such as wine, soft drinks, water and tea. We are hoping for great sunny weather, but are also prepared for worse weather conditions. However, since the weather in Hamburg might be variable, please bring suitable clothes with you.

Outing – Sightseeing in Hamburg

On Wednesday 5th of August afternoon, we head off to experience Hamburg on the typical red double-decker buses which are rich in tradition. Here come the key issues at a glance:

- **Day of the Outing:** Wednesday August 5th
- **Pickup location:**
 - In front of the main entrance of the Helmut-Schmidt-University
 - **Possible option for the registered accompanying persons and their partners:** In front of the southern exit of the Hamburg central station (see figure 3)
Note that there are some additional seats. However, there will be only one bus provided in the city centre and therefore the capacity is limited.
- **Pickup time:**
 - From the Helmut-Schmidt-University: 15:30
 - From the City Centre: 15:30
- **Time of the Dinner:** around 18:00
- **Location:** Blockbräu, nearby the subway station “Landungsbrücken”

5 buses will pick you up at 15:30 in front of the main entrance of the Helmut-Schmidt-University.

The bus for the registered accompanying persons and their partners will be provided close to the city center. You will be picked up in front of the southern exit of the Hamburg central main station (see figure 3). This option is possible since the accompanying persons do not attend the scientific program and it would take additional time to come to the Helmut-Schmidt-University. Note

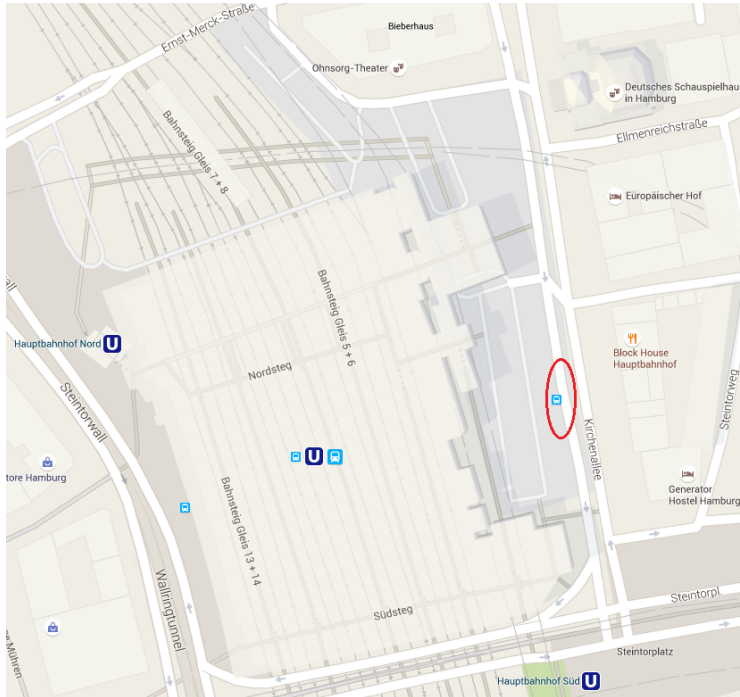


Figure 3: Meeting Point for the Bus in front of the Hamburg Central Station

that there are some additional seats. However, there will be only one bus provided in the city centre and therefore the capacity is limited.

The tour takes around 120 minutes without hopping off and we will visit famous hotspots including, but not limited to, the pulsating HafenCity and harbor, Hamburg's landmark the "Michel" (St. Michaelis Church), the traditional "Speicherstadt" (this city of warehouses has just recently been declared UNESCO World Heritage), the wild Reeperbahn and the Alster lakes.

All this exciting sightseeing will certainly leave you hungry – therefore, we arranged a dinner in the brewery *Blockbräu* just at the wharf *Landungsbrücken*, where we will all meet at 18:00. Brewing has a long tradition in Hamburg and its good beer was already famous in the Middle Ages. So Hamburg was called "Hanse's Brewery" in the 12th century. With more than 500 breweries, beer was the symbol of Hamburg.

We will start the evening with the unique Blockbräu beer cocktail on the terrace. If the sun is shining, you can choose to go on the top deck, enjoy the good weather and appreciate the beautiful view of the Hamburg harbor. The dinner comprises a wide variety of typical Northern German dishes served on big pans which can be accompanied by Blockbräu's self-brewed beer varieties. The starter includes tender herring fillet, crabs à Büsumer style, dressed beef tatar, coleslaw, candied tomatoes, cucumber sticks, farmhouse bread, pretzel and salted butter. For the main course, you can look forward to juicy pigling roast with crackling, tender chicken breast, fried fish in a crunchy beer batter, Hamburg veal bratwurst, potatoes and sauerkraut. Finally, the dinner is completed by a delicious typical red fruit jelly and cheese creations accompanied by fresh fruits.

Conference Banquet

On Thursday 6th of August evening we meet again at the wharf *Landungsbrücken* where we will embark on board of the MS Louisiana Star.

- **Day of the Conference Banquet:** Thursday August 6th
- **Boarding starts at:** 18:00
- **Time on the Ship:** 18:30 sharp – 23:30
Please take enough time into account to reach the Louisiana Star since otherwise the ship might leave without you!
- **Disembarking Time:** Until 12:00 Midnight
- **Meeting Point:** On board of the MS Louisiana Star at the wharf Landungsbrücken

Boarding starts at 6:00 p.m. where you will be welcomed with a so-called portside and starboard cocktail. The ship leaves the harbor at 6:30 p.m. sharp. Please take note that the crew of the ship is unfortunately not able to wait for late participants, so please take into account enough time to get to the wharf and to find the ship.

On board of this paddle wheel ship, the conference banquet as well as the honoring of the MCDM Doctoral Dissertation Award and the MCDM Society Awards will take place. The boat trip takes us through the harbor of Hamburg on the river Elbe for five hours so that the boat will berth at around 11:30 p.m.. You will then have time until midnight to leave the ship.

You are invited to explore the winding staircases from the main deck to the bar in the upper salon. From the salon, you have direct access to the great sun deck. In the front area of the main deck you will find the stage with an open gallery above. The staircases to the upper salon are located at the rear part. Furthermore, you get a great view on the rotating paddle wheel.

The dinner, which includes a buffet of different appetizers, hot meals and desserts, is served on a lifting buffet at the rear part of the Louisiana Star. Starters include but are not limited to smoked pork loin on an apple-plum-salad, shrimps on a cocktail sauce with melon and orange filets or a Romaine lettuce with croutons and chicken strips with Caesar dressing. For the main dish you can enjoy a steak on a red wine-onion-gravy, fried fish or a lens patty with diverse sides. Finally, for dessert, you can enjoy vanilla mousse with stewed apples or Northern German cheese variations with walnuts and grapes.

3.8 MCDM 2015: Record Numbers

Again, a participant record has been broken! 361 participants are registered to the conference. Thereby, we have 231 regular, 114 student and 16 accompanying person registrations from 49 different countries. Moreover, 29 students are involved in the realization of the conference.

Figure 4 shows the number of participants per country. We want to point out that the most participants come from Turkey (62 persons in total). Also we want to thank the German Multiple Criteria Decision Making Research community for their high involvement (39 in total). These numbers are closely followed by Brazil (22 participants), USA (21) and UK (20).

The term “Others” corresponds to the countries with one or two participants, such as Azerbaijan, Bahrain, Israel, Malaysia, Tunisia, South Africa, United Arab Emirates, Austria, Sweden, Greece, Lithuania, Australia, Latvia, Republic of Korea, Serbia, New Zealand, Hong Kong, Ecuador, Russia and Qatar.

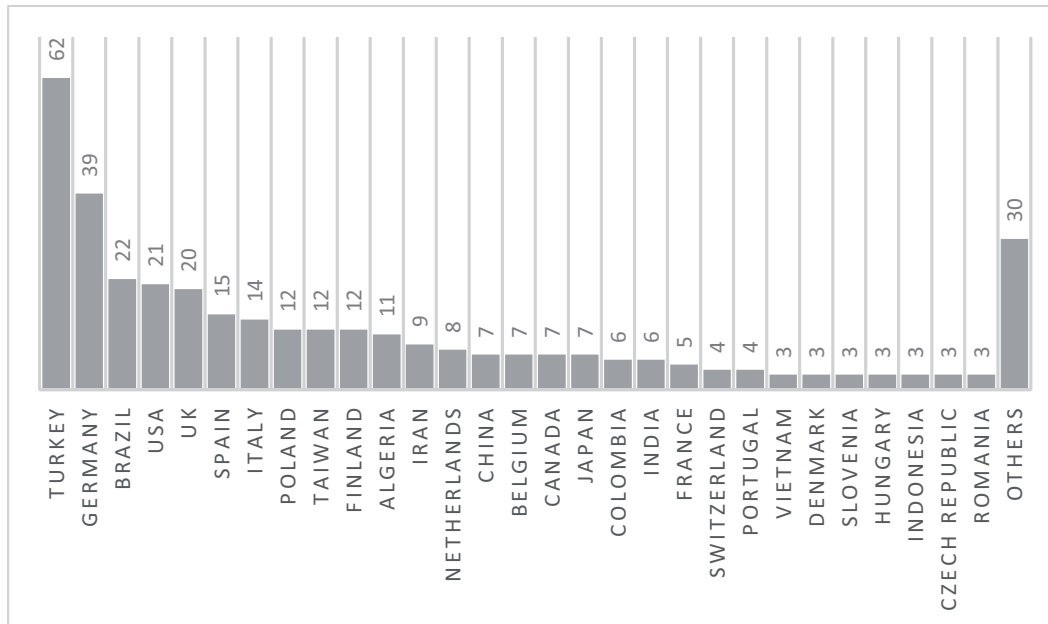


Figure 4: Number of participants per country

A total number of 306 talks have been scheduled at the MCDM 2015 conference. Thereby, 300 presentations have been included in 82 parallel sessions. 225 out of 306 presentations are contributed and 75 talks have been assigned to 22 invited sessions. Also seven plenary sessions are scheduled including the plenary and award talks, the opening / closing session as well as the business meeting.

4 The International Society On Multiple Criteria Decision Making

The International Society on Multiple Criteria Decision Making has a long history and the first International Conferences dates back to 1975 in Jouy-en-Josas, France organized by Herve Thiriez and Stanley Zionts. The other conferences are given below:

- 22nd International Conference, 2013, Málaga, Spain, Francisco Ruiz.
- 21st International Conference, 2011, Jyväskylä, Finland, Kaisa Miettinen.
- 20th International Conference, 2009, Chengdu, China, Yong Shi, Shouyang Wang.
- 19th International Conference, 2008, New Zealand, Matthias Ehrgott.
- 18th International Conference, 2006, Chania, Crete, Greece, Constantin Zopounidis.
- 17th International Conference, 2004, Whistler, British Columbia, Canada, Bill Wedley.
- First MCDM Winter Conference (16th International Conference), 2002, Semmering, Austria, Mikulas Luptacik, Rudolf Vetschera.
- 15th International Conference, 2000, Ankara, Turkey, Murat Köksalan.
- 14th International Conference, 1998, Charlottesville, Virginia, USA, Yacov Y. Haimes.
- 13th International Conference, 1997, Cape Town, South Africa, Theo Stewart.
- 12th International Conference, 1995, Hagen, Germany, Günter Fandel, Thomas Gal.
- 11th International Conference, 1994, Coimbra, Portugal, Joao Climaco.
- 10th International Conference, 1992, Taipei, Taiwan, G.H. Tzeng, P.-L. Yu.
- 9th International Conference, 1990, Fairfax, USA, Richard Soland, Ambrose Goicoechea.
- 8th International Conference, 1988, Manchester, UK, A. Geoff Lockett, Gerd Islei.
- 7th International Conference, 1986, Kyoto, Japan, H. Nakayama, Y. Sawaragi.
- 6th International Conference, 1984, Cleveland, Ohio, USA, Yacov Y. Haimes.
- 5th International Conference, 1982, Mons, Belgium, Pierre Hansen.
- 4th International Conference, 1980, Newark, Delaware, USA, Joel Morse.
- 3rd International Conference, 1979, Königswinter, Germany, G. Fandel, T. Gal.

- 2nd International Conference, 1977, Buffalo, New York, USA, Stanley Zions.

Executive Committee

The Executive Committee is composed of the following members:

- Kaisa Miettinen, President of the Society
University of Jyväskylä, Finland, President@mcdmsociety.org
- Kalyanmoy Deb, Michigan State University, USA
- Matthias Ehrgott, Lancaster University, Great Britain
- Martin J. Geiger, Next Meeting Ex-Officio
Helmut Schmidt University, Germany
- Salvatore Greco, University of Catania, Italy
- Birsan Karpak, Vice-President of Finance
Youngstown State University, USA
- Kathrin Klamroth, Bergische Universität Wuppertal, Germany
- Murat Köksalan, President-Elect
Middle East Technical University, Turkey, President-elect@mcdmsociety.org
- Pekka Korhonen, Aalto University, Finland
- Hirotaka Nakayama, Konan University, Japan
- Carlos Romero, Technical University of Madrid, Spain
- Johannes Siebert, Newsletter Editor
University of Bayreuth, Germany, newsletter@mcdmsociety.org
- Jaap Spronk, Erasmus University of Rotterdam, Netherlands
- Theo Stewart, Chairman of the the Awards Committee
University of Cape Town, South Africa
- Jyrki Wallenius, Immediate Past-President, Chairman of the MCDM Doctoral Dissertation Award Committee
Aalto University, Finland
- Francisco Ruiz, Secretary, Past Meeting Ex-Officio
University of Málaga, Spain, Secretary@mcdmsociety.org

5 General Information

5.1 Banks and Saving Banks

The banks' business hours depend on the branch office. Most of them open at 09:00 or 09:30 and close at 16:00 or 18:00. However there is an extensive network of cash dispensers where you can withdraw cash if you need to.

5.2 Useful Phone Numbers

If you have any trouble during your stay in Hamburg, you can use the following phone numbers:

- Emergency Call / Accidents 112
- Fire 112
- Police 110

In case, do not hesitate to call one of these numbers.

In Hamburg, taxis usually are easy to catch directly on the street. However, it is recommended to call a taxi in advance. You can use the following phone numbers:

- Hansa-Taxi +49 40 211 211
- Das Taxi +49 40 22 11 22

In any case, please, check the price list or ask for the price before you get in the car.

5.3 Disclaimer

The organising committee is not liable for any damage on health or property of any conference participant or accompanying person in the course of or resulting from participation in the conference. Participants are advised to have their own insurance.

5.4 Optional Leisure Activities

Here are presented some of Hamburg's highlights you might want to see.

The River Elbe

Flowing through Hamburg, the Elbe river joins the Hanseatic city to the North Sea. There are numerous ways to explore, including sightseeing boat tours and casual strolls along the banks of the river.

Address: Bei den St.Pauli Landungsbrücken, 20359 Hamburg

Public Transport: U3, S1, S2, S3, Station 'Landungsbrücken'

Parking: Parkdeck St. Pauli (Bei den St. Pauli Landungsbrücken 4)

Without the Elbe river Hamburg would not be the economic power it is today. The river is 1091.47 kilometers long, originating high up in the Czech mountains and crossing two other German state capitals, Dresden and Magdeburg, before passing through the city of Hamburg, eventually reaching the North Sea at Cuxhaven.

Along and across the river

The northern and southern branches of the Elbe, along with numerous out-flowing channels and canals, are what shape the character of the city. Where would Hamburg be without its river and the sprawling port area that opens the door to the rest of the world?

Boat sightseeing trips of the harbour are particularly popular, with most departing from the jetties at Landungsbrücken. Even with the HVV-ferry can a visitor travel across to the opposite shore.

(Visit: "www.hadag.de/english/harbour-ferries.html")

Thanks to the Old Elbe Tunnel, visitors can also walk or cycle under the river through to Steinwerder. At the weekends, the tunnel is closed to traffic, making it a calmer time to pass through. On the other side, you can continue on to Wilhelmsburg, or take in the view of the cityscape framed by the river. Cycling enthusiasts can also enjoy the 23 kilometers long Elbewanderweg path which leads from Wedel, past the nature reserve Wittenberger Heide to Blankenese, then onwards through the beautiful Övelgönne all the way to Landungsbrücken. There are plenty of shortcuts, and return ferries depart from many points along the way.

St. Michaelis Church

This distinctive landmark in Hamburg is better known locally as the "Michel". Visitors can admire the church's impressive central vaulted nave, containing three music organs, and enjoy a beautiful view of the city from the tower.

Address: Englische Planke 1a, 20459 Hamburg

Opening times: May to October: 09:00 – 20:00;

November to April: 10:00 to 18:00.

Public transport: U3, station "Baumwall" / Bus line 112 or 37, stop "Michaeliskirche"

As you pass through the Hamburg inner city, the church tower of Michel can seem to follow you everywhere. This may be due to the fact that, at 132 meters, the tower of the main church dwarfs most buildings in the city center and can be seen from many angles. Whether on a walk through Außenalster; a visit to the "Planten un Blomen" park; strolling by the city walls; or along Landungsbrücken – the history-rich church Michel is a constant feature in the cityscape. The St. Michaelis church as you can see it today is the third one to be built on the site. The original church, built between 1648 – 61 in the baroque style, was destroyed by a lightning strike. The second building was laid out in a form similar to a Greek cross, and later a 132 meter high tower was added (1777 – 85).

This second building was destroyed in 1906 in a fire started during construction work. The Michel was then built for a third time from 1907 – 12, with complex renovations taking place in 1983 including a copper roofing. The St. Michaelis is the principal church within the new city area (Neustadt). The other main churches are St. Petri (1195), St. Nikolai (1195), St. Jacobi (1255) and St. Katherinen (1255).

Binnen- and Außenalster

The Alster is a big attraction for both Hamburg's locals and visitors, offering popular boat trips around the Inner and Outer Alster as well as walks around the water.

Address: Jungfernstieg, 20534 Hamburg

Public transport: S1, S2, S3 and U1, U2, Station "Jungfernstieg".

Parking: Parkhaus "Alsterhaus Hamburg" (Bei der Stadtwassermühle)

This body of water is made up of the Außenalster (Outer Alster) and the Binnenalster (Inner Alster) whose southern part flows into the Elbe. The source of the Alster originates in Henstedt-Rhen, outside of Hamburg. In the north of the urban area is where the river reaches the city before meeting the Krugkoppel bridge on the Außenalster. The water is surrounded by trees, green parks and beautiful buildings which give the area a special charm. To maintain the standard of beautiful scenery it is a rule that all buildings surrounding the Alster must be white and that their roofs should be covered with copper.

Going with the flow

With a size of 164 hectares, the Alster lake also has a long shoreline which is a popular meeting point. Well-used jogging paths run along the waters and small sailing vessels and barges make tours of the lake. Water sports are also a very popular activity. In 1844 the first rowing regatta took place on the Alster. Six years later the first sailing regatta followed. From April to October you can hire sailing boats, canoes, kayaks, paddleboats or rowboats at many places all around the Alster. In the Alster park and numerous other green areas surrounding the lake, people can leave the stresses of a hectic metropolitan life for a moment under the shade of the trees looking out into the lake. The green parks are a perfect place for relaxing, having a barbecue, or even sunbathing or reading on one of the "Alsterchairs".

Fishmarket every Sunday morning

The Hamburg Fishmarket attracts over 70,000 visitors to the Elbe every Sunday. Here you can find fresh fish, fruit baskets and tropical flowers. People get up early in the morning to ensure they get a good variety at the Fischmarkt.

Address: Große Elbstraße 9, 27767 Hamburg

Opening times: Every Sunday:

April to October, 05:00 – 09:30;

November to March, 07:00 – 09:30.

Public transport: S1 and S3, Station "Reeperbahn"; U3, Station "Landungsbrücken"; Bus line 112, Stop "Fischmarkt".

Rumour has it that the hawkers loudly shouting their wares at the Fischmarkt can be heard all the way over in nearby Reeperbahn. Without a doubt, every Sunday morning everything springs up in the Fishmarket area. Whether fish, fruit, flowers, vegetables or clothes, anything can be bought on the stands lined up along the open space next to the Elbe's harbour basin.

At the Fischmarkt the hawkers are willing to haggle and sweeten the deal with an extra bargain or two. With a mixture of families and shoppers arriving early to catch a good deal, along with the dregs of last night's crowds enticed by the live music on offer, Fishmarket has a special atmosphere and definitely one to experience when in Hamburg.

Early morning rock music

You don't have to end your night of dancing in St. Pauli – in the historic fish market hall (Fischauktionshalle) there is plenty of early morning live music to keep you going. Many times wedding parties, including the bride and groom, will find themselves at the Fishmarket as their celebrations wind down. Even locals flock to the Elbe and see the market hall as their final party venue of the night.

As the Fishmarket stands on land below sea level, in stormy weather it can often become submerged in water. In general, visitors leave the Fishmarket with wet feet and seldom with a dry throat – whether also with tropical plants and other wares is another matter.

City Hall

The City Hall is an impressive and eclectic building which was built in 1897. In the City Hall you can find the senate (state government) and the Hamburg Parliament. There are regular guided tours and exhibitions in the Rathaus-diele of the City Hall.

Location: South of the Binnenalster

Public transport: U3, Station "Rathaus"

The current City Hall is the sixth one in Hamburg's history. It took a while until the plans for a new building were made, which is why the Hamburg Parliament and the senate had to meet in other chambers for this period of time. Until 1885 it was impossible to reach a consensus on the submitted concepts. Only when Martin Haller and six other architects founded the "Federation of the City Hall builders" in 1886 the planning was accelerated. 4000 wooden poles had to be put into in the Alster lake to be able to carry the weight of the 113 m wide, 70 m low and 112 m tall building.

After 11 years of construction the new City Hall could be consecrated in 1897. The back of the building was connected to the "Chamber of Commerce" and the "Stock Exchange", which was built in 1841. Inbetween these buildings you will find a courtyard that reminds of a Piazza with its so called "Hygieia-fountain". It is dedicated to the Greek goddess of health. From the outside the City Hall is a building in the Neo-Renaissance style, but from the inside it is an eclectic mixture of different construction epoches. This is what makes the rooms appear huge. Governmental funds and private aid money enabled a complex restoration of the City Hall from 1987 to 1997. From that time on there is a strict ban on smoking in the inside of the City Hall. The City Hall is open from 08:00 to 18:00 every day and there are diverse guided tours every day. The big market-square in front of the City Hall is a constant venue for big events in Hamburg.

Reeperbahn

On the Reeperbahn, Hamburg's red-light district rubs shoulders with restaurants, bars, theaters and nightclubs. Recently the street was voted Hamburg's best street by www.prinz.de, the city's entertainment guide, followed by *Schulterblatt* and *Mühlenkamp*. The street's nightlife has something for everyone and is the first stop for every nightowl.

Address: Reeperbahn, 20359 St. Pauli

Public transport: S1 and S3, Station “Reeperbahn”; U3, Station “St. Pauli”;
Bus line 112, Fast bus (Schnellbus) 36 and 37.
Parking: Reeperbahn-Garagen, Spielbudenplatz 5

In a song well-known in Germany, Hans Albers sings: “On the Reeperbahn at half 12 at night...” Of course, the emphasis is on *at night*. If you were to visit this Hamburg neighbourhood during the day, you would find a rather quiet street with a few shops, and you would perhaps wonder why there were so many closed doors. But when it gets dark, St. Pauli springs to life: neon signs flashing everywhere in competition. The hottest clubs on the Reeperbahn and Hamburger Berg open, with Irish pubs and Hans-Albers-Platz packed full of live music. The most famous street in Hamburg got its name from the old German word “reep”, which means an old heavy rope for a ship. During 1600 and 1880 the space north of today’s Reeperbahn street was used as a “ropewalk” for the production of ropes for the nearby harbour. Nowadays, the street is the first-stop for all sorts of entertainment.

Music history

In the 1960s the Reeperbahn became a mecca for rock music with its “Große Freiheit” area. Everybody from the Beatles to the Searchers was performing in clubs like “Top Ten” or the “Starclub”. Große Freiheit branches just off the Reeperbahn. Here the Beatles had their first appearance on German soil in Club “Indra”. You can trace the Beatles footsteps to the Kaiserkeller, which is still running, as well as the site of the now-closed Star Club, where a plaque commemorates the venue. Beatles-Platz, a tribute to the band, is a circular plaza, painted black and modeled on a vinyl record. Both this and a sculpture of the band’s early members are located not too far from “Beatlemania”, a dedicated Beatles museum.

A mixture of entertainment

Alongside music venues is a varied assortment of entertainment, including Reeperbahn’s famous strip clubs and brothels. Just around the corner from the Reeperbahn is Herbert Street, the principal red light area. Both ends of the street are blocked by barriers and it is inaccessible to women and minors. In Spielbudenplatz you can find three floors worth of waxworks at the Wax Museum “Panopticum” with several famous wax figures including the King of Rock’n’Roll. Also in the area is the Operettenhaus (Opera house) for music lovers, as well as Schmidts Tivoli or St. Pauli Theater for theater enthusiasts which attract the city’s locals as well as tourists.

With so much on offer, a night in the Reeperbahn can go on well into the early hours of the morning.

Miniatur Wunderland

Since its opening in 2000, the Miniatur Wunderland has become one of the tourist highlights of the Hanseatic city. The world’s largest model railroad system is a must see for every Hamburg visitor.

The Miniatur Wunderland is the largest model railway system in the world. Visitors can admire different countries and even an airport in miniature. Up until now the sections Hamburg, Harz, Austria, America and Scandinavia are

completed. There are also open construction sites, so the visitors can observe and understand the construction.

Address: Miniatur Wunderland Modelleisenbahn Hamburg
Kehrwieder 4
20457 Hamburg

Mondays, Wednesday, Thursdays 9:30 – 18:00
Tuesday 09:30 – 21:00
Friday 09:30 – 19:00
Saturday 08:00 – 21:00
Sundays and holidays 8:30 – 20:00

The 200 square meters Hamburg section includes all of Hamburg's main attractions such as Michel and Hagenbecks Tierpark. With over 50,000 "Wunderländer" (as its inhabitants are called) the miniature replica of Hamburg is a bustling city. 1,500 trains arrive in the Hamburger Hauptbahnhof on a daily basis.

*For further information please visit Hamburg's web page:
"www.english.hamburg.de"*

5.5 Smoking

Smoking is not allowed in the conference venue. Please, take into account that smoking is allowed in Germany only outside and not permitted in public facilities at all. You will find ashtrays at almost every exit.

Scientific Program

Monday, 09:00–10:00

★ MO-1

◆ MCDM Plenary

Monday, 09:00–10:00 – Aula

Session: Opening Welcome

Chair: Martin Josef Geiger

Monday, 10:00–11:00

★ MO-2

◆ MCDM Plenary

Monday, 10:00–11:00 – Aula

Session: Opening Plenary: Margaret M. Wiecek

Chair: Kaisa Miettinen

1 - Polysemy of Robustness in Multiobjective Optimization

Margaret M. Wiecek, Department of Mathematical Sciences, Clemson University, USA

Robust multiobjective optimization addressing decision making under multiple criteria and uncertainty has become a research field of vital interest in the last decade starting with concepts of robustness in engineering design (Deb & Gupta, 2004; Azarm & Li, 2005). Earlier efforts had used multiobjective optimization methods to resolve single-objective decision-making problems under uncertainty (Kouvelis & Yu, 1997). In multiobjective optimization problems (MOPs), uncertainty may be assumed in the elements needed to define and solve MOPs such as objective and constraint functions, parameters converting MOPs into single-objective problems, and preference information provided by decision makers (DMs). Additionally, uncertainty can be modeled with continuous or discrete sets depending on the real-life context. In effect, uncertain MOPs may take on different forms leading to multiple concepts of robust counterpart problems (RCs) and to various notions of robust efficient solutions that convey multiple meanings to DMs. In view of this diversity, in the talk we interweave highlights of studies on robust multiobjective optimization with our research to obtain a comprehensive overview of this field. We examine the column-wise (Soyster, 1973) and row-wise (Ben-Tal & Nemirovski, 1998) uncertainty in the constraints of the MOP. For each model we show that the efficient solutions of an RC can be found

as the efficient solutions of a related deterministic problem. We demonstrate the findings on an Internet network requiring multiobjective routing under polyhedral traffic uncertainty. We also apply the row-wise model to six scalarization formulations of the multiobjective linear program (MOLP) in which the scalarizing parameters remain uncertain, a situation being common for many DMs. The min-max solution to the MOLP emerges as robust (weakly) efficient to five out of the six formulations and, in this way, clearly resolves the challenge of choosing a scalarization formulation. MOPs with uncertainty in the objective functions may lead to RCs making use of the (traditional) point domination or a (new) set domination. Again, in each case the RC is reduced into a computationally tractable deterministic MOP and the relationship between their efficient sets is examined. The objective-wise uncertainty helps to obtain stronger results. However, not only the coefficients in the objective functions but the number of objective functions may be uncertain. We analyze MOPs with an uncertain, possibly infinite, number of objective functions using two approaches to constructing a RC: all-in-one (AiO) and all-at-once (AAO). In the AiO approach, the RC assumes the form of a single MOP with an infinite number of vector-valued objective functions. In the AAO approach, the RC involves an infinite number of MOPs, each having a finite number of vector-valued objective functions. Under some conditions, these RCs can be reduced respectively to an MOP with a finite number of objective functions and to a finite number of MOPs, while the efficient set remains unchanged. In conclusion we argue that, in comparison to single-objective optimization, multiobjective optimization offers many more research opportunities to exploit the concept robustness which, in turn, strikes with multiple meanings and interpretations.

Monday, 11:30–13:10

★ MO-3- α -HS1

◆ Behavioral Aspects, Group Decision Making, Negotiations, Interactive Methods, Software

Monday, 11:30–13:10 – Room HS 1

Session: Behavioral MCDM – Biases and scales

Chair: Johannes Siebert

1 - Is the OWA operator an adequate model of preferences in multi-attribute decisions? An empirical study

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In 1988, R. Yager introduced the OWA (Ordered Weighting Average) operator as a tool for multi-attribute decision making. In contrast to many other approaches in MCDM, this operator does not assign weights to attributes per se, but relative to the performance of an alternative in the attribute. Thus, the same weight is used across all alternatives for the attribute in which the alternative performs best, second best and so on. Since it was introduced in 1988, the OWA operator has attracted considerable attention in literature. A search in Google scholar for "OWA" and "multi-attribute" generates over 11,000 hits. A very frequent claim in this large literature is that the OWA operator provides a particularly realistic and intuitive model of preferences. However, despite of the popularity of the OWA operator in literature, to the best of our knowledge there is so far no empirical study to measure how well actual preferences can be represented using this operator, and if it indeed fits observed preferences better than other models.

We thus conduct an empirical study to test how well this operator fits actual preferences of subjects in a ranking task. The task consists of three parts: In the first part, subjects have to rank 8 smart phones according to four attributes (camera resolution, battery capacity, total memory, RAM capacity). Since subjects are undergraduate students, smart phones are a product category with which subjects are very familiar, and about which they usually have already made several purchasing decisions. In the second and third task of the study, subjects had to provide a cardinal evaluation of the same 8 alternatives on a scale of 1 to 100 points, and had to indicate their willingness to pay for each phone. These questions mainly served to test consistency and stability of the subject's preferences.

Based on the claims of the OWA literature, we formulate the following hypotheses:

H1: An OWA model is better able to represent subjects' preferences in the ranking task than a simple additive weighting model.

Since subjects might make mistakes in their ranking, we particularly want to focus on subjects who have more consistent and stable preferences:

H2: The quality of fit of the OWA model will be positively related to consistency of subject's responses across the three tasks, and this relationship will be stronger than for the simple additive weighting model.

Finally, the OWA literature usually suggest weights which are monotonically decreasing, so that the attribute in which an alternative performs best receives the highest weight, and the attribute in which the relative performance of an alternative is worst receives the lowest weight. In

accordance with these specifications from literature, we formulate our third hypothesis:

H3: Weights estimated for the OWA model will be decreasing with respect to the relative performance within each alternative.

A the time of writing this abstract, the main empirical study for our experiment is not yet completed. Data from the main study will be available at the conference in August. The following results are based on a pre-study with 71 undergraduate subjects from the faculty of business, economics and statistics at University of Vienna.

To test hypothesis H1, we employed an approach similar to Vetschera (2014) and fitted weights the ranking statements using an LP model for both OWA and simple additive weighting (SAW). For linear partial utilities, responses from subjects were almost never consistent with the models. The OWA model was not consistent with any ranking provided by the subjects, the SAW model only with the rankings of two subjects. A Chi-square test indicates no significant difference between the two methods.

The LP model used for parameter estimation minimized the maximum violation of the constraints obtained from the rankings, thus the objective value of the model provides an indication of the approximation error. This error was smaller for the OWA model (mean 0.0061) than for the SAW model (mean 0.0089), this difference is statistically significant according to a nonparametric Wilcoxon test ($W = 3705.5, p < 0.1\%$), indicating a somewhat better fit of the OOWA model in accordance with H1.

To test hypothesis H2, we calculated an indicator of the inconsistency of each subject by counting the number of alternatives which were ranked differently in each part of the experiment. Contrary to H2, the correlation between the error in fitting the preference model and inconsistency was not significant both for the OWA model ($r = 0.0083$, n.s.) and the SAW model ($r = 0.1665$, n.s.).

Our results also contradicted H3. On average, the estimated weights for the OWA model were highest for the attribute in which an alternative performed worst (mean 0.5018, SD 0.1205), second highest for the attribute in which an alternative performed best (mean 0.3225, SD 0.0668), and much lower for the other two attributes (mean of 0.0782 and 0.0975, respectively). A Wilcoxon test indicates that the difference between the two "middle" attributes is not significant, all other differences are significant at $p < 0.1\%$. Thus our results seem to indicate that the OWA operator represents a decision behavior that is partly based on the "Take the best"-heuristic (Gigerenzer 1996), and combines it with an "Avoid the worst" approach.

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2 - Proactive Decision Making Validation of a Multidimensional Scale

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On the basis of an extensive interdisciplinary literature review proactive decision-making (PDM) is conceptualised as a multidimensional concept. We conduct five studies with over 4,000 participants for developing and validating a theoretically consistent and psychometrically sound scale of PDM. The PDM concept is developed and appropriate items are derived from literature. Six dimensions are conceptualised: the four proactive cognitive skills systematic identification of objectives, systematic search for information, systematic identification of alternatives, and using a decision radar, and the two proactive personality traits striving for improvement and showing initiative. Using principal component factor analyses and subsequent item analyses as well as confirmatory factor analyses, six conceptually distinct dimensional factors are identified and tested acceptably reliable and valid. It can be proved for decision-makers, decision-analysts, neither nor, and both with different levels of experience that individuals with high scores in a PDM factor, e.g. proactive cognitive skills or personality traits, show a significantly higher decision satisfaction. Thus, the PDM scale can be used in future research to analyse other concepts. Furthermore, the scale can be applied e.g. by staff teams to work on OR problems effectively or to inform a decision analyst about aspects of decision-making in an organization.

3 - Biases and Debiasing in Multi-Criteria Decision Analysis

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Developing models and estimating parameters for multi-criteria decision analysis (MCDA) requires judgments by experts and decision makers. Examples of these judgments are: creat-

ing alternatives, identifying objectives, estimating probabilities for uncertain consequences, developing value functions, and assigning weights. These judgments are subject to biases, which can reduce the quality of the analysis. Some of these biases, like the overconfidence bias and the splitting bias, are due to faulty cognitive processes. Others are due to motivations for preferred analysis outcomes, for example the confirmation bias or the tendency to assign higher weights to objectives that favor a preferred alternative.

We structure the description and discussion of these biases by the steps of a typical MCDA application:

1. Structuring the MCDA problem with alternatives and objectives
2. Developing attributes for objectives
3. Estimating consequences of alternatives on each attribute
4. Eliciting single-attribute value functions
5. Assessing weights
6. Aggregation and sensitivity analysis

The original literature on biases, dating back to Tversky and Kahnemans pioneering work in the 1970s, was concerned with cognitive biases in probability and utility judgments. These biases are primarily relevant to steps 3 and 4. A small, but relevant literature addresses weighting biases (step 5), discovering the equal weighting bias, the splitting bias, and the proxy bias, among others. More recently, Keeney and his associates have identified an omission bias in steps 1 and 2, showing that without tools or prompting, people often develop an incomplete set of alternatives and objectives.

We distinguish between biases that are hard to correct vs. those that can easily be fixed by logic or decomposition. For example, the overconfidence bias has been shown to be pervasive and resistant to corrective procedures. On the other hand, the bias leading to non-regressive prediction can be corrected by decomposition: by asking experts for standard deviations and correlations, one can calculate the correct regressive prediction. While some cognitive biases are easy to correct, all motivational biases are hard to correct.

For biases that are hard to correct, we identify several debiasing techniques. To the extent that they have been tested experimentally, the results are not very encouraging. However, many of the "best practices" for debiasing, developed by practitioners of MCDA, have not been tested at all. For example, counterfactuals are often used to reduce the overconfidence bias, but we know of no tests of this procedure. Similarly, using ranking and ratio estimation have been used to counter the equal weights bias, but there are also no systematic comparisons of this procedure with other weighting techniques. We conclude with a research agenda that has two main elements: Expanding the scope of bias research to include motivational biases, and testing best practices in countering both cognitive and moti-

vational biases.

4 - Debiasing Overconfidence in Multi-Criteria Decision Analysis

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Decision problems with multiple conflicting objectives 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, multicriteria decision 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 this paper is to report on our early findings in assessing the effectiveness of best practices to debias overconfidence in probabilistic estimation of impacts. We report on a pilot study, where we evaluate the performance of undergraduate students at the Polytechnic University of Turin, who were asked to provide probability distributions over a set of variables, and where submitted to alternative debiasing strategies aimed at improving their accuracy. We also discuss further directions of research on this topic.

★ MO-3- γ -HS2

◆ Model Building

Monday, 11:30-13:10 – Room HS 2

Session: IS-INTEG: Integrated MCDM Applications 1

Chair: Y. Ilker Topcu

1 - A Fuzzy Analytic Hierarchy Process Based Approach for a Multi-Objective Multi-Level Closed-Loop Supply Chain Model

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The issue of Closed-Loop Supply Chain (CLSC) management has been more popular with the globalization and the development of the economy in recent years. Particularly new regulations for the recovery and recycling of end products hold manufacturers responsible for their CLSC management. Thus, in order to achieve higher competition/higher service, managers of companies have started to pay more attention to environmental conscious issues. In this study, we investigate a multi-objective multi-level mixed-integer linear programming model with two allied SCs and six different Decision Maker (DM). At the first decision level, the manufacturers of allied SCs are considered as the upper level DMs of the Stackelberg Game. At the second level, raw material suppliers, common suppliers, assembly centers and common collection centers are considered as the lower level DMs. The objective functions of the first level DMs consist of four different components: Transportation cost, purchasing cost, fixed operating cost and inventory cost. The objective functions of the lower level DMs are to maximize the total their profits. In the proposed model, end of product consists of raw material, semi product and parts. Manufacturers can purchase their materials from common sources or own sources. In the solution phase, we proposed a new fuzzy AHP based interactive fuzzy programming approach. In the first step, upper level DMs are asked to determine the priority levels of lower level DMs by using fuzzy AHP method. Then in the second step, all DMs in both levels are asked to determine the importance of their own objectives. In the third step, we solve the individual objective functions via weighted sum method and gain the pay-off table. After this step, the upper level DMs determine the minimum satisfactory level of themselves and lower level DMs. Following Zimmermanns (1978) Max-Min method the revised version of the model with the objective function consisting of individual satisfaction levels multiplied by weights of DMs obtained in the first step of the method via fuzzy AHP. Finally, a numerical example is implemented and analyzed in order to demonstrate the efficiency of the developed approach.

2 - A Multi-Level Linear Programming Approach for Optimizing a Closed-Loop Supply Chain with MCDM Methods

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Especially in the last years, the concept of Closed-Loop Supply Chain (CLSC) has been moved much higher up due to the consumer pressures, environmental awareness and the government laws. Many companies have been applied backward flows of end-of-life product at their supply chain network. Thus, a lot of companies start to focus on CLSC issues that include remanufacturing, refurbishing, recycling and disposal of end-of-life products. We develop a multi-level optimization model for a CLSC consists of two different SCs network with common units. In this model, four different decision makers (DM) are handled. Two of them are the upper level DMs: the manufacturers of allied SCs. The others are lower level DMs: common suppliers and common collection centers. The objective functions of the manufacturers consist of four parts: Transportation cost, purchasing cost, fixed operating cost and inventory cost. The objective functions of the common suppliers consist of only selling costs of the components. The objective functions of the common collection centers consist of selling costs, transportation cost and fixed opening cost. In this model, end product consist of four different components. In this study, we handled the proposed model with Selim and Ozkarahan-SO (2008) approach and Torabi and Hassini-TH (2008) approach. As a new approach, we proposed to find the relative importance of the objectives in the SO and TH methods by using Fuzzy AHP and fuzzy TOPSIS for obtaining these weights. The performance of the proposed approach has been examined on a numerical example and the results are discussed for a number of scenarios.

3 - An AHP Model for Determining Appropriate Public Locations for Automated External Defibrillator (AED) Deployment: A Case Study in the City of Valencia

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Cardiovascular diseases is reported by World Health Organisation to be the leading cause of death globally, more than 50% of these deaths being caused by sudden cardiac arrest. Sudden cardiac arrest may be defined as unexpected loss of heart function, breathing and consciousness caused by an electrical disturbance in heart, which disrupts its pumping action and stopping blood flow to the rest of the body. The only effective treatment is immediate defibrillation supported by cardiopulmonary resuscitation (CPR). The unpredictable and fatal nature of sudden cardiac arrest puts emphasis on the necessity of an immediate treatment for any chance of survival. It is agreed by all authorities that the chances of survival decrease by about 10% with each minute without defibrillation. Automated external defibrillators were designed to make the earliest defibrillation possible. An automated external defibrillator (AED) is a portable device which delivers an electric shock through the chest to the heart, which can restore the normal heart rhythm of a sudden cardiac arrest. An AED does not require the user to be a medical professional since the device decides whether an electroshock is necessary or not. Additionally, it guides the user with visual and verbal instructions throughout the process. AEDs are proven to be safe and effective to be used by not only healthcare professionals but also laypeople. AEDs created a whole different perspective to the concept of resuscitation and first-aid by enabling any first-responder to be able to deliver the life-saving defibrillation treatment within moments of any incident, long before the ambulance arrives. This led the question to be “where to place AEDs?”, searching for a solution to the unpredictability of SCA and the cost of AEDs. This has been a popular topic among researchers in resuscitation domain. Yet, the problem has not been studied under decision making domain sufficiently. The aim of this study was to provide a novel approach to the problem by using Analytical Hierarchy Process (AHP) and offer a solution in terms of a case study in City of Valencia, Spain. After reviewing the previous studies on the subject, criteria and potential categories for alternatives were determined. The decision problem is constructed of four main criteria, three of them having two sub-criteria each. The location alternatives were discussed by local experts and a final list of 80 alternatives were agreed on. The pairwise comparisons were made by a decision maker who is an expert of AED programmes under supervision of a professor who is an expert on AHP. Criterion response time was the most important criterion with a weight

of 65.07%, followed by SCA risk (23.13%). The weight of coverage capacity was 7.65% and that of availability of assigned user was 4.14%. This showed that the most critical criterion for selecting the suitability of a location for AED deployment is the response time. A rigid ranking of the alternatives would not be of perfect meaning since the AED placement project will probably not be done as one AED at a time, and also the main purpose of this study was to serve as a general guideline for projects in the near future. For this reason, the alternatives were grouped according to their global scores with respect to the goal. The global scores of all alternatives were analysed and four groups with descending priorities were formed. These groups were aimed to serve as a guideline or a road map for future projects for AED deployment. Additionally, a sensitivity analysis was performed to test the robustness of the model with regard to the changes in weights of criteria. It was observed that especially the first-priority alternatives are not highly sensitive to the changes in weights of criteria, showing the importance of selecting these locations if a pilot study is intended. However, it should be noted that a pilot study might fail as a determinant of success of an AED deployment project and it might be a better choice to use the results of this study as a road map which will lead a project that will cover all locations throughout a time period.

4 - A New Multi Objective Linear Programming Model for Optimizing a Closed Loop Supply Chain Network using Fuzzy AHP

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Today, along with the reduction of resources of the companies, sustainability, green practices and recycling activities are gained more importance. This study is inspired by a real world Closed Loop Supply Chain (CLSC) modelling problem on the basis of the automotive industry which includes customers, collection centers, dismantler centers, refurbishing centers, plants and distribution centers. According to proposed model the network begins with the purchase of raw materials over the tonnage in specific proportions from the raw material suppliers to be used in suppliers. First converting raw materials into usable parts processed by suppliers, then parts are delivered to the plants ready to be assembled for use in productions. Finally, the products are delivered to customers through dis-

tribution centers. Reverse flow starts with the collection of used products from customers by collection centers. Collected products are sent to dismantler centers for disassembling process. At this point, it is observed heterogeneous flow through the whole network and we developed a weight ratio, which is based on bill of material concept, to transform this heterogeneous flow into homogenous flow. The objective function has four components. The first component represents the cost of transportation on some arcs of the network in the forward and reverse chains. The second component represents the cost of purchasing over all parts. The third component represents the cost of refurbishing of product parts and the last one represents the fixed costs associated with locating the plants and retailers, respectively. The automotive industries nature include an insular management system incapable of reciprocal operation with other, related information systems. Thus, we examined two different decision making types. First, we asked to the top management for evaluating the weights of objective functions and we get a comparison matrix by Fuzzy AHP. Then, we asked to related departments for weighting objectives individually. In order to show the differences of point of views of the departmental silos in the organization and the top management we solve the model with Weighted Sum Method using these two different weights. After obtaining weight of objectives by fuzzy AHP we continue to solution phase by using the Weighted Sum Method for multi-objective programming optimization. Finally the computational results are presented to show and validate the applicability of the model.

★ MO-3- δ -HS3

◆ Industry and Business Applications

Monday, 11:30–13:10 – Room HS 3

Session: Portfolio Optimization 1

Chair: Richard Allendinger

1 - A Rebalancing Worst-Case Omega Ratio Portfolio Model

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It has been documented that the optimal asset

allocation can be misled by the uncertainty in asset returns. A variety of robust portfolios are proposed to deal with this issue to improve the portfolios efficiency. Previous studies by Zhu and Fukushima (2009) and Huang et al. (2010) have integrated conditional value-at-risk (CVaR) with the robust portfolio mechanism to model the extreme loss. However, the extreme loss can be ignored if the expected return is higher than the expected loss. Kapsos et al. (2014) further propose the worst-case robust Omega ratio model (WCOmega) by integrating the maximization of portfolio returns and the minimization of portfolio in the CVaR model. Our study proposes a portfolio model that advances WCOmega model and considers transaction cost and short selling. We apply multiple objective programming and then use the return date of a wide range of international assets during 2001 and 2012. The performance is measured by Sharpe ratio, Omega ratio, weights of short selling, transaction cost, realized market value, and realized return. We compare the performance of our proposed model with two other robust portfolio models, the worst-case conditional value-at-risk (WCVaR) and the relative robust conditional value-at-risk (RRCVaR). The empirical results show that the proposed WCOmega demonstrate better performance than the other two modified CVaR models. The over-time portfolio rebalancing shows the differences in asset allocation that is caused by different model characteristics.

2 - Multiple Objective Chance Constrained Recourse Approach for Portfolio Selection

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This paper addresses the multiple objective stochastic portfolio selection problem where the portfolio return has to be maximized and the portfolio risk is to be optimized (Ben Abdelaziz et al, 2007). We propose to model the portfolio risk using, the Capital Asset Pricing Model, Beta risk measure. We follow Ben Abdelaziz and Masmoudi (2013) and we consider that the Beta of the securities is defined as random variable and depends on the states of the market (the up market and the down market). We suppose that the portfolio return should be at least equal to a predetermined stochastic goal and in case a portfolio doesn't achieve that target, a recourse cost is generated to penalize it. Usually, in a recourse approach, we consider the expected value of the deviation between the portfolio return and the predetermined target as a recourse cost (Masmoudi and Ben Abdelaziz, 2012). In this paper, we propose a new version of the recourse approach where the recourse cost is the

worst deviation that may occur with a predefined probability. The new approach is a mix between a goal programming approach, a recourse approach and a chance constrained approach. We illustrate the paper results using an empirical example of weekly returns from securities listed in the Bourse of Bahrain.

3 - A Multiple Objective Stochastic Programming Model for Portfolio Selection: Case of Bahrain Security Market

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In the security market, many investors are insufficiently skilled or interested in selecting and managing their portfolio and hence they usually refer to professional agents to advise them about the initial portfolio to hold. Agents may belong to a financial institution, an investment company, a bank, etc. Investors may select among competing agents and bargain with them about the desired rate of return on investment. If such a rate is not attained, the investor may not renew his/her investment contract with the agent and thus agents would better fulfill the investor requirements to build a good reputation in the market. In order to select their initial portfolio, agents usually refer to the Markowitz [6] mean-variance model. The Markowitz model can be viewed as a multiple objective program where the portfolios return should be maximized and the portfolios variance has to be minimized [3]. In the literature, additional objective functions were considered, among them, the liquidity, the dividend, the number of shares per market, etc [8]. The variance used by Markowitz to quantify the portfolios risk leads to a quadratic stochastic program model that is difficult to solve for a portfolio selection problem with a large number of securities [5]. Recently, Ben Abdelaziz et al. [4] proposed to optimize the portfolio (market) risk using securities beta instead of the variance. According to the Capital Asset Pricing Model (CAPM), the beta of the i th security quantifies the i th security's co-variation with the market return [7]. Since the beta of a portfolio is a weighted sum of the betas of the component securities, a linear objective function can be used to measure the portfolio market risk. Agents would like to attract and retain investors by offering them higher rates of return [1]. In our study, we differentiate between two rates of return the investors contract with the agent. The first rate is the minimum acceptable rate of return that an investor is willing to receive. If such a rate is not achieved, the agent is forced to pay a penalty to keep the investors wealth in his/her portfolio. Such a rate is usually greater than or equal to the market risk free rate. The second rate is the ideal rate of return for the investor. If such a rate is attained or exceeded,

the agent will improve his/her reputation in the market and will be able to attract other investment funds.

In this paper, we address the single period portfolio selection problem where an agent has to achieve multiple target rates of return. We suppose that target rates, the minimum acceptable rate and the ideal rate, are of stochastic nature and are defined based on the market return. We propose a multiple stochastic goal approach to build a certainty equivalent program for the multiple objective stochastic linear program (4). The proposed approach allows considering multiple stochastic goals for the return objective function. We illustrate the proposed approach using empirical data from Bahrain bourse [2].

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4 - Multiobjective Optimisation of Strategic Biopharmaceutical Portfolio Management with Integrated Supply Chain Management

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The process of selecting, manufacturing and successfully marketing products from the discovery phase is a fundamental yet highly complicated challenge that biopharmaceutical industries face today. Strategic decisions include drug selection, priority of development and outsourcing of activities. With typical development times of a new molecular entity (NME) of 11.4 - 13.5 years and fully capitalised costs currently \$1.8 billion (Paul et al., 2010) it is imperative that drug developers optimise their strategies to ensure minimal cost of testing, time to market and increase profitability. With the added complication of development and outcome uncertainties during the process, encompassing target identification, validation, drug discovery, preclinical testing, clinical trials (PI, PII and PIII), FDA approval and finally manufacturing, the development of NMEs is high risk. For example, in 2007 only 19 NMEs were approved to enter the market by the US Food and Drug Administration (FDA) (Paul et al., 2010). Pharmaceutical drug development management has received significant attention in the literature work (Maravelias and Grossmann, 2001; Colvin and Maravelias, 2008). Chen et al. (2012) then went on to improve the management of clinical supply chain in addition to strategic portfolio management. Based on the work of George and Farid (2008) that tackled the biopharmaceutical portfolio management using an evolutionary algorithm-based framework, this paper aims to provide a scenario-based stochastic mixed-integer linear programming (MILP) framework for the optimal biopharmaceutical drug portfolio strategies, with integration of the supply chain network distribution of drugs during the market stage. The key decisions to be optimised involve (i) the selection of promising drugs forming the drug portfolio, (ii) the timing sequence of stage schedules, (iii) the choice of in-house, out-source or partnership activities for the manufacturing at Phase I/II/III and market stage, (iv) production levels at the different manufacturing sites, and (vi) the logistic network from the manufacturing sites to the markets via distribution centres. Two objective functions are considered, including the maximisation of the expected net present value (NPV), and the probability of being profitable. The classic -constraint method is used to obtain a set of Pareto-optimal solutions. The developed model is applied on a case study containing potential NMEs that are currently at the initial stage of their development cycle. A series of scenarios will be generated that model the probability tree of task outcomes for multiple drugs. This paper will aim to illustrate correlations between NPV and proba-

bility whilst analysing the affect production capacity, available capital and storage capacity has on the two objective functions, and the trade-off between the two objective functions.

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★ MO-3-λ-HS4

◆ Fuzzy Approaches, Decision Making under Fuzziness

Monday, 11:30-13:10 – Room HS 4

Session: Fuzzy Multiple Criteria Decision Making 1

Chair: Heinrich Rommelfanger

1 - Can Fuzzy MULTIMOORA solve the Problem of Excessive Spread in Sampling?

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Decision Making can be quantified by setting up a Decision Matrix with for instance Objectives or Criteria as columns and alternative solutions like Projects as rows. In order to concretize the elements of the matrix a preliminary sampling may be necessary. In this study Decision Making is quantified in its objectives, with the problem of normalization, due to the different units of the objectives and with the problem of importance. A MULTIMOORA method, chosen for its robustness instead of many other competing

methods, will solve the problems of normalization and of importance, whereas Fuzzy MULTIMOORA will take care of the annoying spread in the samples. Indeed Spread, the double of the Standard Error, sometimes concerning deviations up to 38% (circulation of a local newspaper in Belgium on basis of 10,000 interviews), makes the outcome rather doubtful. Is it possible to avoid any spread and in this way make a sample exercise worthwhile inside the usually accepted marketing confidence level of 95%, meaning a 5% probability that outside conditions could interfere? Decision Making in Residential Construction is preferentially based on preliminary sampling with a choice of contractors on the one side and preferences of interested investors on the other. An example is taken from: Brauers, W. K. M.; Zavadskas, E. K.; Turskis, Z and Vilutiene, T. 2008. Multi-Objective Contractor's Ranking by applying the MOORA Method, *Journal of Business Economics and Management* 9(4): 245-255. Construction, taking off, maintenance and facilities management of a building are typical examples of consumer sovereignty: the new owner likes to have a reasonable price to pay, to have confidence in the contractor, to know about the duration of the works, the service after completion and the quality of the work. On the other side the contractor has his objectives too, like the satisfaction of the client, diminishing of external costs and annoyances and the management cost per employee as low as possible. In other words it concerns a problem of multi-objectives. Therefore a final ranking will show the best performing contractor from the point of view of the clients but also from the point of view of the contractors. From information of the Dwelling Owners Association of Lithuania, a panel of 30 owners of dwellings chosen at random agreed with these 9 objectives The 9 objectives with 30 interviews even chosen at random mean a standard error of 0.09, namely 9% under or 9% above the real percentage or a Spread of 18%. Beside this formula: one has to be aware of the universum around the sample, which is not directly quantitative. The Universum was not a disturbing factor in this case. For the high spread of 18% we look for a solution by the methods MULTIMOORA and Fuzzy MULTIMOORA. To the Ratio Method and the Reference Point Method of MOORA a third method is added in MULTIMOORA: the Full Multiplicative Form. The use of three different methods of MOO is more robust than using of one or two, making MULTIMOORA superior to all existing methods of Multiple Objectives Optimization. As in the given example 9% less with 9% more is symmetrical no result is found. Indeed if you take a row or a column in the decision matrix the numbers will form a Gauss curve as a normal distribution, i.e. quite symmetrical. If it had been a particular normal distribution or even a non-normal distribution there would have been no problem. Consequently MULTIMOORA can

not solve the problem of spread. It was Fuzzy MULTIMOORA which brought the solution by considering all the possible extreme positions delivered by the standard error, whereas normal distribution was no more a disturbing hindrance. The example of disclosing the desiderata of potential buyers of property in Lithuania presents an illustration of the theory.

2 - Intuitionistic Fuzzy Hybrid Approach Based Failure Mode Effects Analysis For Risk Assessment

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Failure mode and effects analysis (FMEA) is an extensively employed risk evaluation tool for identifying and eliminating potential failures in manufacturing and service systems. FMEA deals with the proactive treatment of the system in order to prevent the failure while the other risk evaluation techniques find a solution after the failure realize. In conventional FMEA, the risk priorities of failure modes are defined with so-called risk priority numbers (RPNs), which can be achieved by multiplying the scores of risk factors like occurrence (O), severity (S), and non-detection (D). The terms of O, S, and D are the probability of the failure, the severity of failure, and the detectability of the failure, respectively. However, the crisp RPN method has been criticized to have several shortcomings. The conventional FMEA can't take into consideration the importance degrees of O, S, and D so that it admits them in equal importance degree. This situation can be obtained the mistaken results when the conventional FMEA implements to the real life problems. For example, when O, S, D parameters are 2, 4, 1 and 1, 2, 4 for two situations, respectively, both RPNs are 8 and the same. Different values of O, S, and D can provide the same RPN but hidden risks of them can be different totally. Therefore, it can be caused non-determining failure mode with the highest risk, and the waste of resource and time. It is difficult to define the values of O, S, and D parameters precisely. Several information in FMEA is generally expressed with the terms of such important, very high as linguistic. O, S, and D parameters of RPN are discrete ordinal scales according to traditional FMEA so that it causes meaningless and misleading information due to multiplication of O, S, and D parameters. We propose the integrated IFAHP- IFVIKOR approach with group decision making in order to overcome these limitations in the conventional FMEA. Intuitionistic fuzzy set (IFS) contains a membership function, a non-membership function, and a hesitancy function. In this study, intuition-

istic fuzzy analytic hierarchy process (IFAHP) method is used to assess O, S and D risk factors related to weights. IFAHP can be utilized to cope with more complex problems, where the experts have some vagueness in defining preference values to the criteria examined. For selecting the most serious failure modes, intuitionistic fuzzy VIKOR (IFVIKOR) method are used to determine risk priorities of the failure modes that have been identified. IFVIKOR method investigates to rank and select alternatives, and defines compromise solutions, which provides the maximum group utility for the majority and a minimum of individual regret for the opponent, for a problem with conflicting criteria, which can help the experts to achieve a final decision. Therefore, IFVIKOR has big chance of success for failure modes selection process in risk assessment. As a result, IFVIKOR is proposed because the prioritization of examined failure modes is based on the linguistic expression, specifically to overcome some limitations of the traditional FMEA. A number of decision makers interact to achieve unique decision in group decision making. Each decision maker might have special goals, opinions, and different evaluation process, although they aim to select the best alternative. The decision makers have to define their preferences by using a set of numerical values. The utilization of same preference by all the decision makers has been a widespread implementation in group decision making but it can't generally be possible in actual implementation because of special characteristics of each decision maker such experience, abilities, and knowledge. The importance degree of decision makers are assigned in order to show their differences in the group decision making problem. DST, which is called Dempster Shafer Theory, can be utilized to aggregate the opinions of experts based on intuitionistic fuzzy decision matrix. DST, which is the capability of dealing with the vagueness, can combine pairs of bodies of evidence to ensure new evidence. It has been extensively implemented to many domains, such as decision making problems, defining influential nodes, and so on. There is no study about FMEA using integrated IFAHP- IFVIKOR approach with group decision making. This methodology allows decreasing the uncertainty and the information loss in group decision-making. Six criteria are determined as risks that caused from work equipment, noise, non-ergonomic working posture, high heat stress, increasing of work pace by depending on the demand, bullying and victimization according to the experts' opinions and the literature. This study purposes to ensure an analytical tool to determine the highest failure mode for a textile firm. The sensitivity analysis can be realized so that it is to exchange each expert's weight with another expert weight while the weights of other expert remain unchanged.

3 - Advantages of fuzzy systems for

solving real-world optimization problems

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Classical mathematical programming models require well-defined coefficients and right hand sides. In order to avoid a non-satisfying modelling usually a broad information gathering and processing is necessary. In case of real problems some model parameters can be only roughly estimated. While in case of classical models the vague data is replaced by “average data”, fuzzy models offer the opportunity to model subjective imaginations of the decision maker as precisely as a decision maker will be able to describe it. Thus the risk of applying a wrong model of the reality and selecting solutions which do not reflect the real problem can be clearly reduced. The modelling of real problems by means of deterministic and stochastic models requires extensive information processing. On the other hand we know that an optimum solution is finally defined only by few restrictions. Especially in case of larger systems we notice afterwards that most of the information is useless. The dilemma of data processing is due to the fact that first we have to calculate the solution in order to define, whether the information must be well-defined or whether vague data may be sufficient. Based on multi-criteria programming problems it should be demonstrated that the dilemma of data processing in case of real programming problems can be handled adequately by modelling them as fuzzy system combined with an interactive problem-solving. Describing the real problem by means of a fuzzy system first of all only the available information or such information which can be achieved easily will be considered. Then we try to develop an optimum solution. With reference to the cost-benefit relation further information can be gathered in order to describe the solution more precisely. Furthermore it should be pointed out that some interactive fuzzy solution algorithms, e.g. FULPAL provide the opportunity to solve mixed integer multi-criteria programming models as well.

★ MO-3- σ -HS5

◆ Multi Objective Optimization

Monday, 11:30–13:10 – Room HS 5

Session: Vector optimization

Chair: Stefan Ruzika

1 - Properties and Representation of Nondominated Sets of Multi-objective Combinatorial Optimization Problems

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We study the properties of nondominated sets of several multi-objective combinatorial optimization (MOCO) problems. We investigate how the number of nondominated points varies with the parameters of the problem and how those points are distributed over the objective space. To do this, we first partition the objective space into a predetermined number of regions and estimate a density parameter for each defined region. Then, we develop density-based performance measures to assess the representativeness of a given set of points. Based on our findings, we also develop a method to find a representative subset for MOCO problems. We first approximate the nondominated set with a hypersurface and then generate a set of points that represent all nondominated points. We conduct experiments on randomly generated instances of MOCO problems. The results show that a reasonable number of points that represent all nondominated points are generated.

2 - A globally convergent method for multiobjective optimization

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Exact global search methods are a well known class of algorithms belonging to the single objective optimization literature. These methods usually demonstrate appreciable speed of convergence but their specific strength is that they guarantee that the global optimum of the function under exam is approximated with arbitrary precision in a finite time.

A first well known method of this type is the Pijavski-Schubert algorithm.

Unfortunately, it appears that in the available multiobjective literature there has not been so much attention dedicated to the complete or deterministic methods for global search, although now and then we have witnessed the attempt of producing adaptations of some of these methods for the multiobjective case.

However, at least to the knowledge of the authors, most of those adaptations follow one of the following schemes:

1. the method uses a scalarization of the multi-objective problem to a single objective optimization problem and then applies the global algorithm to the scalarization, or
2. the method translates the underlying idea of the global method in the multiobjective format, but then applies a non deterministic method to produce the Pareto set.

In both cases, we encounter the following problems contrasting with the global and exact character desired:

1. the method cannot guarantee a systematic covering of the Pareto set, or
2. the method operates at some point some non deterministic choice.

Well-known and widely used methods belonging to the latter class are the evolutionary multiobjective optimization methods.

In this paper, our main scope is to present a Lipschitz global optimization algorithm for multiple objectives, namely an extension of the Pijavski-Shubert method which does not make use of auxiliary functions and that approximates the set of global Pareto optima within a desired tolerance measured according to the Hausdorff distance.

This method produces an approximation of the Pareto set consisting in a covering composed by arbitrarily small hypercubes. In perspective, the method can be combined with surface tracing methods to generate a faithful geometric surrogate of the Pareto set.

3 - A coverage-based Box-Algorithm to compute a representation for optimization problems with three objective functions

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A new algorithm for optimization problems with three objective functions is presented which computes a representation for the set of nondominated points. This representation is guaranteed to have a desired coverage error and a bound on the number of iterations needed by the algorithm to meet this coverage error is derived. Since the representation does not necessarily contain nondominated points only, ideas to calculate bounds for the representation error are given. Moreover, the incorporation of domination during the algorithm and other quality measures are discussed.

★ MO-3- χ -HS6

◆ Environment, Infrastructure & Emerging Applications

Monday, 11:30–13:10 – Room HS 6

Session: Environmental Decision Making 1

Chair: Victor Sousa

1 - Ranking of the Provinces in terms of Air Quality with a Multi-criteria Decision Making Method

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Every year environment authorities of every country publish the quality reports on the natural elements they have; like air, water and soil. Such reports provide an insight about these essential elements for the directors of the related regions and give them chance to take measures when it poses a risk. Air is the indispensable element of the life phenomenon and is needed by every living creature. At the present time air is one of the most important elements whose availability is sought on other planets in space researches. Air quality varies according to the quantities of the materials in it. Especially during winter tide air pollution is relatively high in some regions depending on the meteorological conditions. Air pollution arising from heating process reduces the quality of life by affecting the human health. Nowadays local, regional and global problems are faced commonly based upon air pollution. There can be air pollution especially in metropolises due to some reasons like extensive urbanization, unplanned settlements, increase in number of motor vehicles, unplanned industrialization, poor quality fuel usage, topographical and meteorological conditions. Numerous pollutants exist in the air such as Particulate Matter (PM), Sulfur Dioxide (SO₂), Nitrogen Oxides (NO_x), Carbon Monoxide (CO), Ozone (O₃). In this study all provinces in Turkey are ranked according to the air qualities they have based on the criteria values published on the Environment Status Report 2013 of the Ministry of Environment and Urban Planning. The status of the provinces in terms of the air qualities they have can be seen with this ranking which is done with SMAA (Stochastic Multi-criteria Acceptability Analysis); a stochastic multi criteria decision making method.

2 - Water resources vulnerability assessment of South Korea using SWAT & SWAT-CUP model

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Climate change has affected our lives in various ways as a result of global warming in recent years and hydrological cycle change according to climate change represented by non-stationarity of rainfall or temperature has also clearly accepted.

For that, much research to water resources vulnerability assessment and strategy are variously being made. However, in South Korea, research has been focused on just one basin and water resources vulnerability assessment according to total basin is not enough. Therefore, this study extends this limited dataset for South Korea by assessing the vulnerability of water resources for 12 basins. The basins were built using a SWAT (Soil and Water Assessment Tool) model, developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds with varying soils, land use, and management conditions over long periods of time. After building SWAT model, parameter optimization in terms of runoff was calculated using the SWAT-CUP model. Runoff for each watershed was estimated using applied optimized parameters to input into the hydrological model (SWAT). In the increasing order of runoff in 2009 and 2011, the river basins can be arranged as follows: Han River, Nakdong River, Geum River, and Youngsan River. The magnitude of runoff for each basin in 2010 was Nakdong River, Han River, Geum River and Youngsan River order. The following basins have been arranged in increasing order of specific discharge, i.e., runoff per watershed area: (as recorded in 2009) Youngsan River, Nakdong River, Geum River, and Han River; (as recorded in 2010) Youngsan River, Geum River, Nakdong River, and Han River; (as recorded in 2011) Geum River, Youngsan River, Han River and Nakdong River and of runoff per population: (as recorded in 2009) Youngsan River, Geum River, Nakdong River and Han River; (as recorded in 2010) Youngsan River, Geum River, Nakdong River, and Han River; (as recorded in 2011) Youngsan River, Geum River, Nakdong River, and Han River. Water resource vulnerability assessments were carried out for 12 basins in South Korea. Based on these results, the indicators were classified by demand and supply side of water supply consisting of Social/Economics, Water Availability, Environmental, and SWAT. To assess water resources vulnerability, we used the technique for order of preference by similarity to ideal solution, which is based on multi-criteria decision making. The results indicate that water resource vulnerability of basins increases as follows: Sapgyo River, Dongjin River, Hyeongsan River, Ansung River, Seomjin River, Mangyung River, Nakdong River, Youngsan River, Taehwa River, Geum River, Han River, Tamjin River. The results from this study will be assessed for current hydrological conditions and be utilized in water resources management through a high-resolution model built in multi-space. Also, this study will be used index development for climate change vulnerability assessment.

3 - Multi-Objective Decision Making in Asphalt Recycling: A Municipality Case

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The usage of asphalt recycling has been increasing since the invention of asphalt recycling machines. The reason is that it saves large amount of bitumen while renewing the roads and this contributes to efficiently use bitumen which is a natural resource. There has been a higher demand on application of asphalt recycling technology in Turkey. Recent years have witnessed serious drawbacks on asphalt recycling, including budget and time limitations. This study investigates the optimum usage of bitumen in recycling the asphalts of a bounded region of Cankaya Municipality by using multi-objective decision making tools. It is concluded that the recycling project meets 90% of the given objectives and large amount of bitumen is saved.

4 - Managing a natural resources system under sustaining limit conditions: a modified MCDM dynamic programming algorithm.

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This approach to sustainability over natural resources management comes as a development of the experience collected through the application of a model based on MCDM techniques, namely to the river basin of Lea in North Portugal. Those techniques facilitated the involvement of the representatives of the several uses of the potentially available water in the design of the rules to carry out the management. There was success with this model of optimization in ruling management decisions ("driving the system", as we like to name it). The initial deterministic approach works with combinations of values of penalty functions for each pair of uses and criteria (Faustino and Sousa, 2002) whenever all demands are not to be satisfied. This MCDM techniques, along with dynamic programming, were compatible with a further stochastic approach (Sousa et al, 2009), using fuzzy numbers, either for the process of inflows to the system or for the flotation on the assessment from the decision makers representatives. However, further concerns arose about the efficiency of the model, with the acknowledgment that simple aggregation of those independent pairwise penalty functions were neglecting different levels of interference between singular effects, some of them with significant correlations. Abbas and Matheson, 2009, introduced and developed the concept of "value aspiration equivalent" to overcome artificial independence of targets and regulate trade-offs among the performance objectives. This concept was very useful and, along with the tech-

niques to find the “triple bottom line” (TBL) of social environmental and economic benefits displayed in Govindan et al (2012), led to the determination of a sustaining inferior limit surface (SILS) where a discrete but large number of parameters of the system are collected with the various combinations values that were considered to border unsustainability. The assessment of the set of these extreme conditions went along with consultation of the board of stakeholders. In the particular system we are dealing with, those parameters include level of water in the reservoir dam, humidity state of the land to irrigate, state of the system of water supply, ecological demands downstream and lowest expectation of immediate inflows. Decision making came across the acceptance of situations always significantly far from the combination of minimal targets for each use of the water and was guided by World Commission on Environment and Development (WCED) recommendations in what concerns the complex definition of sustainability. This process of building that SILS surface began with the elicitation of a situation that conveyed to consensus as being at the borderline of acceptance in terms of sustainability. Besides this basic combination of parameters, the decision makers were asked to agree on trade-offs between each pair of parameters, having in mind the minimal values for each parameter on its own. The multiple crossed influences among all parameters was then studied and placed in a square matrix. All its elements may assume all values between the extreme values of the trade off assigned for each position in the matrix. A discrete variation on each element gives a finite number of those trade-off matrices and, by multiplication with the elicited basic vector, an equal number of vectors that build the SILS surface. The basic combination is related, of course, with the unitary matrix. The incorporation of this sustainability condition in management decisions reflects on the dynamic programming algorithm, still commanded by the minimization of aggregated penalties through the time gap under study, but now with additional state restrictions to the performance of that optimization. As expected, indications for the system driving remain as in the former optimization for most of the simulations, but show significant differences for the uses of water under severe shortage of inflows and, moreover, less resilience of the system in order to overcome those conditions.

Monday, 14:30–16:10

★ MO-4- α -HS1

◆ Behavioral Aspects, Group Decision Making, Negotiations, Interactive Methods, Software

Monday, 14:30–16:10 – Room HS 1

Session: Behavioural Issues and Negotiations

Chair: Gregory Kersten

1 - Behavioral Analysis of Human Subjects in Centipede Games Based on Agent-based Simulation

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This paper attempts to explain the behavior of the human subjects such that they deviate from the strategy related to the subgame perfect equilibrium of the centipede games which is a game model in extensive form. In the relevant research of the games in extensive form, a lot of laboratory experiments using subjects are reported. The experimental results indicate that the subjects have selected the strategy related to the equilibrium in almost types of games in extensive form. However, as the results of experiments relevant to the centipede games, a majority of the subjects have selected strategies deviate from the subgame perfect equilibrium (Murphy et al., 2004; Rapoport et al., 2003). From the result, it is complicated that the subjects make decision based not only on payoff maximization, but also on other criteria. Additionally, the decision of human is not always rational, and trial-and-error process would be adopted in decision making. Therefore, this paper conducts the agent-based simulation for behavioral analysis of the human subjects by using adaptive artificial agents which make decision based on multiple criteria. The mechanism of decision making of the adaptive agents are constructed based on neural network, and the network are evolved by using genetic algorithm based on the result of the games. As mentioned above, the subjects are complicated that they make decision based on multiple criteria and the behavior delivering a good results would be reinforced, adversely, the behavior delivering a bad result would be dumped into the dustbin. Here, a neural network can implement a function such that generate a single or multiple output based on multidimensional input data, and several appropriate neural network can be acquired through the learning process of neural network using genetic algorithms. The decision making of subjects can be interpreted as a mapping from multiple input to multiple output, thus the neural networks which are evolved based on genetic algorithms would be appropriate for decision mechanism of the adaptive agents (Nishizaki, 2007). This paper conducts several kinds of simulation experiments using the agent-based simulation system. By comparing the result of the laboratory experiments using the subjects (Rapoport et al., 2003) and the result of the simulation using such adap-

tive agents, the following findings are shown. (i) The human subjects adopts trial-and-error process of decision making. (ii) The aim of such trial-and-error process of the subjects is not only maximization of the payoff which they obtain in a single game, but the subjects aim to maximize the cumulative payoff or utility which they obtain in whole games. (iii) The risk attitude for the cumulative payoff is risk averse. (iv) The risk attitude of the subjects are inequitable. (v) In the process of trial-and-error, the subjects intentionally make error.

2 - Bounded Capability to Make Rational and Consistent Choices

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In this paper, we have studied the capability of people to make rational and consistent choices. 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 and 3 criteria. All choice problems were generated from one basic data set by modifying the order of criteria and alternatives, and randomly changing the criteria values. The measuring of rationality is based on dominance, and as the measure of consistency we used differences in choices. We also gathered background information with an aim to understand and explain the choice behavior of the human beings. Our results imply that 1) people are making non-rational choices even in a simple experiment, and 2) the choices are not very consistent with a linear value function.

3 - A Paradox of Multi-Criteria Decision Making Processes

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1. Background

In the global environment decision-makers should take into account several objectives, following that decision situations are multi-criteria. Several criteria may contradict to one another,

and the outcomes of some objectives could not be measured quantitatively. It limits a decision-makers' ability of judgment. Moreover, in a dynamic world, in which technological changes occur on a regular basis, the considerations of decision-makers have to be changed also frequently and dramatically. However, decision-makers cannot adjust their decision mechanism instantly. This leads us to the need for better understanding of a human decision process. The rationality assumptions of Savage (Savage 1960) are the basis for the information value assessing which is used the Information Structure Model (McGuire and Radner 1985). According to the rationality assumptions, a decision-maker can change her decisions instantly and formulate a joint utility function constituted from different criteria. But is it so?

The third rationality assumption (Savage 1960) is based on an infinite calculation ability of a decision-maker, whether she can combine different criteria in a joint utility function. Furthermore, the traditional Decision Theory assumes that a decision-maker can identify an optimal decision, although some aspects of Bounded Rationality may cause her to make a decision with satisfied expected outcomes (Simon 1957, Rubinstein 1998). Suppose the following conflict during a decision situation: There are several criteria for decision making and a decision-maker cannot rank them. Hence, the Bounded Rationality leads to a satisfied decision and not to an optimal one.

In contrary to optimizing (getting the maximal outcomes), the term in the context of Decision Making, Simon (1957) suggests satisficing, which means that a decision maker is looking for satisfied outcomes rather than maximal outcomes in a decision situation. Ahituv and Wand (1984) integrate this approach in the Information Structure Model defining a satisfaction level. The outcomes above the satisfaction level get the value of 0, while the outcomes that are less than this level get the value of 1 in the outcome matrix. This model presents a decision situation as a dual problem to the outcome-maximizing problem, in which the possibility to get unsatisfied (risky) outcomes is minimized.

There are some normative models that describe a multi-criteria (objectives) function ("Multi-Objective Utility Function" is presented in Keeney and Raiffa 1993, Keeney 1992). Those models allow to rank criteria and to calculate a joint utility function. Ronen and Spector (1995) use the Information Structure Model in order to set a size of a sample group and a level of acceptance in quality control programs. They assume that a decision process is based on multi-decision criteria, though a decision-maker does not know how to integrate them into a joint utility function.

2. Motivation

The traditional Utility Theory suggests an optimization method. This method, however, is

not always appropriate in a modern decision environment. This research presents a new type of a decision-maker: an optimizer which is subject to rational satisfaction. Such a decision-maker does not intend to evaluate an optimal expected utility. She makes her decision based on a max-min satisfaction level for each criterion. The presented analytical model is an extension of the Information Structure Model (which in fact, is another way of presentation to decision trees), which allows to demonstrate the dual paradox of decision-makers in a multi-criteria decision situation. For example, suppose that the CIO of an organization should choose between two strategies: an innovation that can give her organization a competitive advantage and risk averting strategy that facilitates to avoid risks. The decision to implement a new ICT should take account of these two criteria, although their weights cannot be defined straightforward.

3. Objectives

This research presents an analytical model which is build using a normative approach in order to understand the mechanisms of multi-criteria decision making processes. A consequent analysis allows explaining a decision maker's behavior under the assumptions of bounded rationality. The analysis deals with decision situation where it is assumed that a decision-maker cannot formulate a joint utility function constituted from different criteria which are completely inestimable or estimable partly. Moreover, the model allows revealing problematic issues of multi-criteria decision making processes, for example, when an improvement of a service paradoxically leads to a decline in a firm's market share.

The research defines, characterizes, analyzes and illustrates a new type of a decision-maker, called as an optimizer which is subject to rational satisfaction. The presented model is an extension of the Information Structure Model to a multi-criteria (multi-objective) decision environment. Moreover, the model allows to implement the general informativeness ratio between information structures to a multi-criteria decision situation.

4. Methodology

The research presents an extension of the Information Structure Model to a multi-criteria decision environment. The model allows to implement the general informativeness ratio between information structures to such environments. Moreover, the research extends the Blackwell's Theorem and reveals the abnormal issues of multi-criteria decision-making processes. The model is based on the assumption of Bounded Rationality (Simon 1960, Rubinstein 1998), that is a decision process takes account of several criteria and a decision-maker cannot formulate a joint utility function constituted from different criteria. Hence, the optimal solution could not be obtained and a different approach is proposed, which is called as optimization subject to rational satisfaction.

4 - If I tell you the truth, I get less and you'll be less satisfied

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Most studies on conflict resolution and negotiations focus on bilateral interaction. However, multi-bilateral interactions are no less prevalent in business and government contexts. While multi-bilateral negotiations (MBN) are common, there has been little research on these processes. In contrast, multi-attribute auctions (MAA) that can be used the same or similar problems have been studied extensively. Recently, several systems have been developed that allow the study of MAA and MBN in realistic settings. We used these system to study auctions and negotiations in the procurement context, in which a buyer wants to award a contract to one of several sellers.

There is competition between sellers who want to get a contract from a single buyer. This competition is visible in auctions because the sellers obtain reliable information about the winning bids during the course of auction. This is not the case in multi-bilateral negotiations in which the buyer provides only information which she considers useful. Even if the buyer would tell some or more sellers what the best offer that she received is, the sellers may find this information not trustworthy. This led us to design an MBN experiment in which one version of the system automatically displays the best offer on the table to some sellers, the same way as in the MAA system.

The results of non-verifiable and verifiable MBN and MAA show that the buyers utility values were significantly lower in verifiable than in non-verifiable negotiations. The buyers achieved the best results in MAA. The reverse was true for the sellers, suggesting that showing the best offer to the sellers reduces rather than increases competition among them. Thus, one result from these experiments is that the buyers participation in verifiable MBN decreases their utilities but when they do not participate (as is the case for MAA) they achieve the best results. Remarkably, the sellers achieved the best results in verifiable MBN, however, but they were the least satisfied.

The results of these experiments cannot be explained on the grounds of rational exchanges. However, justification can be found in the social exchange theory, which places economic exchanges in a social-psychological context. Negotiation is a socio-economic process in which fairness and aversion to inequity play a role. They reduce competition because the sellers desist from making more offers when they see that fair and equitable offers have already been made.

In contrast, auctions are economic mechanisms and their users are not concerned with fairness and equity.

★ MO-4- β -R401

◆ Decision Aiding

Monday, 14:30–16:10 – Room 401

Session: Advances in Decision Aiding and Methods 1

Chair: Hanna Sawicka

1 - Setting corporate priorities with the help of multi-criteria decision methods

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The task of setting corporate priorities for a government department or large company is a complex one and requires engaging many high-level decision-makers. A risk assessment framework is presented in which decision-makers assess potential priorities based on their likelihood and the impact of not pursuing them on different corporate objectives. The inputs collected through the risk assessment survey are analyzed using a multi-faceted Multi-Criteria Decision Analysis (MCDA) method to determine the set of priorities that best represents the consensus and the different risk factors. The proposed analysis methodology relies on scores provided on standard five-point scales but subsequently converts the scores into preference rankings. The ranking that minimizes the total disagreement with all participants is determined using a variation on Kendalls tau rank correlation coefficient. The resulting list of priorities, representing the group consensus, is used to increase the confidence in the results obtained through score aggregation. The method has the benefit of requiring only fast and straightforward inputs from the decision-makers while at the same time addressing the biases introduced by different scoring personalities and different interpretations of the rating scales. The combination of the two approaches, coupled with a sensitivity analysis, is useful not only to identify the top and bottom priorities but also to explore the group dynamics and find the issues which elicited greater disagreement in the group. The method has been used by the Canadian Department of National Defence and Defence Research and Development Canada to assist in the determination of corporate priorities.

2 - PCLUST: An extension of PROMETHEE to interval clustering

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In the field of multicriteria decision aiding, solving a sorting problem refers to the assignment of alternatives into ordered categories. In classification problems, the alternatives are associated to categories that are pre-defined, which requires a priori information and knowledge about the structure of the data. While in clustering problems, the categories are detected during the solving process from the analysis of the structure of the data. Then, several clustering approaches had been developed among them we could distinguish between the classical approach and the criteria-dependant approach. The latter uses the additional information that is given by the criteria to define the clusters, and it could be divided into two categories: relational and ordered clustering.

In this paper, we are focusing on ordered clustering approaches, and more particularly we address the question of interval clustering. We have developed the method PCLUST that is based on an extension of the PROMETHEE I outranking method and the FlowSort sorting procedure. A set of clusters is constructed on the basis of the multicriteria preference information among alternatives. In particular, the positive and negative flow scores are used to assign alternatives to the corresponding clusters. Each cluster could be either individual or interval so that they constitute a set with a partial order.

Two initialization procedures and three assignment rules were developed. We tested the model and we measured its performance on real-world ordered datasets from the literature. In particular, we assessed the quality of the final clustering, the convergence of the model and its ability to generate stable clustering distributions. This analysis has pointed out some promising results that we underlined by comparing the model PCLUST with the k-means procedure and the P2CLUST model.

3 - Negotiation styles and group multi criteria decision making

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In the corporate environment, decisions are usually made by more than one individual (Tetlock, 2002, p. 451). In order to aid group decision, mathematical methods have been proposed through aggregation of the individual preferences (Wallenius et al., 2008, Dyer et al., 1992).

However, notwithstanding the method selection, it is necessary to know how the decision-makers behave in negotiation (Jacek Skorupski, 2014). The negotiation styles depend on several factors,

but the main influence is the importance that is given to the relationship compared with the level of conflict (Blake and Mouton, 1964).

Considering the importance of knowing the profile of negotiators, various instruments were developed based on the structure proposed by Blake and Mouton (1964), among them: Thomas-Kilmann Conflict MODE (1978), Organizational Communication Conflict Instrument (OCCI) by Putnam and Wilson (1982), ROCI II by Rahim (1983), Flinders Questionnaire by Leon Mann (1982), Melbourne Questionnaire by Mann, L., Burnett, P., Radford M., & Ford, S. (1997), and, finally, Independent Interdependent Problem Solving Scale (IIPSS) by Rubin, M., Watt SE, & Ramelli, M. (2012).

Most of these instruments are not available on the literature, just presenting the questions of the instrument, but not the scale used to obtain the results, while others presents few application examples. Therefore, the selection of the instrument to determine the decision-makers negotiation style are a difficult task.

The main objective of this research is to analyze the negotiation based on the individual profile of a group of agents and their performance based on a decision making method. By predicting the profile of decision-makers it is expected to have better estimation of the decision-making process. The research presents an application that was developed in class with bachelor students in Business Administration from FEA/USP who attended the Models for Negotiation discipline. Firstly, the students answered the Melbourne questionnaire in order to classify their negotiation profile (Mann, L., Burnett, P., Radford, M., & Ford, S. 1997). The questionnaire aimed to better detail the profiles into four kinds, namely: (i) Vigilance, (ii) Hyper-vigilance, (iii) Buck-passing and (iv) Procrastination. The instrument was made available online in a GoogleDocs form.

After profile classification, the students were separated and participated in a group decision-making process, which consisted of two phases: one individual and another in groups. In the individual phase, students learned the problem, which is to decide together to decide together a travel destination. The alternatives available were Punta del Lest, New York, Santiago, Paris, Istanbul. The criteria used to evaluate the alternatives were Hotel Rating, Travel time in hours, Number of nights, Cost, Shopping, Cultural attractions, Natural Landscapes, Security. Using the ROC Method, the criteria were weighted according to the students preferences, and a ranking of the alternatives was performed with ELECTRE III.

The next step was the group settle. Ten groups were composed of up to 5 people and formed based on the profiles identified in the questionnaires. At this stage, the group was divided into two rooms: in one, those with a more collaborative negotiation profile (Buck-passing and

Procrastination), in another, a more competitive profile (Vigilante and Hyper-vigilant). It was settled a round of negotiation and, when an agreement did not happen, a second round started with the presentation of the ranking proposed by the ELECTRE III method. In the end, the results of the negotiations were collected through a satisfaction questionnaire.

In the groups which had only decision makers with a profile of "Vigilance" the negotiation was longer, but in a collaboratively way, since decision makers with this type of profile are aware also with the opinion and criteria posed by others. One group proved to be more procrastinator than vigilant, so the solution came in the first round of negotiations and they dismissed the use of ELECTRE III as a formal method for aid decision-making, which shows the main feature of those decision makers, who avoid conflict. The Melbourne Questionnaire proved to be satisfactory to forecast the initial expectations in most of cases. However, the lack of publications in this area and questionnaires with satisfactory basis available were the major difficulty in this research.

4 - The Application of a Multicriteria Stochastic Ranking Method in the Distribution System

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The paper presents the solution of a multiple criteria ranking problem with the stochastic values of evaluation criteria. They are formulated as the ranges of variations resulting from the simulation experiments carried out on the real distribution system.

This system is characterized by a high complexity. It is composed of 24 distribution centers (DC) divided into 3 levels i.e. central with 1 DC, regional with 12 DC and a local one with 11 DC spread all over Poland. More than 75 suppliers supply these distribution centers and around 400 main customers are served. There are distributed various electrotechnical products, such as sockets, bulbs, extension cords, clusters, wires. There can be distinguished 38.000 assortments.

The detailed analysis of the system reveals many strengths e.g. modern fleet and handling equipment, as well as weaknesses i.e. high level of inventories. Thus, different ways of changes based on systems redesign are proposed. Due to the complex character of the considered system, the simulation model of its current state is constructed. It allows to formalize material and information flow in the system. Based on the simulation experiments the bottlenecks are recognized and quantitative analysis is carried out. The final information of the system is presented as a set of evaluation criteria. They represent various aspects i.e. technical, organizational, economical, social and environmental. Next, its

heuristically constructed redesign scenarios are modeled in the simulation tool and evaluated by the consistent family of criteria. Their values are calculated on the basis of simulation experiments results. They are presented as a probability distribution.

The decision problem is formulated as a multicriteria stochastic ranking problem. The preference information is collected. The decision maker is a person responsible for the redesign process of the system. He expresses the preferences as values indicating the boundaries of indifferent variants, weak and strong preference between them according to each criterion. Some of the stochastic multiple criteria decision aiding (MCDA) methods have been applied to solve the problem. However, due to many different and complex information the final result couldnt be calculated. Thus, the author has proposed the stochastic multicriteria ranking method based on the application of a multiple criteria decision aiding method and a machine learning method. MCDA method is applied to compute a large number of relations between variants, including indifference, preference and incomparability. The input criteria values in these experiments are randomly generated from the ranges of variations. Machine learning method is utilized to classify the relations between variants and to generate the final stochastic ranking of variants. The results of the computational experiments are completed by the sensitivity analysis. Based on the research carried out, the compromise redesign scenario is selected.

★ MO-4-γ-HS2

◆ Model Building

Monday, 14:30–16:10 – Room HS 2

Session: IS-INTEG: Integrated MCDM Applications 2

Chair: Özgür Kabak

1 - The selection of the most effective type of fuel for electricity generation in Turkey

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Over the last two decades, the importance of generating electricity has more than doubled and electricity demand is rising dramatically around the world because of economic developments of nations. Moreover, environmental concerns also play an important role in increasing the anxiety about the future of next generations. Also, energy efficiency is core to a sustainable energy supply. Generating electricity in Turkey is

usually based on using natural gas, coal, fuel, geothermal, and hydroelectric power. As Turkey has dynamic population growth, the energy demand of Turkey has grown rapidly and is expected to continue growing. However, the investment necessary to cover the growing demand is not at the desired pace and level. Sustainable as well as efficient fuel types should be selected for meeting this demand and new power plants should be constructed. Accordingly, this paper's main focus is on the selection of the most effective fuel for electricity generation in Turkey. First of all, a deep literature survey has conducted and experts are interviewed to determine the criteria and the sub-criteria those can be used for the evaluation of possible alternatives. We come up with a set of criteria; namely environmental aspects, economical aspects, sustainability, safety, useful time, suitability, and reaction of citizen. Two criteria have sub-criteria: criterion of environmental aspect is explained with damage to the nature and damage to residents who live around and criterion of economic aspect is explained with operation and maintenance costs and construction cost. On the other hand, the fuel types taken into consideration are coal, natural gas, diesel, wind energy, nuclear energy, hydroelectric, biomass, solar power, and geothermal energy. Inevitably the problem on hand is a multi-criteria decision making problem where evaluation criteria are several, conflicting, weighted, and incommensurable. As the problem can be modeled as a hierarchy, to analyze it Analytic Hierarchy Process, one of the most widely used multi-criteria decision method, is utilized. To assess the relative impact of criteria on main goal "the selection of the most effective fuel for electricity generation in Turkey" as well as the relative impact of sub-criteria on their related criteria, a pairwise comparison questionnaire survey is conducted to the experts researching at energy issues. At the same survey, in accordance with AHP-rating approach, questions regarding to identify the performance values of alternative fuel types with respect to each criterion and sub criterion are posed to the respondents.

2 - Utilizing social media in decision support modeling for commercial credit lending

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Credit can be defined as allowing certain individuals or organizations to access to specific resources with an agreement imposing predetermined conditions for both of lender(s) and bor-

rower(s). This loan should be paid at regular intervals or after a period of time. In this context, effective management of credit risk that may be originated from borrowers failure or retard to pay has a vital importance for banks, which are main credit funder for organizations. In this study, we aim to build a representative and consistent decision support model for determining the credit ratings of firms that applied to banks for credit funds. Commercial activities and organizational relations have become more complex due to the impact created by globalization phenomenon. Today, financial attributes of organizations are not accepted as sufficient by credit analyzers of financial institutions (banks). They consider a set of non-financial features regarding applicant organizations commercial activities for this reason. While the operationalization and quantification of financial measures are easier because of comprising numerical values, similar treatments need to be handled very carefully for nonfinancial measures. For instance, adaptability of organizations to strategic plans, seizing and improving of customer satisfaction or the future projection of a new product/service are under consideration in quantification focused literature. Nowadays, even just a news page broadcasted in online environment or a situation assessment/mention circulated in social media (for instance, microblogs like twitter, instagram, facebook or news pages in internet) has a very big potential to change the agenda of all over the country. Similarly, good or bad mentions, complaints and any kind of opinions about firms current or new products, services, campaigns and customer relations activities shared by individuals or other organizations; or announcements of products, services, promotions, any kind of organizational revisions and responses against customers complaints shared by organizations themselves in social media environment can be seen as important measures influencing the efficiency of financial and operational activities of organizations. There are many papers studying the relations between social media efficiency and financial condition (for example, share prices) of firms in the literature. Particularly, while the credit analyzers reliability perceptions on financial or nonfinancial measures in a region are insufficient for considering them as representatives of firms credibility, usage of social media efficaciousness of firms are getting importance. According to the literature research, to our best knowledge, there is no study considering social media in credit risk analysis until today. With this study, text/web mining techniques (sentiment analysis) that allow us to collect social media data from Internet will be taken into account for credibility analysis for the first time in literature. By this way, we will integrate MCDM with text mining approaches with the aim of constructing a more stable, accurate and reliable credit rating system. It is clear that considering all the criteria affecting a firms cred-

ibility calculation is very important in order to forecast the situation of the firm under consideration in a more effective manner and to reduce the credit risk by protecting the bank funds from loss at the same time. Our aim is twofold in this study: firstly, the relation between social media usage and financial measures will be revealed; and then, we will build our basic decision support model. a. For the first aim, we collect social media information by utilizing text mining application and financial measures by using financial reports released by Borsa Istanbul, stock exchange market of Turkey. We present the relationship between these constituents and determine the significant social media attributes for Turkey as a result of successful results from our statistical analysis. b. The primary version of our commercial credit lending decision support model has two types of input: financial scores and internet/social media scores that are collected in the previous step. Firstly, the performance scores of firms are calculated in terms of an MCDM approach. Then, homogeneous credit ratings are constructed according to these scores. This first version gives us some clues regarding the appropriateness of the usage of social media data and MCDM techniques to the credit lending analysis issue. This decision support model will be the first study considering social media in credibility analysis of firms in the literature. If the accuracy tests show us the models results superior to the other methods, it will contribute to credit operations of banking industry by providing them a more sophisticated rating methodology. This methods proactive approach can be useful for protecting the funds from loss that may be originated from the borrowers' default.

3 - A New Allocation Process For Organ Transplantation

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Organ transplantation has a vital role in treatment of the end-stage organ failure patients. Transplantation improves quality of life and life expectancy in most cases. Among the others, kidney and liver are the mostly transplanted organs. However in the transplantation perspective kidney and liver have different characteristics. Kidney patients can live by dialyses treatment during the waiting, alternatively but it is not a persistent treatment and only helps to improve living condition. However, such kind of a treatment is not valid for liver patients. It means that liver patients are more likely to die while waiting the new liver. However, suitable deceased (Cadaver) donors are scarce while patients who wait the organ transplantation treatment in the waiting list are continuously increas-

ing. Therefore, well-modeled organ allocation system is required to manage this kind of imbalance between the donors and recipients. In this study, we focus on allocation process of kidney transplantation. In the current system in Turkey, medical emergency is the first step of all organ allocation processes. If a patient in the waiting list is in emergency situation, the donor organ is assigned to him or her. If there is no emergency patient, then the allocation process is designed for each organ particularly. Allocation process is mainly based on scoring of waiting patients with respect to some predetermined criteria. As the first step of kidney transplantation, the tissue compatibility matching process is conducted. Six different tissues are analyzed and matched. If a patient is compatible with the donor in all of the tissues, kidney is assigned to this recipient regardless of any other information. Otherwise, waiting patients scores calculated based on their tissue compatibility degree, duration of dialysis, age of the patient and location. The current kidney allocation system defined as the combination of utility and equality conditions. In the scoring scale, tissue compatibility test results refer utility of the kidney whereas the duration of dialysis and location information takes into consideration the patient equity. However, the variables and their weights are not defined with the respect to utility and equity considerations, properly. In many countries, tradeoff between the utility and equity of allocation system is well modeled using mathematical methods and tools of decision science. The aim in this study is to propose a new allocation process to sorts the waiting patients considering the tradeoff between equity and utility for kidney transplantation. For this aim, firstly, the related criteria are defined based on current methods, literature and expert opinions. The criteria are classified into two main categories: Equity criteria such as duration of dialysis, medical status, waiting time and utility criteria such as tissue compatibility degree, success probability of transplantation. Subsequently, the weights of the criteria are determined by analyzing the current system data and according to expert opinions. This organ allocation process can be defined as multi criteria decision making (MCDM) problem as it includes multiple conflicting criteria to sort the waiting patients. In this study, a MCDM method is proposed based on TOPSIS for the organ allocation problem. TOPSIS is suitable method to develop simple, faster, and accurate model results compared to other MCDM methods. As an initial effort, we have applied the proposed method to kidney allocation process in Turkey. The first results are promising compared to current process. Furthermore, we will present our results to the experts and practitioners to check the validity of the methodology. As a further study we plan to develop a model for liver allocation process and we will try different MCDM methods to compare

with the initial results.

4 - An Interactive Approach for Bi-attribute Multi-item Auctions under Quasiconvex Preference Functions

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In this study we address multi-item auctions; also known as combinatorial auctions. In these auctions, typically, bidders offer a combination of items with the attribute values of the corresponding combination. We developed an interactive method to find the most preferred bid combination of a buyer having a quasiconvex preference function, in a bi-attribute, multi-round auction setting. We try different versions for this method and report the results for several test problems. We then consider a special case of quasiconvex preference functions: weighted La distance functions. We modify the original method to exploit the structure of this special case. The modified method estimates both alpha and weight values of the underlying preference function. In both algorithms, we aim to converge to solutions that are beneficial for the buyer and are produced by more competitive bidders. This result is tried to be achieved by estimating the underlying preference function of the buyer based on his/her past choices and providing this information to the bidders. The test results show that both methods work well for the problems we solved.

★ MO-4- δ -HS3

◆ Industry and Business Applications

Monday, 14:30–16:10 – Room HS 3

Session: Portfolio Optimization 2

Chair: Ralph Steuer

1 - Genetic Algorithm for a Reference Point Approach to Project Portfolio Selection

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This work is a re-implementation of a multiobjective project portfolio optimization model developed some 25 years ago. A key feature of the formulation includes recognition of the need for balance in various categories as systems-wide objectives. At the time of the original development, computational constraints required a quite simple formulation, and solution by a simplistic heuristic (which still required a substantial computational time). Recently, the same client

requested that we re-develop the system taking account of current needs. Initially, a reference point approach was implemented as before, but solved with a specially designed genetic algorithm. This turned out to be very effective and sufficient, and extensions to the original formulation were easily implemented.

The GA/reference point approach could then be extended to generate samples from the efficient frontier by simultaneously considering multiple reference points in an extended GA approach. This extension facilitates use of the model in an interactive decision support sense. Numerical experience and client responses with these extensions will be discussed.

2 - An iterative mixed integer program for bi-objective cardinality constrained portfolio selection

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In Finance, the portfolio selection problem is one of the most popular areas. In this work, we will rely on the theory of Harry Markowitz (1952), the works of Chang et al. (2000) and Khin Lwin et al. (2014), for a quad-lin bi-objective mixed integer model. Next, we will propose an iterative method for its resolution based on the steepest gradient and a new exploration strategy of problems generated at each step. The main idea of this method is to compute the best (Maximum) point for the return (Mixed Integer Linear problem), and find a way (descent direction) to go to the best one for the risk objective. The proposed algorithm will also be applied to different cardinality constraint conditions, experiments are performed using real-world data; for seven data sets involving up to 2196 assets for different values of cardinality. The results show that this new method finds efficient portfolio frontier in a reasonable time.

3 - Multiobjective portfolio selection models with complementarity constraints

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We extend Markowitz's portfolio selection model to include transaction costs in the presence of initial holdings for the investor. Our approach is new. We obtain a multiobjective optimization model. The objective functions are risk and expected return. Starting from the multiobjective

optimization model we formulate several single objective models. Our aim is to obtain an optimal portfolio which has a minimum risk or a maximum return. Our portfolio selection models include complementarity constraints. This type of constraints increases the difficulty of the problems, which now enter in the category of combinatorial optimization problems. The set of feasible solutions for the problems from the above mentioned class is the union of a set of convex sets but it is no longer convex. We propose several algorithms for finding solutions to the portfolio selection models with complementarity constraints. One of them is a hybrid heuristic algorithm that uses quadratic programming solvers. Several numerical results are discussed.

4 - Tri-Criterion Modeling for Constructing More-Sustainable Mutual Funds

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One of the most important factors shaping world outcomes is where investment dollars are placed. In this regard, there is the rapidly growing area called sustainable investing where environmental, social, and corporate governance (ESG) measures are taken into account. With people interested in this type of investing rarely able to gain exposure to the area other than through a mutual fund, we study a cross section of U.S. mutual funds to assess the extent to which ESG measures are embedded in their portfolios. Our methodology makes heavy use of points on the nondominated surfaces of many tri-criterion portfolio selection problems in which sustainability is modeled, after risk and return, as a third criterion. With the mutual funds acting as a filter, the question is: How effective is the sustainable mutual fund industry in carrying out its charge? Our findings are that the industry has substantial leeway to increase the sustainability quotients of its portfolios at even no cost to risk and return, thus implying that the funds are unnecessarily falling short on the reasons why investors are investing in these funds in the first place.

★ MO-4-λ-HS4

◆ Fuzzy Approaches, Decision Making under Fuzziness

Monday, 14:30–16:10 – Room HS 4

Session: Fuzzy Multiple Criteria Decision Making 2

Chair: Rachung Yu

1 - Markovian decision making models in queuing systems.

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One of the crucial factors which should be taking into account in the process of making decision is the random factor. One should remark that random factor is not adequate to the uncertainty one because while taking into account "randomness" is necessary that mass phenomena possess property of statistical stability. This implies that random phenomena follow the specific statistical regularity, the requirements of which are not obligate while considering uncertainty. The condition of statistical regularity allows using effective mathematical methods of the stochastic processes theory in the process of making decision, in particular, one of its parts Theory of Markovian processes. In this paper we consider Markovian decision process models to determine "appropriate" service level in the queuing systems. In these models higher level of service means decreasing waiting time in the system. Functional index of the service system which was obtained earlier for the different models was applied for searching balance between two conflicting factors (service level and waiting time in the system). Analysis of the queuing system models, essentially, doesn't solve problem. It helps to evaluate functional indexes of the service system in order to imply them in some decision process models.

2 - How to improve notebook computer ODM companies competitive advantage based on fuzzy DEMATEL method

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This research explores how notebook computer original design manufacturers (ODM) companies to establish their competitive advantages. This research adopts the Decision Making Trial and Evaluation Laboratory (DEMATEL) and fuzzy theory as the main analytical tool. To segment the required competencies for notebook computer ODM companies competitive advantages through DEMATEL. The results of this research show that the critical factor of ease use with the largest amount is the most important cause factor for enhancing the competitive advantage for the notebook computer ODM companies and could make the significant role in responding to the performance of notebook computer ODM companies. From research results, the supply chain capability and manufacturing capability

are the most important dimensions of the cause group. This paper draws on the research results for implications of managerial practice, and then suggests some empirical tactics in order to enhance competitive advantages for the notebook computer ODM industry.

3 - A Strategic Decision Making Model based on Hesitant Fuzzy Environment

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Rapid developments in technology and consequently increase in the rate of consumption of electronic goods make the electrical and electronic equipment production sector one of the fastest growing sectors in recent years. In this paper, a strategic decision that is selection of the best outsourcing firm for waste electrical and electronic equipment (WEEE) management is analyzed based on hesitant fuzzy sets. For this aim, a multi criteria decision making (MCDM) approach for Istanbul Metropolitan Municipality (IMM) is performed. Consequently, the best outsourcing firm that should be work together with IMM for WEEE management has been determined.

4 - A Simulation of Investor Life Cycle using Fuzzy Decision Maps

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Investor life cycle depicts the decision behavior in indifferent stages of the investors. Risk averse, risk neutral and risk loving are three major investment philosophies on decisions making. But these decision processes may alter when the risk endure variables change, such as ages, more controlling ready money, domain knowledge, economic cycle, interest rate & exchange rate and... etc. In this study, it uses DEMATEL to simulate the risk neutral decision and the fuzzy decision maps to simulate risk averse and risk loving decisions. Investors could expand the investment stages strategies and modify the only choice of the decision process.

★ MO-4- σ -HS5

◆ Multi Objective Optimization

Monday, 14:30-16:10 – Room HS 5

Session: Multi Objective Programming and Problems 1

Chair: Refail Kasimbeyli

1 - A New Algorithm for determining the whole set of Integer Efficient Stochastic Solutions

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In this paper, we study the problem of optimizing an aggregate function over an integer efficient solution set of a Multiple Objective Stochastic Integer Linear Programming problem (MOSILP). Once the problem is converted into a deterministic one by adapting the 2-levels recourse approach, a new pivoting technique is applied to generate all efficient solutions. The combination of both approaches, L-Shaped and the aggregation of objectif method, enables us to come up with the whole set of non-dominated stochastic integer solutions.

2 - Stochastic optimization over the Pareto front by the augmented weighted Tchebychev program

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In this paper, we describe an algorithm for optimization of a given stochastic linear function over the set of efficient solution of a Multi-objective Stochastic Integer Linear Programming problem (MOSILP). After representing uncertain aspirations of the decision maker by transforming MOSILP into a deterministic problem by adapting the 2-stage recourse approach. Nondominated trial solutions are generated by solving Augmented Weighted Tchebychev Programs by improving the value of the main objective function and going through some non-dominated solutions, without explicitly having to enumerate all of them, with a search an other alternate integer efficient solution. The problem is solved using a sequence of progressively more constrained integer linear programs generating a new solution at each step. A numerical example is also included for illustration.

3 - Robust solutions of nonlinear multiple-objective programming problems

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In many multiple-objective programming problems arising in real world applications, it is essential to take account of uncertainty. One way to deal with uncertainty is robust optimization approach. Recently, various scholars have proposed different definitions for robustness in multiple-objective programming. In this presentation, we extend the definition of robust efficient solution, recently introduced by Georgiev et al., from linear problems to nonlinear case. We call a given feasible solution as a robust solution if it stays efficient under small linear perturbation of objective functions. We investigate relations of this notion with some existing definitions. Moreover, we demonstrate that every robust efficient solution is a proper efficient solution in the sense of Geoffrion under the compactness of feasible set or convexity. We obtain necessary conditions for robustness with regarding tangent cone and non-descent directions, which are also sufficient for the convex case. An interesting question about this concept is to find robustness radius (perturbation length). We construct a single-objective optimization problem that provides us with robustness radius. The last part of the work is devoted to alteration of the objective function. We obtain some conditions under which weak, proper and robust solutions are preserved.

4 - Conic Scalarization Method

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This work presents the conic scalarization method for scalarization of nonlinear multiobjective optimization problems. We present the nonlinear separation theorem and show that two closed cones having only the vertex in common can be separated by a zero sublevel set of some monotonic sublinear function. It is shown that the scalar optimization problem constructed by using these functions enables to characterize the complete set of properly efficient solutions of multiobjective optimization problems without convexity and boundedness conditions. The conic scalarization method guarantees a most preferred properly efficient solution, if a suitable scalarizing parameter set consisting of a weighting vector, an augmentation parameter, and a reference point is chosen. This talk presents the comparison of different scalarization methods in multiobjective optimization. The methods are compared with respect to the ability to consider the preferences of decision maker, the ability to generate different kinds of efficient solutions such as weak efficient, efficient and proper efficient solutions. Theorems establishing relations between different scalarization methods are presented. The computational skills and dependence on the parameters sets for different scalarization methods are discussed and demonstrative examples are presented.

★ MO-4-χ-HS6

◆ Environment, Infrastructure & Emerging Applications

Monday, 14:30–16:10 – Room HS 6

Session: Environmental Decision Making 2

Chair: Nele Schuwirth

1 - A Socio economic problem regrading poplar plantation and a problem solving model by AHP

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The aim of the research is to present best solution for socio- economic problem regarding poplar plantation in Eastern and Western Azerbaijan of Iran. Using fast growth species for example poplar has high profit in wood farming in Eastern and Western Azerbaijan of Iran, then identification of socio- economic qualifications of poplar plantation will solve wood and paper industries factories problems regarding wood supply in coming decade. On the basis of previous researches and visiting poplar plantation surfaces in the provinces, 51 sub criteria were identified. These sub criteria categorized in 5 major groups: Application, economic & financial, social & cultural, Technical and infrastructure. Priority and weight of the criteria and sub criteria were determined with surveying first and catching the experts and poplar farmers in wood and paper industrial part and poplar plantation. Results shows economic and financial criteria is the most important criteria, the sub criteria of pre purchase contract, water sources and improved species have the highest priorities, respectively. For selecting the best and optimized solution in the provinces, three groups of alternatives were selected: poplar farmer promotion & education with use of national and foreign experts, offering multiple facilities and increasing the participation of wood and paper industries and investors in poplar farmers problems. For selecting the best solution a questionnaire was designed and distributed among the experts then evaluated with respect to the sub criteria. The results of synthesizing by AHP and Expert Choice software indicated polar farmer promotion & education with use of national and foreign experts is the best solution for providing proper situation of poplar plantation in the area and consumption of wood & paper industries factories. The result of sensitivity analysis indicated economic & financial and technical criteria are more sensitive when they affect on the solutions.

2 - Finding ways to realize MCDA processes which fit in with the needs and constraints of real-world projects ex-

amples from Finland

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MCDA is a generic approach which can be used in many different types of decision situations. There are many MCDA methods and many ways to apply them, and no one-size-fits-all solution exists. Many practitioners share the opinion that the MCDA process itself is often more important than its outcome. It is a delicate task to design and realize real-world MCDA processes that are meaningful and understandable for participants and that do not take too much time and resources. In this paper, we reflect our experiences of applying MCDA in different ways in four projects related to flood risk management, peat extraction, river restoration and urban planning. One of our earlier findings is that the potential benefits of MCDA are best achieved when i) MCDA and planning processes are tightly connected from the early stages, ii) stakeholders are actively engaged to the different phases of the MCDA process, and iii) weight elicitation for the criteria is carried out with intense interaction between the respondent and the analyst. However, in our four cases personal interviews were not possible due to the time limits and scarce human resources. This forced us to consider alternative ways to carry out the weighting process so that it would still be meaningful and theoretically sound.

Building a value tree is one of the most important phases of MCDA. The structure and size of hierarchy affects the weight elicitation and criteria weights as well as how the results are presented and discussed. There are several reasons which favor the development of hierarchies consisting of rather too many than too few criteria. One of these is that in this way, the decision analyst can be in the safe side by avoiding the situation where stakeholders feel that their opinions are ignored. The number of attributes in our cases was 15-30, which in some cases, was too much and resulted in unreasonably laborious analyses. In this respect, we think that more attention should be paid for considering the true needs of the case, so that we can develop hierarchies that are meaningful for this particular purpose. One of our future plans is to develop a systematic procedure which can be applied to eliminate criteria of minor importance already in the problem structuring phase in a way that stakeholders understand and accept.

In two of our projects there was and in two there was not preference modelling phase. MCDA was used as a framework for discussions and evaluation and the outcome was consequence tables, preference modelling was used and in two of the projects. Our experience suggest that in some cases preference modelling can bring added value and in some cases not. It is the question of the

decision analysts expertise to identify the situations where preference modelling is useful.

In the urban planning project, we developed a new and lighter way to realize weight elicitation. In this, we first created a value tree for the problem in collaboration with the project group and City Council. Then, we organized two workshops, one for the decision-makers and one for the stakeholders. In these, we first described the impacts of the project alternatives on different criteria with the MCDA framework, but we did not ask any explicit weight elicitation questions from the participants. Instead, we asked them both structured and open questions about how significant they consider the various impacts of the possible project alternatives. To involve wider public, we also realized a web questionnaire, in which similar types of questions were asked. From all this material, we were able to get quite a comprehensive overall view of the different viewpoints of the various stakeholder groups. On the basis of this response, we were able to identify four different perspectives that represented typical possible viewpoints for the problem. For each perspective, we created a value profile, i.e. the combination of criteria weights reflecting the opinions and values of that perspective, and carried out a value tree analysis to get overall values of the alternatives for each profile. The aim was not to produce a true preferences of certain stakeholder groups, but to illustrate and identify the main points where the peoples preferences differ from each other. This can be seen as a kind of if then approach: if the preferences are like this, then the result would look like this.

This kind of a use of the value profiles developed by MCDA experts is a much quicker and inexpensive way to generate preferences than e.g. personal decision analysis interviews. Compared to workshops where people are asked to give e.g. explicit SWING weights, this way is cognitively less demanding because no numerical questions are asked. In addition, without enough personal support there is a great risk that the given SWING weights can be distorted due to behavioral biases and misunderstanding of the questions. However, there are many open questions related to the use of expert generated value profiles: How to identify perspectives and create value profiles in a systematic and transparent way? How to present and discuss value profiles with stakeholders? How credible, useful and relevant stakeholders find the perspectives and value profiles developed by the analyst? We are currently developing ways to make this approach sound in terms of these issues.

Finally, we would like emphasize that when realizing MCDA it is important to be flexible and be ready to make changes in your plans to realize MCDA if needed. Signals for the need of change can be participants feedback or new issues regarding the decision situation. It is also vital that decision analyst is aware of the dif-

ferent options to apply MCDA. Typically people have their favorite methods and ways to work, but too often the true need of the cases are ignored when planning the process of applying the methods. Therefore, both learning and unlearning may be needed before new practices can be adapted into use.

3 - Conceptual Aspects of Decision Support for Environmental Management

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Decision support for environmental management intends to use the best available scientific knowledge to help decision makers find and evaluate management alternatives. The goal of this process is to achieve the best fulfillment of societal objectives. This requires a careful analysis of (i) how scientific knowledge can be represented and quantified, (ii) how societal preferences can be described and elicited, and (iii) how these concepts can best be used to support communication with authorities, politicians, and the public in environmental management. We discuss key requirements for a conceptual framework to address these issues in an optimal way. We argue that a combination of probability theory and scenario planning with multi-attribute utility theory fulfills these requirements, and discuss adaptations and extensions of these theories to improve their application for supporting environmental decision making. Here, regarding (ii) we focus on the importance of value functions, in addition to utilities, to support decisions under risk. We discuss the need for testing non-standard value aggregation techniques, the usefulness of flexibility of value functions regarding attribute data availability, the elicitation of value functions for sub-objectives from experts, and the consideration of uncertainty in value and utility elicitation. With respect to (iii), we outline a well-structured procedure for transparent environmental decision support that is based on a clear separation of scientific prediction and societal valuation.

Reichert, P., Langhans, S. D., Lienert, J., Schwirth, N. (in press). The Conceptual Foundation of Environmental Decision Support.

Journal of Environmental Management.

4 - Composite indicators for the comparative assessment of soil consumption among municipalities in Southern Italy

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The concept of soil consumption has often been associated with data on imperviousness. Recently, an increasing number of research approaches to land-use evaluation consider soil consumption as a multidimensional phenomenon, in both quantitative and qualitative terms. Therefore new assessment tools seems necessary for the evaluation of land use policies in terms of soil consumption. Our methodological proposal uses a multicriteria approach based on TOPSIS algorithm for the construction of a composite indicator for comparative qualitative and quantitative measurement of soil consumption among the municipalities. The methodology is tested on a sample of municipalities in Apulia Region, province of Lecce, in Southern Italy. The case study selection is based on the analysis of all the provinces of Apulia Region; the province of Lecce is selected because of a remarkable over time reduction of urban fringes compatible with future urbanization. The output of the analysis, that is the composite indicator, can be helpful in improving evaluation of future urbanization scenarios and in a monitoring processes of urban growth.

due to the involvement of several decision makers, the presence of multiple, and often conflicting criteria, and the existence of subjectiveness and imprecision in the decision making process. To ensure effective decisions being made, the interest of all the decision makers usually represented by the degree of consensus in the decision making process has to be adequately considered. This paper presents a consensus-based approach for effectively solving the multicriteria group decision making problem. Five multicriteria methods were integrated and applied in order to ensure the group opinions. A navy problem was used to simulated the model created.

2 - Developing a Distance-Based Group Consensus Model under Risk Assessment for Effective Watershed Management

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One of the most important steps in group decision making problems is the consensus measurement among decision makers (DMs), which leads to robust decision. Several consensus models have been developed to estimate the consensus degree between DMs. One important approach is the distance-based method calculating the degree of consensus according to the distances between each DMs opinions with regard to that of the group. However, the most important challenge in this method for consensus is the consideration of risk attitudes of DMs. Furthermore, the distance-based method should be comprehensive for use with both numerical and linguistic values. Therefore, this research develops a novel method of measuring the consensus based on the weighted Minkowskis method, which considers several risks of decision making. Fuzzy membership functions are also used to measure the linguistic values. The induced ordered weighted averaging operator (IOWA) is used to aggregate the DMs opinions and to determine the final scores of scenarios after sensitivity analysis. Results show that the Minkowskis parameter, which is related to risk attitudes, affects the consensus measurements and the final group decision making outputs. To evaluate the applicability of the proposed method, it will be used in a real study on watershed management of the Kashafrud River Basin in northeastern Iran.

3 - Convergence of autonomous

Monday, 16:40–18:20

★ MO-5- α -HS1

◆ Behavioral Aspects, Group Decision Making, Negotiations, Interactive Methods, Software

Monday, 16:40–18:20 – Room HS 1

Session: Consensus Seeking

Chair: José Luis García-Lapresta

1 - Group decision and negotiation models: a multicriteria analysis

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Consensus decision making is complex and challenging in multicriteria group decision making

aggregation-disaggregation procedures for group decision-making: efficiency analysis of a multi-criteria sorting algorithm

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Group decision-making methods and procedures may provide various levels of support to decision-makers. Several simple approaches aggregate preferential parameters of individual group members into an approximate compromise solution that is compensatory in nature and does not necessarily correspond to any opinion. More efficient and commonly used approaches utilize robustness analysis and visualization techniques, or incorporate the role of a human moderator to identify conflicts and facilitate the group in reaching an agreed upon solution. The most advanced methods, however, are able to autonomously assess divergence in judgements and suggest necessary actions to iteratively approach consensus by applying appropriate metrics and algorithms. Some are supplemented with mechanisms to automatically adjust evaluations of individual decision-makers in order to overcome discrepancies in the problem solving team while assuring that the collective decision remains robust and does not violate personal constraints of group members. It is essential for any method of the latter type to implement (1.) metrics that determine the levels of (dis)agreement of individual decision-makers with the direction to which the group as an integral entity is heading, (2.) robustness measures that ensure a reliable decision and prevent group members with firm judgements to conform to opinions of other colleagues or intelligent agents, and (3.) an algorithm to iteratively and autonomously adjust preferences of the most discordant group member in order to unify him with the majority opinion of the group. The aim of the presented work is hence to define and evaluate a general procedure for convergent autonomous group consensus seeking which is based on the aggregation-disaggregation paradigm, and is independent of both the decision-making problematic and the preference model. Metrics and algorithms for the unification of preferences are defined with regard to the most common problematics of ranking alternatives and sorting alternatives into an arbitrary number of ordered categories. Introduced metrics assess the majority opinion, determine the direction of the group and identify the most discordant decision-maker. Proposed algorithms adjust preferential parameters of the most opposing group member with the purpose to iteratively unify opinions. The main goal of the presented research is to assess the efficiency of the generalized autonomous aggregation-disaggregation procedure for group decision-making, primarily to determine if it is able to converge towards a consensual solution. The universal framework for the assessment of

group decision-making methods and systems is used for this purpose. Many factors are observed, including the ability of autonomous guidance, conflict resolution, convergence of opinions, ability to reach a compromise, initial cognitive load, cognitive load during the process of decision-making, overall time taken to reach the decision, time taken for the active involvement of an individual group member, ability to learn about the problem situation, breadth and depth of analysis, robustness, richness of cardinal discriminating information, correctness and relevance of judgments, decision accuracy, validity of results, thoroughness of problem domain analysis, and focus on problem solving. The study focuses on a sorting algorithm, and is based on a simulation experiment with varying numbers of decision-makers and criteria. The quantitative and descriptive interpretation of simulation results shows that autonomous aggregation-disaggregation procedures can be successfully applied for the purpose of convergent group consensus seeking.

4 - A collective and multi-criteria decision-making procedure in the context of non-uniform qualitative scales

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In this paper, we consider a group of agents must take a collective decision by ranking a set of alternatives regarding different criteria. In order to do this, agents judge the alternatives by means of a finite qualitative scale, not necessarily uniform. In this setting, we propose a collective and multi-criteria decision-making procedure where individual assessments are managed in a purely ordinal way through ordinal proximity measures.

★ MO-5-γ-HS2

◆ Model building

Monday, 16:40–18:20 – Room HS 2

Session: IS-INTEG: Integrated MCDM Applications 3

Chair: Özgür Kabak

1 - Multi-Criteria Decision Analysis of the Impact of Financial Crisis on Economic Performances of EU Countries

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The European economy is in the midst of the deepest recession since the 1930s, with real GDP projected to shrink by some 4% in 2009, the sharpest contraction in the history of the European Union. Although signs of improvement have appeared recently, recovery remains uncertain and fragile. The EU's response to the downturn has been swift and decisive. Aside from intervention to stabilise, restore and reform the banking sector, the European Economic Recovery Plan (EERP) was launched in December 2008. The objective of the EERP is to restore confidence and bolster demand through a coordinated injection of purchasing power into the economy complemented by strategic investments and measures to shore up business and labour markets as stated in the report of European Commission in mid year of 2009.

The purpose of the study is to find out best and worst performing EU countries based on main economic indicators during the period from year 2005 to 2013. The data used in the analysis obtained from Eurostat Statistics and covers also the period of financial crisis. The financial crisis started in USA in September 2008 and spread to European Economy in the same year. In the analysis recovery period assumed to be 2009 and onwards so the study provides an opportunity to investigate also the effectiveness of EERP. In this study different MCDA methods were used to rank EU countries by their economic performances in order to determine any variation in the ranking results due to methodological differences.

2 - A Multiple Objective Decision Model for Locating Disaster Response Warehouses

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Since the human beings are still vulnerable about natural and human-made disasters, the number of studies aiming to prevent and decrease disaster effects is significantly increasing in recent years. Disaster management is a composition of systems that is designed for reducing and preventing the effects of disasters, during, before and after disaster (Nikbakhsh and Farahani, 2011). Emergency response studies are mainly divided into two phases: pre-disaster and post-disaster. While pre-disaster studies include assessing and analyzing potential dangers and mitigation of possible damages before occurring of it, post-disaster studies are interested in events starting with disaster such as relocation of depots, management and coordination of available resources (Altay and Green, 2006). One of the most important parts of disaster response is humanitarian logistics including processes and systems involved in resources such as food, tent,

water, equipment etc. to help vulnerable people affected by disasters. It consists of a range of activities such as supply, tracking, transportation, warehousing, and last mile delivery and has a critical importance in terms of efficiency of relief operations (Nikbakhsh and Farahani, 2011). Humanitarian logistics differs from business logistics in several ways. The purpose of business logistics is usually to minimize logistic costs. The transportation is a flow from suppliers to customers where the demand and nature of the commodities is known. In contrast to commercial logistics nature, humanitarian logistics includes high uncertainty. According to Balcik and Beamon (2008), key challenges of humanitarian logistics with compared to commercial logistics are additional uncertainties (unusable routes, safety issues, changing facility capacities, demand uncertainties), complex communication and coordination (damage to communication lines, involvement of many third parties, government, and civilians, inaccessibility to accurate real-time demand information), efficient and timely delivery and limited resources often overwhelmed by the scale of the situation (supply, people, transportation capacity, fuel). According to a literature survey, we found that humanitarian logistics studies are mostly focused on post-disaster response phase. Therefore in this study, we analyze pre-disaster phase and one of the most critical issues of this phase is selecting facility location that will be used for disaster relief operations. As well as supplying relief commodities can be expensive when it is directly from international or local suppliers to affected people, time for delivering relief supplies might be longer than planned time because of some transportation problems that can occur due to disasters adverse effects such as closed roads. To overcome these problems humanitarian relief organizations pre-position essential relief items and equipment in central warehouses, local warehouses and permanent relief facilities. Therefore, dealing with locating these kinds of facilities within the disaster region is a critical issue for relief operations. This study proposes a multiple objective decision model to locate disaster response warehouses that will be used for transportation of relief supply to affected people in the disaster zone. The originality of the model comes from planning the main warehouses and local distribution centers at the same time under multiple objectives. The model has three objectives: Minimizing distances among local distribution centers, demand points and main warehouses, minimizing number of local distribution centers and main warehouses, maximizing the number of satisfied demand points by taking into account closed roads and connections. The proposed mathematical programming model is solved on illustrative examples. Although the initial results are promising, the computation time may become too long as the size of the problem increases. Therefore, in future studies, we plan to propose heuristic

approaches to deal with real life problems.

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3 - Transport Mode and Climate Change Interaction in Turkey

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Freight transport has become a basic part of modern life. It is expected to continue to grow in the next decades. At the same time air pollution and in particular climate change remain important challenges of modern society. As freight transport is a significant contributor to both, the discussion about freight transport emissions will continue. Last two decades, air pollutant emissions decreased for all transport modes. However, they are still on the political agenda, because the EU air quality standards are not yet met at many locations, let alone the tighter 2020 standards and the 2020 national emission ceilings (NEC). Also the differences between test cycle values and real life emissions, the long vehicle lifetimes of some transport modes and the increasing evidence on the severe health impacts of some emissions, in particular small particle emissions, play a role in this discussion.

Unlike for most other economic sectors, the greenhouse gas (GHG) emissions of transport rise. Within the transport sector, freight transport shows the highest growth, both in the past decades as in projections for the coming decades. Various GHG reduction options are considered, including a modal shift from road to alternative modes. For the latter, ambitious targets have been defined in the recently published Transport White Paper of the European Commission.

Transport (freight and passenger transport) accounts for 20% of all EU GHG emissions. The share of transport emissions is continuously in-

creasing and could reach more than 30% of total EU emissions by 2020 if no action is taken. Emissions from freight transport account for approximately one third of total transport GHG emissions. 93-95% of GHG emissions from transport operations is accounted for by CO₂ emissions. Significant efforts have already been made by industry to improve the energy efficiency of freight transport. These gains in energy efficiency have however not been sufficient to outweigh the growth in emissions caused by larger transport freight volumes, due to a strong increase in global trade and the further integration of the enlarged EU. This research will focus on the effect of GHG emission at transportation sector on climate change. For this purpose an integrated decision support approach will be used. Opinions of experts and related issues in the literature will be gathered and a convenient model will be proposed. As the problem on hand is a complex one and consists of several interrelated concepts affecting each other, a network model will be generated. Fuzzy cognitive mapping may be an appropriate approach for this purpose. Cognitive mapping is a method that captures the diverse mental models of the experts in simple directed graphs where concepts are represented by nodes and relations between concepts are represented by arcs. The relation is positive if there is an increase at the affected concept when affecting concept increases. If there is a decrease at the affected concept when affecting concept increases, the relation is negative. By interviews with experts or by examining published reports or studies, the related concepts and interrelations among them can be revealed. These beliefs and judgments are brought together to have an aggregated cognitive map. Qualitative analyses can be conducted on this map. However causal cognitive maps may have drawbacks. For instance if there are two concepts affecting a concept C, and one relation is positive and the other one is negative, it cannot be determined whether C will increase, decrease, or remain same in the long run.

To predict the overall system behavior of the concepts in the cognitive map, a formal analysis can be conducted. One potential approach may be the use of fuzzy cognitive map (FCM) which is based on Fuzzy Set Theory and the Theory of Neural Networks, improves the ability of decision makers to understand the dynamic behavior of causal cognitive maps. Instead of assigning (-1, 0, +1) for the representations of the relations as done in causal cognitive maps, a value at the interval of [-1, +1] is assigned at FCMs. They are therefore fuzzy.

FCM are regarded as a simple form of recursive neural networks, with concepts being the equivalent to neurons. However, concepts of FCMs, are not either off or on (0 or 1), but can take values in-between [0, 1]. Fuzzy concepts are non-linear functions that transform the path-weighted activations directed towards them

into a value. When a concept changes its value (a neuron fires), it affects all concepts that are causally dependent upon it. Depending on the sign of the relation and the strength of it, the affected concepts subsequently may change their values as well (further concepts are activated at the network). For this purpose a simulation is conducted as follows: a given state vector with values of -1, 0, or 1 for the concepts (i.e. the value of a concept will be -1 if decision makers let it decrease and it would be 1 if it is let to increase) is multiplied with adjacency matrix (a $n \times n$ square matrix representing the fuzzy causal relations among n concept) in each iteration to come up with an updated state vector. System reaches a stable state at the end. By reading the values of concepts at the final state vector, one can understand to which extent which concept will increase and which one will decrease in the long run.

In this research, after making several meetings and interviews with experts using Delphi technique and examining the written materials, a FCM will be constructed for examining how GHG emission at transportation sector affect climate change and this effect may be reduced. Fuzzy MICMAC will also be used in order to analyze mutual influence among concepts and to specify influential, rely, independent, and dependent concepts. Several scenarios will be generated to analyze how the increase or decrease at some certain concepts will affect the overall system behavior of the all concepts of the network.

4 - Operational Performance Evaluation of Airlines Operating in India using ELECTRE and AHP

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In India, six major airlines (including one from public sector and five from the private sector) operate and contribute to almost 99.9% of the domestic air travel market share. In this paper, we present an approach using ELimination and Choice Expressing Reality (ELECTRE) and Analytic Hierarchy Process (AHP) to evaluate the operational performance of these major airlines operating in India. The proposed method is called OPEAHP. The proposed approach consists of various stages, in the first stage the fourteen criteria are classified into two dimensions (the logistics dimension and the customers perspective dimension). This results in the hierarchical structure of the problem. Weights are then assigned to criteria using AHP approach. A group decision-making approach involving various stakeholders is considered here. Later, ELECTRE is applied to rank the various domestic airlines based on the data obtained

from the office of the Director General of Civil Aviation in India. Data for the period of January 2015 is considered for this purpose. Further, the approach proposes an Operational Performance Number (OPN) to relatively compare their performances. A quick comparison of the proposed OPEAHP and other methods such as TOPSIS and AHP is also provided.

The proposed approach not only enables to benchmark an airline with the other, but also allows the airlines to introspect and develop strategies for better performance.

★ MO-5- δ -HS3

◆ Industry and Business Applications

Monday, 16:40–18:20 – Room HS 3

Session: Portfolio Optimization 3

Chair: Cristinca Fulga

1 - A Framework for Sustainable Index Tracking

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Sustainable investment is perhaps the fastest growing area in the mutual fund industry today. It is based upon the desire of many investors to only allocate investment dollars in a way that supports ethical corporate behavior and keeps an eye on the general social good. However, as an investment strategy, the objective is still to generate positive financial return. One strategy to construct portfolios which has significantly increased in popularity recently is index tracking. In traditional index tracking, the goal is to maximize portfolio return while simultaneously minimizing the tracking error to a certain index. In this paper, we extend such a bi-criterion model to include sustainability as a third criterion. Hence, the goal is to construct portfolios that (a) maximize portfolio return, (b) minimize tracking error, and (c) maximize portfolio sustainability. Based on real world data we show the applicability of our model.

2 - Effects of Multiple Criteria and Cardinality and Weight Constraints on Portfolio Optimization

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Portfolio optimization is the problem of allocating your available resources between different assets in the market in order to maximize your wealth. Following the innovative work of Markowitz, Modern Portfolio Theory has emerged. The original problem has two criteria of mean return and variance; later several approaches with different criteria have been proposed. Alternative risk measures such as the well-received Conditional Value at Risk have been employed; and criteria that address concerns other than return and risk have been considered. Taking return, variance, liquidity and Conditional Value at Risk into account, we study the effects of multiple criteria on decision and criteria spaces of portfolio optimization problems. Using single-period optimization settings, we use several combinations of these criteria to see how they interact and conflict with each other, and how they provide the decision maker with different investment options. We also consider cardinality constraints on the number of assets chosen and weight constraints that limit the proportions of assets, and discuss their effects on the results. We make tests with stocks from Istanbul Stock Exchange (Borsa Istanbul) and use the augmented epsilon-constraint method to find efficient solutions.

3 - Multiobjective Portfolio Optimization for Drug Discovery Using Deterministic and Stochastic Methods

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In this work, a problem of selecting a subset of molecules, which are novel molecules predicted to be drug candidates, is considered. This molecule subset selection problem is formulated as a portfolio optimization problem, well known and studied in financial management. The financial return, more precisely the return rate, is interpreted as return rate from a potential drug and calculated as a product of gain and probability of success (probability that a selected

molecule becomes a drug). This probability is related to predicted performance of the molecule, in particular, its (bio-) activity. The risk is associated with not finding active molecules and is related to the level of diversity of the molecules selected for the portfolio. It is possible that some molecules, which when considered in isolation look inefficient, contribute to decreasing the risk of portfolio as a whole. Such molecules are expected to be located in sparsely covered regions and are different from the other molecules in their features. Computing the risk in portfolio optimization requires the definition of a covariance matrix. In the domain of drug discovery, we suggest to derive it as the covariance matrix considered in the Solow-Polasky diversity measure. The Solow Polasky diversity is currently used in bio-diversity conservation and relates to the utility of species (e.g. plants) in a population given unknown future demands (e.g. medical cures). We suggest a method to adapt the Solow Polasky diversity to the context of chemistry using problem specific dissimilarity and correlation expressions.

The resulting molecule portfolio optimization problem can take into account diversity (dissimilarity), individual success probabilities, and price of molecules (or costs of experiments). Several different formulations of molecule portfolio optimization are considered here taking into account the limited budget provided for buying molecules and the fixed size of the portfolio. The proposed approach is tested in experimental settings for three molecules datasets using exact solvers and/or genetic algorithms. Both are compared with each other with respect to computation time, accuracy of Pareto front approximation, and the portfolio optimization models that they support. The results obtained for these datasets look promising and encouraging for application of the proposed portfolio-based approach for molecule subset selection in real settings.

4 - Downside risk and portfolio optimization under loss averse preferences

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In this paper, we consider the portfolio problem in the Mean-Risk framework and complement this approach with the consideration of investor's loss aversion. We propose a risk measure calculated only with the downside part of the portfolio return distribution which, we argue, capture better the practical behavior of the loss-averse investor. We establish the properties of the proposed risk measure, study the link with stochastic dominance criteria, point out the relations with Conditional Value at Risk and Lower Par-

tial Moment of first order, and give the explicit formula for the case of scenario-based portfolio optimization. Moreover, in the proposed Mean-Risk model the investor's loss aversion is also captured in the first objective function where the usual expected return is replaced with an expected return - based function that presents the general characteristics of loss aversion. We analyze the efficient portfolios provided by the proposed model and compare them from different viewpoints with the classical Mean-Risk models, Mean-Variance, Mean-Conditional Value at Risk and Mean-Lower Partial Moment of first order. The comparisons between the models were performed using real data. In each case, we describe and interpret the results and emphasize the role and influence of the values of the loss aversion parameters on the optimal solutions.

★ MO-5- κ -HS4

◆ AHP/ANP

Monday, 16:40–18:20 – Room HS 4

Session: AHP/ANP for and Behavioural Issues
In Group Decision Making

Chair: Monica García-Melón

1 - How the behavioral characteristics of the facilitators can positively affect quantitative and qualitative model-based multi-actor decision processes

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A multicriteria decision aid (MCDA) process develops in interaction with decision makers and stakeholders. When an MCDA intervention is specifically oriented to facilitate the Intelligence phase of a decision process, stakeholders and decision makers may be less present because their roles are not yet clearly defined. These interventions may produce a kind of preliminary study, which includes modelling and application of methods, in order to clarify the situation and to propose a new approach for the later phases of the decision process. Aiding model building and validation for a new and not sufficiently known problem situation is not a so unusual request and it is always challenging. These requests can be made in a research context, but also when a completely innovative procedure could or should be activated, and are also frequent when a decision situation is complex and not well structured. If there is time, a simulative approach to the problem can be developed, to structure a possible model and use a method in order to produce results that can be analysed and used to improve the model (and the knowledge of the situation) or to propose a specific behaviour to deal with the problem situation. The need for understanding and including in a model the dif-

ferent aspects of an analysed system (not only economic and engineering aspects, but also organizational, sociological, psychological and so on) can be satisfied with the use of multicriteria (MC) models and methods. But the elements that characterize a complex and unstructured problem situation often limit the use of MC methods in problem solving and decision aiding in practice. A proposal can be made on how to improve the effectiveness of an MCDA intervention by means of the study of the behavioral characteristics of facilitators that can positively affect the conduct of model-based multi-actor processes. After a sequence of interventions in relation to these situations, some important behavioural factors, which have an important impact on the model-based processes, have been identified and systematically analysed. Some of them seem to be rather general and can always be applied, as facilitator characteristics. Others are closely connected to a specific context of action and can therefore be activated only in these situations. Some behavioural factors can be more easily activated and can therefore be translated into formal procedures and integrated with MC methods. How a model has to be structured and detailed, changed and improved, until its final validation, and which behavioural factors can positively or negatively impact this process are tacit knowledge elements that are not easily transferred. The large number of students (more than 3000 over the last fifteen years) that have been involved in a laboratory course, with a sequence of modelling exercises and proposals of realistic decision problems to be analyzed and modelled, have allowed interesting observations to be made on how a new practitioner reads decision aiding problems and how he/she can acquire acceptable expertise in structuring and detailing an MC model and using MC methods. The skills that have been obtained from the literature and real experiences, and their use and improvement in teaching practice will be described together with some methodological results.

2 - Simultaneous Interval AHP in a multiple-criteria group decision making

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Regardless of whether the organization is public or private and the decision problem is local or global, decision making is made by two or more people. Most decisions, at least in organizations and society are the responsibility of groups rather than individuals. It is often difficult to reach a consensus among a group of decision makers, since there exist some communication barriers to understand one another. It is sure that the decision makers have some knowledge on the decision problem. However, it is not often easy for them to express their decisions precisely to the others. It is useful to help a group of decision makers realize their decisions based on

their intuitive judgments. From the viewpoint of an individual, it is rare that the group decision is exactly the same as his/her decision. The goal of the group decision making is not only to reach a group decision but also to obtain the individual decision which may be better than what is done alone. The individual decision in a group decision making is expected to be improved, in other words, it is different from what is obtained only from his/her judgments. The group decision based on such improved individual decisions is more reasonable than just a mixture of the individual ones. These are the motivations of being a group rather than alone. This study focuses on the possibility of the given judgments and obtains the group and individual decisions from them individually given judgments by making good use of them.

For the easiness of a decision maker, s/he gives his/her intuitive judgment as pairwise comparisons following AHP (Analytic Hierarchy Process). AHP is an approach to multi-criteria decision making problems. When a decision maker gives the comparisons of all pairs of criteria, his/her preference is obtained as the weights of the criteria. The inconsistency of the given comparisons is well-known and discussed a lot in AHP studies. One of the ways to treat inconsistency is to introduce the consistency index and distinguish whether the given comparisons are too inconsistent. On the other hand, Interval AHP takes the comparisons possibly into consideration instead of being distinguished. It is based on the idea that a decision maker perceives a range of weight vector in his/her mind but does not a precise weight vector. In Interval AHP, a comparison is considered to be from a part of the rational decision. In short, AHP and Interval AHP induce plausible and possible decisions, respectively, from the given judgments. Interval AHP, which considers all the possibilities of the comparisons into the decision, is suitable to improve an individual decision through a group decision. Therefore, the model to obtain the individual and group decisions simultaneously is proposed based on Interval AHP.

In the following, the detailed conditions of the individual and group decisions in the sense of group Interval AHP of this study are shown. At first, the group decision in this study is not independent of any of the individual decisions so that no one in a group is ignored. The group interval weight vector intersects with all the individual ones and both the group and individual interval weight vectors are obtained from the individually given comparisons. As for the individual interval weight vector, it is possible as far as it includes the given comparisons and the more similar to them it is, the better it is. The former to include the comparisons is its necessity condition and the latter to be close to them is a kind of its sufficient condition. In case of a single decision maker, the latter condition is optimized under the former condition. While, in case of a group

of decision makers being affected one another, the latter condition is flexible to the effect of the others. An individual decision in this study is related to the given judgments by the other decision makers in a group, as well as those by him/her. There is often a trade-off between its closeness to his/her comparisons and to the others comparisons. As for the group decision, it is based on two assumptions. One assumption is the preciseness of the group decision, which is denoted as the sum of the widths of the group interval weights. The group decision can be rigid or rough reflecting the correlation between the decision makers in a group which represents how much each individual decision is affected by the others'. The more precise the group decision is, the more an individual decision is affected by the others and the less similar to his/her judgment it is. However, an individual is willing to widen his/her view by taking the others views into account through a group decision. The other assumption is the loyalty of the individuals to a group, which is denoted as the common weights between group and individual interval weights. When the group decision does not only intersect with but is included in an individual decision, such a group decision is strongly supported by the individuals. While, such a group decision that narrowly intersect with each individual decision is weakly supported. It is possible to assume between these extreme loyalties. There are two group interval weight vectors whose qualities are the same but the backgrounds are different. The individuals widen their views more for the strongly supported group decision than the weakly one, when the former is as precise as the latter. When the preciseness and loyalty of the group decision is assumed, the group and individual decisions are obtained.

Furthermore, the conditions of practice are considered since the decision is evaluated when it is performed. The effectiveness of practice varies the conditions such as the difficulty and/or limitation of performance. This paper treats such conditions as the potential scores of the criteria and defines a performance as the weighted sum of scores.

3 - Applying Group Decision Making Methods in Human Resources

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The aim of this case study is to focus on real-life application of multiple decision making methods (MCDM) methods and their adaptation in a way which can be acceptable for human resource practice. The study will apply the group decision making methods on a various types of human resources tasks, such as employee selection, training and development and employee performance management. The study is mainly concerned with multiple criteria decomposition methods of analytic hierarchy process (AHP), DEMATEL

method and TOPSIS method. These techniques have been already applied in several business domains such as planning, evaluation of regions; Porters generic strategies; benchmarking; business performance evaluation; competency models etc. However, most of these methods were implemented only as an example how it could work in practice, but they were not investigated as a part of continual human resources decision making. In this paper the AHP method will be used to determine which criteria is most important for the company i.e. which employee qualities are the most important for the company and the DEMATEL method will be used to find causal relations among the criteria in order to find out which criteria affects the most the others. The TOPSIS method will be used to evaluate employees performance. Main aim of this paper is to describe and show that MCDM methods can be used by the human resources professionals for a better decision making when it comes to hiring new employees, selecting training and development program and evaluating their performance.

4 - Influence Analysis in Group Decision Making. A DEMATEL-SNA Comparison in Environmental Management. Case Study: El Cocuy National Park

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A. Purpose - The aim of this paper is to propose a methodology for addressing complex (social, environmental and economic) problems in environmental management, by combining: multi-criteria and influence methods (social network analysis, DEMATEL). And to investigate the importance of influence analysis in GMCDM)

B. Design/methodology/approach - The complex and dynamic nature of environmental problems requires flexible and transparent decision-making that embraces a diversity of knowledges and values (Reed 2008). Three tourist paths are visited for observation; recording GPS points in each environmental damage. The first tour takes place in January 2014, the second in November 2014 and the last in January 2015. Covering the paths corresponding to the snowy peaks: Ritacuba blanco, Concavo, Concavito. Next, the environmental problems are ranked by a qualitative approach (AHP) and by a quantitative approach (Entropy method). Next, by a social network (SNA) and a network influence map (DEMATEL) we can see influence paths for design a participatory group ANP - VIKOR process.

C. Findings The study shows multiple Group

decision methodologies, for participative decision making (with multiple and diverse decision-making groups).

★ MO-5- σ -HS5

◆ Multi Objective Optimization

Monday, 16:40–18:20 – Room HS 5

Session: Multi Objective Programming and Problems 2

Chair: Phong Ho Thanh

1 - Output-Sensitive Complexity of Multiobjective Combinatorial Optimization Problems

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In this talk, we study output-sensitive algorithms and complexity for multiobjective combinatorial optimization (MOCO) problems. We develop two methods for enumerating the extreme nondominated points of MOCO problems and prove their output-sensitive running time for each fixed number of objectives under weak assumptions on the MOCO problem. Further, we show the practicability of the algorithms. On the negative side, we show a few first results on the output sensitive complexity of multiobjective shortest path problems.

2 - An Exact Algorithm for Mixed 0-1 Integer Linear Programming Problems

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In a linear programming problem if there are two challenging objective functions, the problem needs to be evaluated in the biobjective linear programming (BOLP) context. Adding 0-1 requirements to all variables yields the biobjective 0-1 integer linear programming problem (0-1 BOILP). In a more general form, a biobjective mixed 0-1 integer linear programming problem (0-1 BOMILP) arises when some variables are real-valued and others are binary. Although there is no difference in the notion of computing the extreme supported Pareto points of these three problems, the properties of Pareto frontiers are different. It is well-known that the set of Pareto points of BOLP is convex, hence connected and all Pareto points are supported. In 0-1 BOILP, Pareto points are isolated and some of these Pareto points might be nonsupported which makes the problem challenging.

Since 0-1 BOMILP have common characteristics with both BOLP and 0-1 BOILP, the set of Pareto points might be partially connected as well as might include isolated points. In this study, we develop an exact algorithm for 0-1 BOILP. It uses a well-known local branching strategy where the solution space is divided into two parts in terms of neighbors of an incumbent solution as different from the classical branching idea. Each subproblem is explored with the dichotomic search. Although we use classical bounding strategies and fathoming rules, we develop a new fathoming rule which significantly improves the performance of the algorithm. We also apply different cuts. We test the performance of the algorithm and present our results.

3 - De Novo Programming approach for Multicriteria Aggregate Production Planning

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De Novo programming in Multiple Criteria Decision Making is a promising tool for designing an optimal system. In this study, De Novo programming approach has been proposed and applied to an aggregate production planning problem comprising of three objectives: minimizing decreasing of workforce level, maximizing profit and minimizing late orders for a multi-stage production system. The traditional Goal programming (GP) method was also employed. A comparison of the results obtained from the De Novo method and the GP one indicates that the proposed model and solution algorithm provide better performances. The application of the De Novo method on the production system in Ho Chi Minh City, Vietnam has been suggested.

★ MO-5- χ -HS6

◆ Environment, Infrastructure & Emerging Applications

Monday, 16:40–18:20 – Room HS 6

Session: IS-SMART: MCDM for Smart and Sustainable Communities

Chair: Ivan Blečić

1 - Multi-Criteria Decision Aiding: a decision support approach for green chemistry-oriented synthesis of nano-materials

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Stuart Coles, University of Warwick, United Kingdom of Great Britain and Northern Ireland

Mallikarjuna Nadagouda, U.S. Environmental Protection Agency, USA

Jerzy Błaszczyński, Poznań University of Technology, Poland

Roman Słowiński, Poznań University of Technology, Poland

Rajender Varma, U.S. Environmental Protection Agency, USA

Kerry Kirwan, University of Warwick, United Kingdom of Great Britain and Northern Ireland

A large number of “green” labelled synthesis protocols for the generation of nanomaterials have been advanced in recent years. However, an evaluation of such preparations in the context of the principles of green chemistry has not been performed on a comparative basis. Our recent multidisciplinary research endeavours have culminated in a model supporting decision-making oriented towards green chemistry in the area of synthesis of nanosilver, one of the most widely used nanoparticles in the consumer industry. We envision that this strategy will benefit comparative evaluation of existing greener processes or future attempts by beginners in the nanosynthesis arena to identify a sustainable protocol. The research integrates peer-reviewed literature on synthesis processes for nanosilver with knowledge of practicing chemists in this area, by means of a Multi-Criteria Decision Aiding (MCDA) method (i.e., Dominance-based Rough Set Approach). The collaboration between chemists and decision analysts has enabled the development of a model for classification of existing or new production processes as applied to nanosilver in preference-ordered classes, on the basis of the implementation of the principles of green chemistry. The main goal of this research is to show that the MCDA approach can have a substantial contribution in understanding how green nanosynthesis is performed and perceived presently in spite of the lack of data for a full blown quantitative Sustainability Analysis. The case study application to nanosilver does not limit the applicability of the model, as it can be adapted to other materials of interest, such as nanometals, nanocellulose and other nanomaterials or nanocomposites.

2 - Urban regeneration, industrial heritage and local communities: an ap-

plication of the Social Multi-Criteria Evaluation

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Urban regeneration can be defined as a comprehensive and integrated set of actions which lead to the resolution of urban problems and which seeks to bring improvement in the economic, physical, social and environmental conditions of an area subject to change. The evaluation is a crucial point in the overall transformation process because it allows the project proposal to be decomposed and a series of fundamental information to be produced that can support the decision-making process. In this sense, it is possible to say that the evaluation plays a constructive role and it is not a form of decision-making but a support to the decision-making process (Patassini, 2006). In the past, the evaluation used to be considered as a set of procedures and techniques finalized to the definition of the links between causes and effects. More recently, the scientific literature in the domain of environmental evaluation and planning agreed in considering the evaluation as a social learning process (Bobbio, 2002; Dente, 2014) where reflecting and interpreting complex situations are the basis of the overall assessment. In this sense, it is possible to highlight that traditional approaches based on financial and economic feasibility analysis are not able to help the comprehension of such complex phenomena because they consider few quantitative variables and a limited group of experts and are not able to deal with environmental uncertainty, social risks and inter-generational equity factors. Moreover, a fundamental role in urban and territorial decision-making processes is played by the population. Inclusive approaches that enhance public participation and collective learning processes among different actors, with different perspectives and objectives, are thus central in the creation of new responses in territorial transformation processes. For the aforementioned reasons, Multicriteria Decision Analysis (MCDA, Figueira et al., 2005) is a valuable and increasingly widely-used tool to aid decision-making in the domain of sustainability assessment and urban and territorial planning, where a complex and inter-connected range of environmental, social and economic issues must be taken into consideration and where objectives are often competing, making trade-offs unavoidable. It is possible to highlight that MCDA gives not only a toolbox, but, overall, a well developed methodology to support decision-making processes. This paper considers the application of the Social Multi-Criteria Evaluation (SMCE) which combines MCDA with institutional and social analysis (Munda, 2004). SMCE agrees on the need of extending MCDA by incorporating

the notion of the stakeholders, which are defined as those groups of individuals who can affect the realization of the project's organizational goals or who can be affected by the project's organizational goals. Therefore, SMCE is based on an interdisciplinary approach able to analyze the problem considering the different disciplines and dimensions; moreover, SMCE proposes a transparent and participated process, which enables the inclusion of the local community and thus increases the democracy of the evaluation process. The present study aims at investigating the role of SMCE in decision problems related to urban regeneration processes. In particular, in the research the SMCE was applied on a real-world problem concerning the requalification of a former industrial area in Greece. In the evaluation different scenarios were compared on the basis of several criteria, such as environmental impacts, economic costs, accessibility etc.; moreover, the evaluation included the opinion of different stakeholders having a role in the problem under examination. The results of the application show that SMCE is able to integrate the socio-economic and technical dimensions inside a coherent framework and to support the definition and the choice of urban regeneration strategies.

3 - Multicriteria Spatial Decision Support Systems and evaluation of multifunctional landscape: a smart landscape approach

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The research framework aims at the development of a Collaborative-Multicriteria Spatial Decision Support System (C-MC_SDSS) for the evaluation of multifunctional landscape. The SDSS has to be helpful in addressing landscape transformation or preservation processes, leading to coherent decisions with the principles of local self-sustainable development, resilience and inclusion of multiple societal issues.

The problematic and stated issue is to find compromise scenarios for local self-development based on landscape resources enhancement. The decision-making environment is heterogeneous and made by numerous groups of interests that can be classified into Explorers, Exploiters, Catalysts and Governors. They are all interested in landscape resources, but they are based on different and sometimes conflictual points of view. In the first stage the process for knowledge acquisition is described, based on on-field surveys, literature review and collection of spatial data.

The second stage deals with the methodological framework for the construction of spatial composite indicators for landscape evaluation, based on the comparison of three multicriteria approaches, namely additive rule, sorting procedures and fully overlay. In the third and last stage, the application of the methodological application to the case study of the National park of “Cilento, Vallo di Diano and Alburni” (Southern Italy) is described. The results demonstrate that nowadays the inclusion of web-based data and information in spatial multicriteria decision support systems is a major challenge, in order to guide transparent and democratic decision processes that could be really helpful in selecting and implementing landscape enhancement policies. Moreover, from a methodological point of view, the three above-mentioned aggregation approaches in spatial multicriteria evaluation for landscape evaluation enlighten different aspects of the decision problem, thus allowing an expansion of the knowledge-base to sharpen questions and improving the quality of the decision process.

4 - From Evaluation to Design: the case of Urban Walkability

Ivan Blečić

Arnaldo Cecchini

Giovanna Fancello

Giuseppe A. Trunfio

We explore the possibility of developing urban design support tools centred on pedestrian accessibility and walkability of places.

A range of formal methods have been proposed for the evaluation of (various aspects of) the quality of urban space. We have recently constructed a planning decision-support system, Walkability Explorer, based on one such evaluation model focusing on the notion of walkability, conceptualised in terms of (urban) capabilities. A multicriteria evaluation model, at the core of the decision support system, is used to assign walkability scores to points in urban space. Walkability scores are obtained through algorithms which process spatial data and implement the evaluation model in the software in order to derive potential pedestrian routes along the street network, taking into account the quality of urban space on several attributes relevant for walkability. One of its notable characteristics is a certain reversal of perspective in evaluating walkability: the walkability score of a place does not reflect how that place is per se walkable, but instead how and where to can one walk from there, that is to say, what is the walkability the place is endowed with. This evaluation incorporates three intertwined elements: the number of destinations/opportunities reachable by foot, their walking distances, and the quality of the paths to these destinations.

The use of such evaluation models as tools for the assessment of urban projects is straightforward: to estimate the effectiveness of a project in terms

of walkability, one codifies both the current situation and the project into the system, runs the model to compute walkability scores, and then compares the results.

But, what would it amount to to turn this around and address the inverse problem? Here arises an interesting prospect to have the system itself generate hypotheses of projects, given some (user-provided) objectives and constraints. There seems to reside a potential for developing not only evaluative, but also such generative procedures, in other words, to develop not only tools for assessing projects, but for designing them.

In this talk we present our first take of that inverse problem, by offering a possible transposition of our approach to evaluating walkability into one such generative procedure. This, it turns out, remarkably increases operational and computational complexity. Given the in principle great amount of combinatorial options and thus a vast search space of solutions, the problem calls for specific search heuristics which proves to be an intricate challenge. There are many different routes one may try to take here. The proposal hereby presented must be seen as a preliminary exploration of one among many such possible routes.

Differently from standard decision support systems developed for the purpose of evaluating given pre-defined urban projects and designs, we address the inverse problem to have the system itself generate hypotheses of projects and designs, given some (user-provided) objectives and constraints. Taking as a starting point a model for evaluating walkability, we construct a variant of a multi-objective genetic algorithm (specifically NSGA-II) to produce the frontier of non-dominated design alternatives to satisfy certain predefined constraints. By way of example, we briefly present an application of the system to a real urban area.

★ MO-5- π -R401

◆ Special Sessions

Monday, 16:40–18:20 – Room 401

Session: MCDM Doctoral Dissertation Award

Chair: Jyrki Wallenius

1 - Adaptive Parametric Scalarizations in Multicriteria Optimization

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In this talk we summarize the main results of our thesis in which a new adaptive parametric algorithm for multicriteria optimization problems is elaborated.

The algorithm computes the nondominated set or a subset of it by solving a sequence of scalarizations whose parameters are varied in an adap-

tive way. More precisely, the parameters are chosen so that with every scalarization solved either a new nondominated point is computed or the investigated part of the search region, i.e. the part of the outcome space containing possibly further nondominated points, can be discarded. Besides an appropriate computation of the parameters, the main ingredient of such an adaptive parametric algorithm is a systematic decomposition of the search region.

In the tricriteria case we present a redundancy-free decomposition which permits to show that the number of scalarized optimization problems that need to be solved in order to generate the nondominated set depends linearly on the number of nondominated points. This improves former results which showed a quadratic dependence in the worst case.

The presented adaptive parametric algorithm is not restricted to a special scalarization and can be used, e.g., with the classic ϵ -constraint or the weighted Tchebycheff method. For the augmented variants of these scalarizations, particularly for the augmented weighted Tchebycheff method, we show how all parameters, including the one associated to the augmentation term, can be chosen adaptively such that a nondominated point in the selected part of the search region is generated whenever there exists one and at the same time the augmentation parameter is chosen as large as possible in order to avoid numerical difficulties reported in the literature.

We validate our theoretical findings by numerical tests. Moreover, we demonstrate the flexibility of the presented algorithm by applying it also to continuous multicriteria optimization problems. Indeed, the algorithm is universally applicable to generate (discrete) representations of discrete and continuous, convex and non-convex multicriteria optimization problems.

2 - Exact And Representation Methods For Multiobjective Optimization Problems

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Many real-world decision-making situations involve simultaneous consideration of conflicting objectives. When a mathematical programming framework is utilized to model such problems, the result is a multiobjective optimization problem (MOP), which no longer possesses a unique optimal objective function value. In multiobjective optimization, the set of efficient solutions is used instead of the optimal solution. An efficient solution has the property that no improvement on any objective is possible without sacrificing at least another objective. The solution to a multiobjective optimization problem consists of the efficient set which portrays all relevant tradeoff information to a decision maker. Con-

tributions to the theory of multiobjective optimization date back to the 1970s. During the last two decades there has been significant progress in terms of practically implementable algorithms to solve several versions of the multiple objective optimization problem. Most of these consider two objective functions, and enumerating the efficient set remains a challenge for the general case. In this work, we revisit the theory of multiobjective optimization with the goal of building algorithms that are capable of solving problems with more than two objectives. Our main concern is to develop methods that enumerate or represent the efficient set for MOP.

We develop a new algorithm to generate all nondominated solutions (images of efficient solutions in the outcome space) for a multiobjective discrete optimization (MODO) problem with any number of objective functions. In this algorithm, the search is managed over $(p1)$ -dimensional rectangles where p represents the number of objectives in the problem. For each rectangle, two-stage optimization problems are solved where the first stage problem is an ϵ -constraint scalarization. The method searches $(p1)$ -dimensional space exhaustively, and guarantees to find all nondominated solutions in a finite number of iterations. The algorithm is compared with former studies on multiobjective knapsack and assignment problem instances with up to five objectives. The method outperforms former studies in terms of solution time. More importantly, the method solves at most 1.99 and 1.45 subproblems per nondominated solution for multiobjective knapsack and multiobjective assignment problems, respectively. Since the best possible bound is one subproblem per nondominated solution, the algorithm gives a highly competitive ratio.

In this dissertation, we develop another exact method to compute the nadir point for MODO problems with any number of objectives. The nadir point is constructed from the worst objective values over the efficient set of a MOP. We characterize the determination of nadir point with two-stage subproblems. Based on the characterization result, we present an algorithm that searches $(p2)$ -dimensional space exhaustively. Also, the algorithm utilizes the nadir point underestimator information to eliminate some portion of the search space beforehand. We show that the algorithm guarantees to find the nadir point for MODO problems in a finite number of iterations. The method is tested on multiobjective knapsack, assignment and integer linear programming problems and it outperforms former algorithms in terms of solution time.

The efficient set of an MOP is generally a large set to deal with. Instead of generating the entire efficient set, obtaining a finite subset, a representative set, can be more preferable. In general, the aim of finding a representation is to obtain a good subset of the efficient set. Particularly, a representative subset should contain so-

lutions from every portion of the nondominated set without missing any region. This assessment criterion is defined as coverage error, which is one of the quality measures for representative sets. Our main goal is to generate a representative set that satisfies specified coverage error. First, we propose an algorithm to obtain representation for MODO problems. We utilize p -dimensional rectangles to search the outcome space. During the search, some of the rectangles can be eliminated when they satisfy the specified coverage error. Computing the coverage error is a bilevel optimization problem, and even linear bilevel programming problems have been shown to be NP-hard. We present a method to compute the upper bound for the coverage error in polynomial time and use this upper bound to eliminate rectangles. We show that the algorithm terminates in a finite number of iterations, and generates a representative set that satisfies specified coverage error factor for MODO problems. This algorithm is limited to solve MODO problems, and increasing the desired coverage error level degrades the performance of the method due to navigation problem in the outcome space. We give a bilevel programming formulation to obtain a nondominated solution in any subset of the outcome space. We show that the bilevel programming problem is able to find a nondominated solution in a given set if such a solution exists. Otherwise, the formulation identifies that there exist no nondominated solution. By using the bilevel programming formulation, we present a partitioning algorithm that searches the outcome space. We show that algorithm generates a representation with specified coverage error level for any MOP. This algorithm also generates an approximation of the efficient set as a union of rectangles.

As a summary, we have developed algorithms to generate true nondominated set, representation of the nondominated set and approximation of the nondominated set. While the exact algorithms are competitive in terms solution time and the number of models solved per nondominated solution, the representation and approximation algorithms are competitive in terms of solution quality.

3 - Towards Automated Treatment Planning in Radiotherapy

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Introduction to Radiotherapy

Radiation therapy (or radiotherapy) is one of the main treatment modalities for cancer, along with surgery and chemotherapy. About 50% of the newly diagnosed cancer patients (more than 3 million each year in Europe alone, and 12 million worldwide) are treated with radiotherapy. Because each patient is anatomically unique, a personal treatment plan is generated. A treatment plan contains information on how

the dose, and consequently the probability of physical damage from irradiation is distributed inside the patient. The goal is to deliver a sufficient amount of dose to the tumour, while minimizing the (unavoidable) dose to the other structures (organs-at-risk), where each structure has a different radiosensitivity. Healthy tissue damaged by irradiation can cause severe short and long-term complications. For example, reduced functionality of salivary glands after radiotherapy treatment of a head-and-neck tumour may result in xerostomia (dry-mouth syndrome). Xerostomia urges the patient to drink some water every half-an-hour (day and night). Side-effects after radiotherapy of prostate cancer may be rectal bleeding, urinal and erection problems. It goes without saying that each complication has a significant impact on the quality-of-life of the patient, and it is thus of utmost importance to reduce the probability of developing treatment-induced complications. From a mathematical perspective, treatment plan optimisation is a multi-criterial, large scale, non-convex, combinatorial, and mixed continuous and discrete problem. The planning is currently done by a team of specialists, which is a time-consuming manual trial-and-error process. Due to the multi-criterial nature of the problem and insufficiently quantified relations between dose and probability of complications, the planning problem is complex (existing of 10-20 different criteria). The quality of the final treatment plan is determined by time constraints, planner (operator) skills, and the quality of the software used. Manual planning times ranges from a few hours to days. The work presented in the thesis describes and clinically validates Erasmus-iCycle, a novel approach to automate treatment planning. Automating treatment planning is essential in order to deterministically navigate through this complex search space. It allows generation of structural high-quality plans, utilising more complex techniques (irradiation direction problem), spare more organs-at-risk (because a human decision-maker can generally only take 5-10 criteria into account simultaneously), and perform planning studies (objective and quantitative answer if technique A is better than B).

Automating Decision-Making

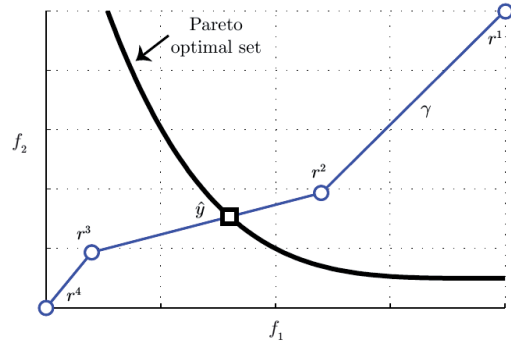
A treatment plan carefully balances tumour dosage and dose to the healthy organs. If sufficient irradiation of the tumour is attained, it does not make sense to fully minimise the dose to one (most important) organ-at-risk. A consequence of such an approach is that there is no room left to spare other healthy organs, and may therefore result in loss of functionality in those (and induce complications). The approach presented in this work is a mix of lexicographic optimisation and goal programming, and solved using sequential -constraint programming. The method is structured as follows: each criterion has an associated priority and objective. The ob-

jectives are bounded from above, i.e. are always allowed to improve. The rules are summarised in a so-called wish-list. The following is an example wish-list:

Constraints			
Nr	Volume	Type	Limit
1	Tumour	maximum	50 Gy
2	Tumour	maximum	43.7 Gy

Criteria			
Prio- rity	Volume	Type	Objec- tive
1	Salivary	minimise	39 Gy
	Gland (R)	mean	
2	Salivary	minimise	39 Gy
	Gland (L)	mean	
3	Salivary	minimise	20 Gy
	Gland (R)	mean	
4	Salivary	minimise	20 Gy
	Gland (L)	mean	
5	Oral Cavity	minimise	20 Gy
		mean	

Here there are 2 constraints for the minimum and maximum tumour dosage. The highest prioritised objective is to reduce the mean dose to the right salivary gland to 39 Gy (Gray, unit for absorbtion of radiation). If 39 Gy is achievable, it turns into a maximum constraint of 39 Gy, and then continues to the next objective. The next objective is then minimised subjected to this constraint. If however, 39 Gy is not achievable, but 45 Gy is, then the value is slightly relaxed and constrained to e.g. 46 Gy. Relaxation is necessary, otherwise the solution would end up in one of the end-points of the Pareto-curve, which faces an unacceptable trade-off. These steps are continued until all objectives are processed. In a last step, the list is processed again, but all objectives are now fully minimised in order to ensure a Pareto-optimal solution. The rationale behind this wish-list is that it is expected that the salivary gland will remain its functionality when receiving 39 Gy for 50% of the patients. It is therefore the aim to reach 39 Gy for both glands, rather than having 1 gland receiving 30 Gy and the other 50 Gy. The next step in the list is 20 Gy for the salivary glands, aiming at functionality for the majority of the patients. The fifth objective is dose to the oral cavity, which should be minimised to 20 Gy (or whatever is achievable), before further minimising the dose for the salivary glands again. Visually these rules set out a trajectory in the objective space (see next figure), intersecting the Pareto-optimal set. The trajectory is identical for all patients, but the Pareto-optimal set is patient-dependent. This method allows to find a clinically acceptable Pareto-optimal solution per patient. Clinical wish-lists can contain 30-50 different rules in the wish-list for 10-25 different criteria.



Developments

The work on treatment planning started while utilising a quadratic objective function, where the difference between an achievable and an ideal dose (only dose to the tumour, nothing outside) is minimised. As this is physically unachievable, the dose is iteratively modified and reoptimised in order to steer it into the desired shape. It is in this work that initiated the concept of the wish-list. Due to the iterative nature of the approach, it required an automated decision-making heuristic to indicate when enough is enough, and the algorithm should try to minimise the other criteria. This work learned us that automated treatment planning is feasible, and that constrained optimisation is essential for this goal. The downside is that this optimisation approach does not have optimality conditions: it is simply attempted to reach a certain solution for a (virtual) constrained optimisation problem, and if it takes too many iterations, it is considered infeasible. Another disadvantage is that it only worked for local objectives: more global objective functions, like a mean dose, is impossible to optimally integrate in this approach.

To overcome these limitations, a new solver was implemented based on primal-dual interior-point optimisation. There are many advantages to prefer a custom implementation over a commercial/out-of-the-box solver. To summarise a few: preprocessing is done at a high level, effective warmstarting, hardcoded functional derivatives, efficient memory management, optimal reduction of the Newton system, support for non-convex criteria, and a custom, highly-optimised level 3 BLAS implementation. Although the academic challenge was the most dominant for making this decision in the first place.

The new solver allowed us to test and better formalise our automated planning methodology. We have proven that the weighted-sum method and my -constraint-based method are capable of achieving identical solutions. This equivalence relation allows reaching a very similar solution for a moderately perturbed problem. As a result, acceptable similar solutions can be achieved by only a single optimisation, instead of using a lengthy, multiple optimisation as required by sequential -constraint programming.

This equivalence relation is used for the beam

direction optimisation problem. This is a combinatorial, discrete task (i.e. select 9 directions (beams) out of 72 candidate directions), and can only be solved by heuristics. Erasmus-iCycle starts with an empty set of directions, evaluate each candidate and adds the best one. Then a full automated multi-criteria optimised plan is computed. The next iteration uses the equivalence relation to transform the result to a weighted-sum problem, and evaluates all candidate directions again by keeping the already selected ones fixed. This is feasible in time because it only takes a single optimisation run. The best one is added to the set, and again a full automated multi-criteria optimisation is run. This process is repeated until a sufficient number of directions have been selected.

The clinical feasibility of automated planning for head-and-neck cancer patients is evaluated by a retrospective and a prospective study. In the prospective study, 33 plans for 20 patients were generated both the traditional (manual planning) and the automated way, and presented blind to the treating physician. In 32 out of 33 cases, the physician selected the automatically generated plan to treat the patient with, a success score of 97%. Not only the average plan quality improved, the variation in plan quality greatly reduced compared to traditional planning. This fuelled the introduction of Erasmus-iCycle in the clinic.

Another advantage of automated planning is that you can perform objective treatment planning studies. If one wants to investigate whether technique A works better than technique B, a number of plans need to be generated for both techniques. In the traditional way, this is a very labour-intensive and time-consuming process, and the produced plans are not always objective (i.e. if a planner has to re-plan the same patient with a different technique, he already has background knowledge of what is achievable, and is therefore biased). Another consequence is that the number of patients included in those studies is rather small. Using automated planning, these studies can be performed objectively and with sufficient scale. For one study, 1500 plans were automatically generated to investigate the dosimetric effect of the physical limitations of a certain treatment device, compared to a virtual machine not having any limitations. It was concluded that the current design of the device was sufficient (good news for the vendor), and adding more degrees of freedom will not be beneficial. For another study, the added value of daily re-planning was investigated. A treatment is delivered in several fractions, generally ranging from 3 to 40. The patient's internal anatomy differs day-by-day, and as a consequence the original treatment plan may not fit that particular day. This study investigated the effect of daily re-optimisation for this group of patients, or daily re-optimisation including re-optimisation of irradiation directions (beams).

It was concluded that daily re-optimisation only was most favourable, and a re-optimisation of irradiation directions did not lead to significant improvements. This is a favourable finding, as the whole optimisation in this case should ideally not consume more than 1 minute, while re-optimisation of the directions would take considerably longer.

Implications and Future Developments

Erasmus-iCycle was introduced in the clinic in 2010, and is currently the basis for treatment of 500 patients per year. Due to the objective nature of planning and the ability to perform studies on large datasets, it is also the base of many PhD projects, investigating different aspects of radiotherapy treatment.

From an MCDM perspective, we are still developing novel approaches to improve plan quality. Recently our group extended the reference point method with a lexicographic component, loosely mimicking our existing sequential-constraint optimisation approach. As a result, trade-offs for complex cases are generally better (the new plans are clinically preferred), and the optimisation times reduced by a factor 5-12. Another branch is to automatically pick plans from a (Pareto-optimal) set, as if done by the physician (i.e. a human operator). This will improve the quality of the irradiation direction selection, i.e. pick the best direction from 72 generated plans. This requires fuzzy prioritised decision-making based on preference relations.

As a by-product, automated treatment planning aids in reducing costs in health-care. Obviously, the planning phase itself reduces required personnel. However, it also allows to make a per-patient choice for the best available technique, resulting in not overtreating patients with more expensive treatments. One example is the use of proton therapy, a novel therapy. In The Netherlands, new proton therapy centres are being constructed, but only allowing several hundred patients a year for treatment. The challenge is to select patients who will benefit most from this novel, more expensive therapy. Automated planning allows generation of two plans (normal and proton) for each patient, while not increasing the workload. The lack of sufficiently trained and experienced personnel to provide the patient with the best treatment possible for the available techniques is another issue where automated treatment planning aids. This can occur in low and middle-income countries, but also in new upcoming economies such as China and Brazil. A similar development in Europe is the ageing of the population: more health-care is required while the active working population decreases. Enhanced decision-making is also crucial for daily re-planning, a new radiotherapy paradigm that currently gets the highest attention in literature. To compensate for daily anatomical changes, each of the up to 40 treatment sessions require generation of a new plan. This action has to be performed fast and

thus directly requires to meet clinical standards, without physicians' intervenience.

Tuesday, 09:00–10:00

★ TU-1

◆ Plenary Session

Monday, 09:00–10:00 – Aula

Session: Plenary talk: Roman Słowiński

Chair: Murat Köksalan

1 - Decision Aiding with Multiple Criteria Hierarchy Process

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Hierarchy in the family of criteria helps decomposing complex decision making problems into smaller and manageable subtasks. We present a methodology called Multiple Criteria Hierarchy Process (MCHP) which permits consideration of preference relations with respect to a subset of criteria at any level of the hierarchy. In Multiple Criteria Decision Aiding (MCDA), knowing these preference relations is important both for collecting preference information from the Decision Maker (DM) at different levels, and for explaining recommendations proposed at higher levels using preferences identified at lower levels. The MCHP is not restricted to any particular MCDA method. We concentrate on combination of MCHP with Robust Ordinal Regression (ROR), that takes into account all sets of parameters of an assumed preference model, which are compatible with preference information elicited by a Decision Maker (DM) in terms of ordinal pairwise comparisons of some alternatives and criteria. As a result of ROR, one gets necessary and possible preference relations in the set of alternatives, which hold for all compatible sets of parameters or for at least one compatible set of parameters, respectively. One can analyze these results not only with respect to the whole set of criteria, but also with respect to any subset of criteria at different levels of the hierarchy. We show this methodology for value function preference models, including a general additive value function and the Choquet integral, and for outranking preference models used in ELECTRE and PROMETHEE methods.

Related works with co-authors:

S. Corrente, S. Greco, R. Słowiński: Multiple Criteria Hierarchy Process in Robust Ordinal Regression. *Decision Support Systems*, 53 (2012) no.3, 660–674.

S. Corrente, S. Greco, R. Słowiński: Multiple Criteria Hierarchy Process with ELECTRE

and PROMETHEE. *OMEGA, The International Journal of Management Science*, 41 (2013) no.5, 820–846.

S. Corrente, S. Greco, R. Słowiński: Multiple Criteria Hierarchy Process for ELECTRE Tri methods. Submitted for publication 2014.

S. Angilella, S. Corrente, S. Greco, R. Słowiński: Robust Ordinal Regression and Stochastic Multiobjective Acceptability Analysis in Multiple Criteria Hierarchy

Tuesday, 10:30–12:10

★ TU-2- β -HS1

◆ Decision Aiding

Tuesday, 10:30–12:10 – Room HS 1

Session: Advances in Decision Aiding Methods 2

Chair: Selin Özpeynirci

1 - Aggregation techniques beyond weighted averaging to describe preferences within the multi-attribute value theory

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To describe preferences regarding multiple objectives, objectives can be structured hierarchically and aggregated to an overall objective. Multi-attribute value and utility theories have the advantage to impose only few constraints regarding the choice of the aggregation function - it mainly has to describe the subjective opinion of the decision maker. However, in practice there are only few examples where other functions than additive (weighted average) aggregation are used. Additive aggregation allows for a compensation of bad aspects with very good ones and is therefore not appropriate for describing preferences regarding complementary sub-objectives that should be fulfilled jointly. Especially in an ecological context, additive aggregation is often inappropriate, since well-balanced outcomes are often more desired than outcomes that consist of very bad and very good aspects. To complement the decision analyst's toolbox of aggregation functions to describe preferences regarding

multiple objectives, we introduce new aggregation techniques that increase the flexibility for the description of preferences. We include minimum aggregation, geometric mean, reverse- and off-set aggregation techniques as well as mixtures of these. We explain their properties, illustrate them with examples, and give recommendation on the choice of aggregation functions in typical situations.

2 - Robust Ordinal Regression and SMAA in Multiple Criteria Hierarchy Process for the Choquet Integral

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Interaction among criteria and hierarchical structure of criteria are two important issues of Multiple Criteria Decision Aiding. To deal with the interaction, fuzzy integrals are often used, in particular the Choquet integral. To handle the hierarchy of criteria, a recently proposed methodology, called Multiple Criteria Hierarchy Process (MCHP), can be used. While Robust Ordinal Regression (ROR) and Stochastic Multiobjective Acceptability Analysis (SMAA) have been already applied to estimate the capacities compatible with some preference information provided by the Decision Maker (DM), this paper aims at applying both of them to the Choquet integral as preference model in the case where the considered criteria have a hierarchical structure. To get a clear insight into the proposed methodology we shall apply it to a real world decision problem.

3 - An Approach of Including the Confidence Level of Experts in Pairwise Comparison Matrices and Estimating the Corresponding Probability of Rank Reversal

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In the context of multi-criteria decision the first step is to identify a set of criteria on which the decision should be based and then decide on their importance. The pairwise comparison method (PWC) provides a convenient and reliable means

to rank both the criteria involved in the decision making process and the alternative courses of action. In the context of PWC instead of having the experts rank the various criteria or alternatives directly, they rather compare these criteria in pairs. This can reduce the influence of subjective point of views associated with eliciting the weights directly. PWC plays a key role in structured decision making systems and especially in MCDM methods, such as the analytic hierarchy process (AHP). The final outcome is the estimation of the weights which determine the ranking of the alternatives.

There are several alternative methods for the completion of PWC matrices. A commonly used approach is the nine level scale, proposed by Saaty [1], in order to carry out the comparisons. In a typical application scenario, the experts submit their judgments without providing any additional information on the confidence of their opinion. It would however be very useful if the experts could provide some information quantifying their confidence when carrying out the pairwise comparisons. In this paper, we aim to shed light on this problem by proposing an alternative approach where the experts are asked to quantify their confidence on each judgment. Towards this end, the experts not only fill out a pairwise comparison but a corresponding confidence matrix, containing the certainty levels for each pairwise comparisons. These certainty levels range from zero to one, the former signifying lack of any confidence while the latter signifies complete certainty on the judgment. As such, we interpret the certainty levels as probabilities that the pairwise comparison in question is correct. We also discuss an appropriate discrete distribution that can be used to estimate the probabilities that some other element of the nine scale should have been completed instead. The choice of this distribution is not unique however and actually, although it is a tedious task, the expert could instead complete his own occurrence probabilities.

In order to account for the reliability of the decision making process we can use the confidence levels to estimate the probability of rank reversal PRR [2]. We discuss how this can be done analytically. We demonstrate that the average weights calculated as the geometric mean of the weights obtained by each single expert, obey a nearly Gaussian distribution and calculate their mean values and covariance matrices based on the confidence levels. We also show how the probability of rank reversal is related to the multivariate normal cumulative distribution function (MVNCDF). This approach provides a powerful theoretical framework for quantifying the uncertainty in the final outcome of the decision making process. The theoretical approach is compared to a numerical procedure, using Monte Carlo simulations, in order to validate our model. The results reveal a very good agreement between the two approaches, since the values of

PRR are fairly similar. We deduce that the values of PRR obtained by the theoretical method are quite accurate. This has been verified by considering several variations including different uncertainty levels as well as different number of criteria etc. This is a very important finding, giving a theoretical framework in the evaluation of PRR without using needless numerical simulations. According to the proposed model, a decision maker may have a very useful tool in order to validate the reliability of the results in PWC, based on the opinion of the experts and their certainty for the judgments they complete.

References

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- [2] G. Dede, T. Kamalakı, and T. Sphicopoulos, Convergence properties and practical estimation of the probability of rank reversal in pairwise comparisons for multi-criteria decision making problems, European Journal of Operational Research, vol. 241, no. 2, pp. 458-468, 2014.

4 - An Interactive Algorithm for Multiple Criteria Constrained Sorting Problem

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Multiple criteria sorting addresses the problem of assigning alternatives evaluated on several criteria to ordered categories. This problem appears in real life in several situations, such as star-based categorization of hotels, grouping of countries based on their debt repayment performance, and evaluation of students that apply for a program.

In this study, we consider the multiple criteria sorting problem where there are restrictions on the number of alternatives assigned to categories, i.e. constrained sorting problem (CSP). CSPs may arise in several situations such as when there is an upper limit on the number of students that can be accepted to a program or on the number of projects that can be funded due to budget limitations. The decision maker (DM) may define different constraints on category sizes, such as exact values or upper and lower bounds.

We develop an interactive algorithm that assigns alternatives to categories according to the initial information provided by the DM, and occasionally requires the DM to make assignments. We check whether assignments are consistent with underlying sorting model and category size restrictions. We eliminate inconsistencies, if any. The algorithm is applicable to both compensatory and non-compensatory sorting methods. We illustrate the proposed algorithm on two real-world examples: categorization of buses according to their technical states and selection of students to a program. We consider UTADIS and MR-Sort as the underlying sorting models. In both examples, the algorithm requires very short computation time and a reasonable amount of information from DM. Also, when there are more than two categories, the algorithm presents the DM the possible interval of categories for the alternative to be assigned, which makes the process easier.

During this study, the first and second authors were supported by the Scientific and Technological Research Council of Turkey (TBTAK-2219 International Postdoctoral Research Scholarship Programme)

★ TU-2- γ -HS2

◆ Model Building

Tuesday, 10:30-12:10 – Room HS 2

Session: IS-MB-SERVSYSY: Building MCDA Models in Service Systems

Chair: Caroline Mota

1 - IT Project Investments: An Analysis Based on a Sort and Rank Problem

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Decisions on Information Technology project investments should consider tangible and intangible benefits. However, measurements of intangible benefits are usually subjective and require a formal procedure to minimize the difficulty and consequence of this. Due to the concernment of evaluate IT projects, this paper presents a multi-criteria approach that describes the importance of classifying and prioritizing IT projects before taking any decisions, enabling us to handle the subjectiveness. This approach includes the identification of IT project investment, the construction of IT project categories or IT investment, the assessment of the importance of criteria and establishes final recommendations. At the end, a numerical illustration is presented to exemplify the applicability of the model, considering suggestion for future studies.

2 - A multicriteria group decision model for supporting Energy Utility to coordinate distributed real-time operation in smart grids

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There are several definitions of the term intelligent electricity grids (IEG), so called Smart Grids, in the literature. The fact is that smart grids use monitoring, communication, control, and automation to improve the way electricity is generated, distributed, and consumed. Efficiency, accommodating, motivating, opportunistic, quality focused, resilient and green are attributes expected of smart grids. All these attributes influence the way that smart grids will be operated, especially by accepting energy from any fuel source (distributed energy sources - DER) and using better energy storage technologies in order to support efficient real time operation. This study proposes a multicriteria group decision model based on a Dominance-based Rough Set Approach (DRSA) method and an aggregative procedure, which considers different decision makers weights, to support an Energy Utility so as to establish a set of decision rules to coordinate distributed real-time operation in a smart grid operational plant.

3 - A GIS-MCDM Model for Classification of Urban Areas in Public Safety Planning

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We present a MCDA model integrated with a geo-referencing tool to map urban areas favorable to crimes. The model aims to classify areas from a city according to a set of factors that influence the criminality including, in addition to criminal rates, demographic, economic and social issues. A spatial analysis shows the influence of these factors in each area. We applied the model to a Brazilian city where it was divided into human development units. The result of the model provides information for the development of public safety strategies appropriated to each region of the city.

★ TU-2-δ-HS3

◆ Industry and Business Applications

Tuesday, 10:30–12:10 – Room HS 3

Session: Knapsack and Packing Problems

Chair: José Rui Figueira

1 - A Heuristic Approach to Solving the Packing Problem With Additional Joint Constraints

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There is a wide range of potential application for packing/nesting problems. This has resulted in many variations of the original problem [1]. The reason for such modifications is twofold. First, in many cases it is necessary to add additional constraints that correspond to specifics of the real life application. The second one is the lowering the computational cost, by defining and solving a closely related but simpler problem. One such example is not allowing or limiting the rotation of the objects that are being packed. Dense periodic packings of polyhedra have shown to be essential in the prediction of complex structures in the field of material sciences [2]. Packing problems, and especially its jammed versions [3], have proven to be of a significant importance when exploring the self-assembly of such structures. The inclusion of validation/generation of jammed states has resulted in a significant increase in the problem complexity. In this work we propose a new version of the packing problem that includes joint constraints that can be suitable for application in structure prediction, but manages to avoid the validation of jammed states. To be more precise, we are solving a multi-criterion optimization problem in which polygons are packed inside of a two dimensional box. It is important to note that there are no additional constraints regarding rotation or translation. Each vertex of a polygon has a corresponding type (a, b, c). A joint is defined as an unordered pair (a, b) with length l . The goal is to have a tight packing of polygons inside of a container, with a maximal number of connected vertices. We will consider two vertices, with types a and b, connected if joint (a, b) exists and the distance between the vertices is equal to l . Each vertex can only be connected once. We propose a randomized greedy heuristic algorithm for solving the newly defined problem. To be exact two heuristic functions are used dependent on the stage of the algorithm. The first one is based on the areas of global and local convex

hulls which is essential for having a tight packing. The second one is focused on maximizing the satisfaction of joints, and it considers the number of vertices that are being blocked (losing the possibility of connecting) when a polygon is added. The proposed method consists in consecutive expansion and pruning stages. The performance of the proposed algorithm is further improved by performing multiple runs with different random seeds with an addition of a pheromone based learning mechanism. We also propose a series of benchmark instances for the newly defined problem.

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2 - A branch-and-cut method for the bi-objective bi-dimensional knapsack problem

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Multi-objective multi-dimensional knapsack problems (pOmDKP) are widely used to represent practical problems as capital budgeting or allocating processors. It aims to select a subset of n items such that the sum of weight of the selected items does not exceed the capacity on any of the m dimensions, while maximizing p objective functions. Each item has a weight on each dimension and a profit for each objective function. This problem is known for being particularly difficult as soon as the number of dimensions exceeds one, even in its single-objective version.

There are many published papers focusing on the exact solution of multi-objective single-dimensional knapsack. The solutions methods are often two-phases methods. The second phase is either a branch-and-bound method (as in [1]

for the bi-objective case or in [2] for the three-objective case), either a dynamic programming method [3], or a dedicated ranking method [2]. Only a few works have studied exactly the multi-objective multi-dimensional case. Concerning the single-objective multi-dimensional knapsack problem, many works have investigated cutting inequalities to speed-up the computation of solution [4].

In this work we are interested in the exact solution of the bi-objective bi-dimensional knapsack problem (2O2DKP), using a branch-and-cut method. A branch-and-cut method is a combination of a cutting plane method and a branch-and-bound method. According to its name, one of the main component of a branch-and-bound method aims at computing bounds of the problem. Convex relaxation has been a key component for successful bi-objective branch-and-bound algorithm (see for example [5]). It defines indeed a tight upper bound set, which can be computed easily if the single-objective version of the problem can be solved in (pseudo-)polynomial time. However, this is not the case for 2O2DKP. On the contrary, the linear relaxation remains relatively easy to compute, but the resulting bound set is less tight, which makes more difficult the exploration of nodes and leads to larger search-trees.

To improve the quality of the upper bound set based on linear relaxation, we introduce cover inequalities at each node of the branch-and-bound method, turning it to a branch-and-cut method. Cover inequalities consist of cuts defined for single-objective binary problems [6]. A cover is a set of objects such that the sum of the weights associated to these objects exceeds the capacity. In [6], the authors remark that computing all possible cover inequalities would be time-consuming and even impossible to implement. Instead, they consider the optimal solution of the linear relaxation and solve a smaller binary problem to find a cover inequality that is violated. In the bi-objective context, the linear relaxation is described by a set of extreme points, which are associated to efficient solutions. Moreover, each of these efficient solutions may be fractional and have a different subset of fractional variables. The generation of cover inequalities is therefore more complex, particularly to get a good trade-off between quality of the improved upper bound set defined and computational time. This leads to numerous strategies to generate cover inequalities.

This presentation will describe the mechanisms used in the multi-objective branch-and-cut method that we have developed (separation procedure, bound sets, generation of cover inequalities...). These strategies have been then experimentally validated.

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3 - Techniques for solution set compression in multiobjective optimization

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A major drawback of implicit enumeration algorithms for multiobjective combinatorial optimization problems is the large usage of memory resources that is required to store the set of potential solutions during the search process. In this work, we introduce several techniques and data structures that allow to compress a set of solutions during the run of an implicit enumeration algorithm for the particular case of the biobjective $\{0,1\}$ -knapsack problem. Particular emphasis is given on understanding the trade-off between memory usage and computation time, both from a theoretical and practical point of view. The experimental results indicate that some of these techniques allow to have a high compression ratio with very small computational time overhead.

4 - Multiple Objective Optimization for Multidimensional Knapsack Problems

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In constrained optimization some of the constraints may be soft in the sense that a slight

violation is acceptable, or even favorable, if the corresponding gain in the objective function is beneficial. The trade-off between constraint satisfaction on one hand and original objective value on the other hand can be analyzed by formulating an associated multiple objective optimization problem. As a concrete example, we consider multidimensional knapsack problems and relax one or several of the knapsack constraints. We apply this transformation on bidimensional knapsack problems (i.e., one objective and two knapsack constraints) and solve their associated biobjective counterparts using dynamic programming based algorithms. Numerical results suggest that in this way, trade-off information can be obtained at little extra cost. We also consider the tridimensional and the associated triobjective case, respectively, and discuss strategies for bound computations and for the selection of representative efficient solutions.

★ TU-2-λ-HS4

◆ Fuzzy Approaches, Decision Making under Fuzziness

Tuesday, 10:30-12:10 – Room HS 4

Session: Fuzzy Multiple Criteria Decision Making 3

Chair: Yu-Wang Chen

1 - Additive fuzzy priorities obtained from additively reciprocal fuzzy pairwise comparison matrices

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In multicriteria decision making methods based on pairwise comparisons, both the multiplicatively and additively reciprocal pairwise comparisons are used. Elements of multiplicatively reciprocal pairwise comparison matrices express how many times one object is preferred over another while the elements of additively reciprocal pairwise comparison matrices express the difference in preferences of two compared objects. Analogously, also the priorities of objects obtained from pairwise comparison matrices can be either multiplicative or additive. Most often, the multiplicatively reciprocal pairwise comparison matrices are used in the decision making, e.g. in Analytic Hierarchy Process, and the multiplicative priorities are computed from these matrices. However, the multiplicatively reciprocal pairwise comparison matrices and from them obtained multiplicative priorities are not suitable for every decision making problem. For some types of problems, as was already discussed in the literature, additively reciprocal pairwise comparison matrices and from them obtained additive priorities of objects are more appropriate.

The information about the problem is usually incomplete or vague in real decision making prob-

lems and, therefore, it is difficult to express the preference on a pair of compared objects precisely. This problem is handled by introducing the fuzzy extension of additively reciprocal pairwise comparison matrices by means of triangular fuzzy numbers. Formulas for obtaining additive priorities from additively reciprocal pairwise comparison matrices are fuzzified properly in order to obtain additive fuzzy priorities of objects. Three normalization conditions are applied on the formulas for obtaining additive priorities and their fuzzification. The choice of the normalization procedures is justified, and the properties of the resulting additive fuzzy priorities are given. The formulas for obtaining fuzzy additive priorities of objects are based on optimization, and they are designed in such way that the resulting fuzzy additive priorities are as wide as possible in order to capture the vagueness of information obtained in the additively reciprocal fuzzy pairwise comparison matrix. Moreover, the proposed optimization formulas preserve the additive reciprocity of pairwise comparisons, which is a key property of additively reciprocal pairwise comparisons.

2 - Analyzing Dynamic Capabilities with Hesitant Fuzzy Cognitive Maps

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In this paper, a new fuzzy cognitive map (FCM) that utilizes hesitant fuzzy linguistic term sets has been proposed. With this new FCM entitled Hesitant Fuzzy Cognitive Map (HFCM), experts can express their hesitant judgments on the relationships between the factors of a concept.

These expressions are defined with hesitant linguistic fuzzy term sets, which enables representing uncertain and hesitant information.

HFCM is more realistic and flexible than the traditional fuzzy cognitive maps for reflecting experts knowledge and experiences since the hesitant linguistic preference evaluations can be used.

Experts evaluate the causal relations among concepts with a degree of influence using hesitant fuzzy linguistic term sets (HFLTS), such as at least low influence, at most high influence, between medium and very high influence, absolute influence, very high influence, low influence. We applied a fuzzy envelope method that uses an Ordered Weighted Average (OWA) as an aggregation operator in order to aggregate the hesitant fuzzy linguistic expressions. The fuzzy envelope for HFLTS represents a linguistic interval within its upper bound and lower bound. The OWA operator for an aggregation of the linguistic terms is used to obtain a fuzzy membership function of the HFLTS.

Dynamic capabilities provide the opportunity for a firm to gain competitive advantage and increase performance through integrating, building and reconfiguring its resources in rapidly changing environments. A detailed literature review on dynamic capabilities shows that there are no exact relationships among factors affecting and affected by dynamic capabilities. It reveals that there is a knowledge convergence and no a common view among researchers and their decisions about the relationships among factors and the place of dynamic capabilities in organizations. This is a signal of uncertainty in literature and decisional hesitancy of experts, and it requires to apply the hesitant fuzzy linguistic preferences of experts on the evaluation of relationships among factors around the dynamic capabilities.

In this study, we gather an information from three experts hesitant evaluation on the relationships between the factors around dynamic capabilities and create a comprehensive Dynamic Capability model that explains consistent and sensible relations among concepts in organization and environment. This data structure that includes hesitant fuzzy linguistic expressions and fuzzy causal relationship between concepts direct us to study on HFLTS and FCM. So, the new HFCM model is applied to analyze the dynamic capabilities in organizations where experts can only provide hesitance and fuzzy information.

3 - Building key success factors of culture-creative Industry by using the modified fuzzy Delphi under heterogeneous semantic scale

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The term “culture-creative” more often refers to multicultural collision and fusion, which might be the transnational culture like the east and west, or different kinds of culture such as material culture and non-material culture, even cultures from a range of disciplines. Industrial revolution accelerating the rapid development of transportation technology causes the time-space compression between different cultures. The globalization of internet and information also speed up the flow of knowledge and cultures, which can help to create more “creativity”. Therefore, the industry of “culture-creative” is mainly based on the flow of knowledge and cultures. The study tries to identify the

definitions and relations of “culture”, “creativity” and “culture-creative”. According to the fuzzy Delphi method theory, expert fuzzy semantics must be built on the same semantic scale for all criteria. And this method cannot explain the heterogeneous under different criteria of semantic scale. So, this research explores the success factors of culture-creative industry in multiple criteria and presents a modified fuzzy Delphi method of considering heterogeneous linguist to construct. Finally, take Taiwan as an empirical case to demonstrate the proposed indexes for planning the culture-creative industry development strategies in the real world situation, and also provides some references for government to make the best decision.

4 - A belief rule based expert system for predicting consumer preference in new product development

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In the decision making process of new product development, companies need to understand consumer preferences for the newly developed products. A recently developed belief rule based (BRB) inference methodology is used to formulate the relationship between consumer preferences and product attributes. When the number of product attributes is large, the methodology encounters the challenge of dealing with an oversized rule base. In the paper a method of combining factor analysis with BRB methodology is proposed to overcome the challenge, and a prototype of expert system is developed for predicting consumer preferences. Firstly, a small number of factors are extracted from product attributes by applying factor analysis. Then a belief rule base is constructed to model the causal relationship between the characteristic factors and consumer preferences using expert knowledge. Lastly, the evidential reasoning approach is used to aggregate activated rules in the belief rule base. To validate the proposed method and illustrate the prototype system, consumer preferences for red teas are collected from 100 consumers of several tea stores through a market survey. The results show that the prototype of the belief rule based expert system has superior fitting capability on training data and high prediction accuracy on testing data, it has great potential to be applied to consumer preference prediction.

★ TU-2-σ-HS5

◆ Multi Objective Optimization

Tuesday, 10:30–12:10 – Room HS 5

Session: IS-EMO: Evolutionary Multiobjective Optimization (EMO) 1

Chair: Boris Naujoks

1 - Infeasibility in multiobjective optimization – a curse or blessing?

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For decades, since the inception of optimization, infeasibility has been regarded as an unfavorable situation which should not happen or if has happened, some repairing to regain feasibility should take place as soon as possible. No information is drawn from the occurrence of infeasibility to direct the course of computations. In this presentation we adopt the opposite attitude to infeasibility. We demonstrate that in the Multiobjective Optimization framework occurrence of infeasibility can be a source of valuable information which, if used properly, can have a significant impact on the course and length of computations to derive elements of the Pareto Front for Multiple Criteria Decision Aiding. Because of a close resemblance of our perspective on infeasibility to the classical duality we have coined up the term “constructive duality” for it. We discuss the significance of our approach to infeasibility in the context of large-scale Multiobjective Optimization and Multiple Criteria Decision Aiding, specifically in the context of Intensity Modulated Radiotherapy.

2 - A surrogate-assisted inverse model based evolutionary multiobjective optimization algorithm for computationally expensive problems

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Evolutionary multiobjective optimization

(EMO) algorithms are widely used to solve multiobjective optimization problems because of their advantages. For example, they can obtain a set of nondominated solutions in one solution process and have the ability to handle problems with multiple local and nonconvex Pareto fronts. Despite these advantages, EMO algorithms do not guarantee convergence to optimal solutions. Moreover, they are often criticized as they consume many function evaluations which increases the computation time. This concern is particularly relevant when EMO algorithms are employed to deal with computationally expensive problems. Here, we develop a surrogate-assisted EMO algorithm based on a recently proposed model based EMO algorithm, termed IM-MOEA for handling such problems.

IM-MOEA provides an extra advantage over traditional or state of the art EMO algorithms by generating samples directly in the objective space which can be convenient as the dimension of the objective space is usually lower than that of the decision space. In addition, sampling in the objective space can provide a possibility to the decision maker (DM) to generate solutions in preferred regions. Moreover, model based EMO algorithms have recently become popular in last few years as they can alleviate the requirement on the diversity of solutions both in objective and decision spaces.

In surrogate-assisted IM-MOEA, we address two main challenges, how and when to update the inverse models so that a diverse set of nondominated solutions can be obtained in fewer function evaluations. Here, samples are generated uniformly in the objective space and mapped to the decision space using Gaussian process based inverse models. We use multiple univariate models to ease the inverse modelling. A random grouping technique is used to obtain a fixed number of inverse models. After a mapping into the decision space, an adaptive evolution control strategy is used to update the models. Here, we select a minimum number of individuals for re-evaluation which can balance exploitation and exploration. In other words, individuals with good fitness values and contributing to a high degree of diversity of the population in the decision space are selected for re-evaluation. Uncertainty indicated by the Gaussian models is used to measure the diversity in the decision space. In addition, we check whether and when the models need to be updated. For example, if the existing models are accurate enough and can provide diverse solutions, they are not updated.

The new algorithm is compared with the original IM-MOEA on some benchmark multiobjective optimization problems and is able to generate similar or better solutions (in terms of inverted generational distance values) in fewer function evaluations.

3 - A preference-based evolutionary approach for solving a three-objective

competitive facility location and design problem

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A continuous competitive facility location and design problem with three conflicting objectives is considered in this research. Several evolutionary multi-objective optimization strategies have been applied in the literature for obtaining a discrete set approximating the complete Pareto front when only two of those three objectives are taken into account. However, when three or more objectives are considered, as we do here, classic evolutionary algorithms become computationally very expensive and time consuming for obtaining the aforementioned approximating set. Additionally, only a reasonable number of solutions should be provided to the decision maker so that he/she can carry out an adequate decision avoiding the usually complex analysis of a large amount of information. This fact suggests using optimization methods based on decision maker's preferences, with the aim to approximate only the part of the Pareto front that is of interest for the decision maker. In this research, we apply a preference-based evolutionary approach to the recently proposed three-objective location and design problem. The applied method enables to find a suitable solution for the decision maker in a reasonable amount of time.

4 - A Multiobjective Consistency Decision engine for a Manycore compilation platform using an Evolutionary Approach

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New emerging embedded applications (ex. multimedia, automotive) have increased the demand for architectures that provide a higher computing performance with efficient power management. Manycore architectures promise to overcome such challenges by embedding hundreds to thousands of simple cores on a single chip. However, the memory speed is not scaling with these

architectures which is limiting the efficiency of using the available computational power. The way of programming that highly parallel applications is a key factor to address these limitations. The existing programming models, based on different paradigms (ex. Message passing, Shared Memory) have many pros and cons depending on the context. We focus in our work on the Shared Memory model that consists in a virtual address space shared among processes on physically distributed cores. One main advantage offered by this model is the ease of programming as the user is not concerned with managing shared access issues. The user implementation level relies on the consistency model defined by the Shared Memory system. The application performance depends then on the efficiency of the different mechanisms characterizing the model. Several works were proposed for different systems which leads to multiple consistency approaches (ex. Lazy, Sequential, Release). Therefore, some platforms combine different mechanisms to provide a better tailoring with the application behaviour and the execution environment. Such platforms have been studied in Shared Memory systems like Munin, DSM-PM2 and JuxMem. To address this issue for manycore architectures, we proposed a multi-protocol compilation platform. The main purpose of this platform is to assign to each shared data access a specific protocol and appropriately configure it. The platform offers a protocol library where each protocol is characterized by one or more parameters. The range of possible values of each parameter depends on some constraints mainly related to the targeted platform. Therefore, the configuration complexity increases exponentially with the number of protocols parameters, the range values of each parameter and the evaluation process overhead. We present in this paper a multi-objective decision engine which is the main phase of the multi-protocol compilation platform where protocols are configured. It consists of instantiating the chosen protocols according to the application behaviour defined during the static analysis step and the given performance objectives. The proposed decision model uses the Rank-based Multi-objective Genetic Algorithm. It aims to minimize the number of iterations required to converge towards an optimized protocol configuration. The platform supports different performance objectives (ex. Cache miss rate, Access latency, On-chip Traffic). The on-chip access latency and the cache miss rate are the multi-objective performance constraints used in this model. One interesting case study is the Data Sliding protocol. This protocol was proposed in previous works in order to enhance the on-chip storage efficiency by allowing data migration to available cache memories in the neighbourhood. This leads to less off-chip data ejection and therefore less cache misses which provides a better performance. However, the more the data travel the more the owner core will

pay to bring it back to its local cache. This is why, the migration radius assigned to each data is an important parameter to make a trade-off between on-chip access latency and the cache performance in order to reduce the cache miss rate while keeping the access distance reasonably low. Thus, the decision engine allows to assign a higher migration radius to each data while keeping it as long as possible in the chip. To apply the proposed optimization model on the Data Sliding protocol, we consider a population as a set of N configurations. We define a configuration as a data access trace with the assigned protocols instances. The multi-protocol model allows to assign a different protocol to each single access. Such a granularity will increase the complexity of the decision process. We first applied our model on the sliding protocol with small shared data instances (less than 10 accesses) targeting a 64-cores 2D mesh-based platform. The decision engine has up to 46% performance enhancement compared with an exhaustive search. A complete performance study is conducted by using different workloads and varying protocols assignment within a single application. Several improvements are possible to speed up the optimization model through the selection and the mutation operators (ex. introducing a dynamic mutation function).

★ TU-2- σ -R401

◆ Multi Objective Optimization

Tuesday, 10:30-12:10 – Room 401

Session: Multi Objective Programming and Problems 3

Chair: Erdal Aydemir

1 - Data Pre-treatment for Solving bi-objective Knapsack Problem

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In this paper, the admissible domain of a bi-objective knapsack problem is our interest platform. Although the reduction of the feasible region has been studied by some authors but yet, it has to be investigated more in order to explore deeply the domain before solving the problem. We proposed however, a new technique based on the supported efficient solutions combined with the dominance relationship between items's efficiency. We illustrate the algorithm by a didactic example and some experiments and comparisons are presented, showing the efficiency of the procedure compared to the previous techniques in the literature.

2 - A Bi-objective Mathematical Model for Train Platforming Problem

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In railway stations, one of the most important processes is about control of traffic. To make an effective plan with regard to timetable can be reduced delay of trains. The aim of the paper is to propose a decision making tool for dispatchers. A bi-objective mathematical model has been developed to schedule of incoming trains. The objectives of the model are to minimize deviations from planned departure time and to maximize number of connected trains to be assigned to the same platform. The proposed model has been verified with generated small test instance using GAMS/Cplex solver. Different scalarization methods are applied to the model and the obtained results are discussed.

3 - A bi-objective parallel machine scheduling problem under resource constraints

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In this study, an identical parallel machine scheduling problem under sequence dependent set up time, machine eligibility restrictions and resource constraints is considered. The objectives of the problem are to minimize the makespan and to minimize the total tardiness. Randomly generated instances are solved both conic scalarization method and epsilon-constraint method. Strengths and weaknesses of the methods are discussed.

4 - Future Directions for Multi-objective Inventory Routing with Uncertainties

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The inventory routing problem (IRP) is concerned with the combination and coordination of two components of the supply chain management which are inventory management and transportation. These components are two key logistic factors for companies to gain competitive advantage. The classical IRP has three decisions that are starting service time, delivery

amount and distribution routes. Many studies have concerned to IRP for solving the practical IRPs and they used methods which are exact, heuristics, and meta-heuristics. According to the literature, IRP studies have addressed to integrate with vendor-managed inventory routing problem, and enrichment of vehicle routing problems. The first paper is presented by Beltrami and Bodin (1974) including modelling and sample solutions of IRPs. For the IRP instances, Fisher et al. (1982) and Bell et al. (1983) are developed a mixed integer programming model. Then the following studies are presented considering a large IRP by Golden et al. (1984) and Dror et al. (1985). Consequently, IRPs have been classified in Time Horizon, Products, Structure, Routing, Inventory Policy, Inventory Decisions, Fleet Composition, Fleet Size and Objective Functions (modified from Coelho et al., 2012). IRPs also belong into the class of NP-Hard problems. Many heuristics which are modified sweep, tabu search, simulated annealing, local search, and also genetic algorithm with their hybridization are developed to solve IRPs for obtaining near optimal solutions. About the computation time, the better solution times by the side of reasonable times and also the better algorithms are obtained, developed, and presented in the solver challenges on the scientific platforms at this point (Verolog, 2014).

Points of the literature review and industry, stochastic approaches are more important for modelling of IRPs. Main assumption of the approaches is the known probability distribution for customer usage. In the meantime stochastic IRPs involves the future usage amounts that are uncertain. At the present time, most of the optimization models are formulated by eliminated the uncertainties of the systems in the real world applications. Some of these uncertainties are demand (customer usage), variable routing frequency, routing cost, inventory costs, lead time etc. That is, the stochastic IRPs want to eliminate all of the uncertainties via known probability distributions, because modelling and solution are extremely difficult for complex real world applications. In addition, the objective functions of IRPs are rapidly changed in forms from the single objective to bi-objective and multi-objective. Because of the global competition, companies have to concurrently satisfy two or more objectives that can be routing cost, routing profit, routing/driving time, fuel consumption, balance, time windows, customer satisfaction, fleet usage, collection/delivery, etc.

Consequently, the some further research areas and the cases of real world applications are offered as follows: - External uncertainties (Fuzzy logic methods),

- Internal uncertainties (Grey Systems Theory),
- Demand disruptions,
- Fleet breakdowns,
- Unexpected/Extraordinary cases (Disasters, geographical situations, etc.),

- Customer classifications/ Priorities,
- Specialized orders,
- Emergency orders,
- Traffic and road effects,
- Green supply chain management (Considering environmental effects, emissions etc.),
- The new product/item types: Imperfect, Perishable, Deteriorating, Growing, Re-cyclic, Recovery, Waste/E-waste items etc.,
- The new approaches must be presented on cyclic inventory routing,
- Inventory routing with financial situations (Penalties, taxes, economic incentives etc.),
- Cloud inventory routing,
- Overseas inventory routing.

Through the use of the further research areas proposed in this paper, decision makers would then be able to assess the impact of the real world problems and regulations. These areas can differ from the industrial scopes and enriched to cases which are different to countries. The proposed research directions are provided to make contribution for the scientific literature and industrial expectations.

★ TU-2-χ-HS6

◆ Environment, Infrastructure & Emerging Applications

Tuesday, 10:30–12:10 – Room HS 6

Session: Environmental Decision Making 3

Chair: Raimo P. Hämäläinen

1 - Comparison of AHP/ANP Decision Making Methodologies in a Case Study of Renewable Energy in the Dominican Republic

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In the energy sector, the Dominican Republic offers an opportunity for domestic and foreign investment for urbanized areas with the introduction of a legal framework where renewable energy producers receive legal benefits and tax exemptions. This leads us to believe that emerging countries should start to implement the methods used worldwide to make clear decisions. A study was performed in which we applied and compared the Analytic Hierarchy Process (AHP) and the Analytic Process Network (ANP) methodologies for the best places to install solar panels on a government building in the Dominican Republic. Experts belonging to the sector were surveyed to verify the advantages and disadvantages offered by these decision-making methods, so that concrete priorities in developing viable projects are achieved. Comparing these methods provides graphical tools to measure the consistency of certain opinions, and modeling the

case study it is found that there are several different indicators that assess the complexity of the methodology to obtain robust results.

2 - Sustainability Roadmap with Changing Societal Preference as Extension to Lifecycle Analysis

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Research and Development (R&D) roadmaps serve as decisions aiding tools for stakeholders in government, industry, and academia. Roadmaps have been developed to guide research efforts in a variety of topics such as nanotechnology, biofuels, and other technical innovations. Such emerging industries are subject to deep uncertainties from emergent conditions and future scenarios. Deep uncertainties involve structural and qualitative perspectives or trends that are disruptive to priorities and decision-making. A common failure of R&D roadmaps is to consider the impact future uncertainties have on the prioritization of R&D initiatives.

This paper will demonstrate an integration of scenario planning with multi-criteria decision analysis (MCDA) for the prioritization of R&D initiatives for developing a roadmap, which identifies robust research and development efforts. An iterative approach to scenario-based preference analysis accounts for the dynamics of preferences throughout the system life cycle. The proposed effort will apply life cycle assessment and other systems analysis methods (e.g., life cycle costing, sensitivity analysis, stakeholder analysis, etc.) with scenario-based preferences to demonstrate the development of roadmaps for sustainability. In particular, life cycle assessment can be used to highlight uncertainties that are critical to consider for scenario analysis and strategic planning. At the same time, scenario-based preference modeling, which includes analyzing business decisions and policies, brings context to life cycle assessments.

Integration of MCDA with scenario planning has been suggested as a flexible, simple, and transparent approach for strategy evaluation and selection (Goodwin and Wright, 2001). In the context of investment or R&D strategies, the integration can identify which strategies are robust across various alternate future scenarios or according to different stakeholder preferences. Iterative MCDA can increase robustness in decision-making, especially when considering different

combinations of future scenarios (Lempert, 2003; Groves and Lempert, 2007). Analyzing different scenarios as new information provides insight on potential disruptive emergent conditions is essential for long-term strategic decision-making. Application of these methods is shown for two sustainability cases, specifically (i) the development of aviation biofuel supply chains and (ii) “net zero water” use at military installations. Aviation biofuel research initiatives include investigation and optimization of bio-feedstock production, aviation biofuel conversion technologies, transportation logistics, and others. “Net zero water” initiatives include water efficient sanitary equipment (e.g., toilets, showerheads, faucets, etc.), irrigation and landscaping techniques, and leak detection technologies. Common criteria for these case studies are related to life cycle cost, emissions, and fossil fuel consumption. Examples of future scenarios that could be disruptive to research priorities for these sustainability roadmaps include climate change impacts, environmental regulations, national security concerns, technology innovation, and economic downturns.

Methods such as life cycle assessment (LCA), life cycle costing (LCC), and techno-economical analysis (TEA) can be used to inform the assessment of how well R&D initiatives meet criteria. Specifically, LCA, LCC, and TEA are used to evaluate the extent to which R&D initiatives address various objectives (or criteria) such as minimizing climate impacts from GHG emissions, minimizing fuel cost, and maximizing economic growth. The results describe which R&D initiatives perform best in terms of multiple criteria and which are robust under different scenarios. Multiple iterations of the analytical framework reveal how priorities change under scenarios of various economic, political, and technological conditions as well as with respect to various system boundaries or scopes (global, national, regional) and from different stakeholder perspectives. Based on the robustness of initiatives and the disruptiveness of emergent conditions or scenarios, the results are used to develop R&D roadmaps to guide future efforts that are in line with stakeholder preferences. These methods can be used for the coordination of research initiatives applicable to various fields that involve diverse stakeholders from government, industry, and academia. Future work will involve the integration of value-of-information analysis and uncertainty analysis to ensure that R&D initiatives significantly contribute to the mitigation of system vulnerabilities.

3 - Prioritization of Maintenance Related Waste Using Evidential Reasoning Approach

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Recently reduction and elimination of maintenance waste has taken a lot of attention by the researcher because of its importance in decreasing their negative affect on the production capacity and increasing budget blindly. So the overall goal of this research is to identify and prioritize factors creating maintenance-related waste. Evidential Reasoning (ER) approach which is one of the latest developments within Multi-criteria decision making (MCDM) literature is used for prioritization. In order to apply ER approach, maintenance wastes as a general property is broken down to multiple attribute framework having the form of a tree(hierarchy) structure. So five manufacturing companies participated in a workshop for identifying root-causes for maintenance-related waste in manufacturing industry. The 16 found categories, related to root-causes of maintenance-related waste, were analysed. Results shown that the maintenance-related waste are heavily reliant on human factors/errors as a root or major contributory cause in different levels which can affect performance and productivity. So basic tree structure necessary for ER assessment is developed based on literature on maintenance related waste with focus on human factors. Those 16 categories incorporated into this hierarchy model and surveys are designed based on basic attributes at the lowest level of this tree. After applying ER, results shown that management condition at first place and maintainer condition and working condition are respectively in second and third place as the most responsible maintenance waste created by human factors in proposed manufacturing industry. This prioritization methodology can be used as a tool in creating awareness for managers for making decision to target for reducing or eliminating maintenance waste.

4 - Supporting Environmental Decision Making with Portfolio Decision Analysis

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Environmental management decisions are often portfolio problems. In practice, the decision making process typically goes so that experts de-

velop a number of feasible decision alternatives which consist of a set of actions each contributing to the overall goal. These alternatives are then evaluated by the stakeholders using Multiple Criteria Decision Analysis (MCDA; see, e.g. Linkov and Moberg 2011). This traditional approach limits the analysis to the predetermined portfolios of actions developed by the experts. Thus one risks the possibility that dominating portfolios are left out of the evaluation. This can happen because of lack of optimization and due to behavioral effects such as insensitivity to scope, favoring champion projects or failure to see synergies and how actions complement each other (Fasolo, Morton and von Winterfeldt 2011).

Here we present a framework for the use of Portfolio Decision Analysis (Salo, Keisler and Morton 2011) in environmental management and also show how to incorporate incomplete information in the analysis. The framework consists of steps that are applicable to a broad range of portfolio decisions. Compared to earlier MCDA frameworks the framework includes a new step related to specifying constraints, action interdependencies and modeling the overall consequences of the portfolio of actions.

We demonstrate the framework and the possibilities of computer support with an illustrative case related to providing urban water services. We use the RPM-Decisions software which is an implementation of the Robust Portfolio Modeling (RPM) methodology by Liesi, Mild and Salo (2007). It enables the use of incomplete preference information in portfolio decision analysis. This possibility can be beneficial, as in environmental decisions we can easily face the situation where precise preferences or consequence data is incomplete or uncertain.

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Tuesday, 13:30–15:10

★ TU-3-β-HS1

◆ Decision Aiding

Tuesday, 13:30–15:10 – Room HS 1

Session: Advances in Decision Aiding Methods
3

Chair: Jussi Hakanen

1 - The WINGS Method with Negative Influences

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The WINGS (Weighted Influence Non-linear Gauge System) method represents systems modeling in solving decision problems. It is an attempt to bridge two different approaches to operations research: soft and hard. Using network representation for analysis of interrelated factors and causal relations among them, WINGS enables evaluating alternatives when interrelations between the criteria cannot be neglected. In this paper we discuss the possibility of allowing negative influences among the model elements in the WINGS method. Such an extension can substantially enhance the ability to solve a variety of multiple criteria problems. Strategic decisions in public relations (PR) are an example of practical utility of the WINGS method with negative influences.

2 - Ranking the Factors of Human Quality Treatment by TOPSIS Method

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The roots of being ought to treat humans well in the organizations first grounds in the early 1900s. At first, people used to be seen as machines and at those times this topic was studied by Taylor in his scientific management; by Fayol in his managerial principles and by Ford in his assembly line work. Necessity of treating people well has firstly been explained by Elton Mayo in 1933 under the name of Human Relations Movement. Then Maslow followed him as claiming human needs and motivation to work with the notion of job satisfaction. Following this trend of the importance of human; organizational justice has been appeared. Then maybe the closest term to HQT that is Humanistic Management has been popular since 1980s and first roots about this approach was born with M.P. Follet in 1925 as his opinions claim that human factor is inseparable from the mechanical side in business. Humanistic management holds a new vision for business as serving the societies in which business operates, increasing their citizens' quality of life. Though there are some reasons why managers do not follow humanistic approaches such as because of fear and vulnerability; treating people right in organizations can provide a "more humanized business, by fostering human flourishing, the enhancement of human capabilities, and the pursuit of a more humane development for each and every person". Also it enhances productivity and devel-

ops human potential; while it is a “way to cope with old problems motivation, work satisfaction and morale”. Only research that has been found and that used the term “Human Quality Treatment” was investigated in Melé’s research in 2014. In this study, HQT has been investigated as considering the levels of treating people in organizations from maltreatment to indifference, justice, care and development stages. In that study, the purpose is to identify those levels to be the pathfinder for managers of organizations while treating to the employees to get benefit from them at maximum level. In this study, it is aimed to determine and order the factors in a hierarchical way of the HQT by using the TOPSIS to help managers by showing them how to treat their employees to get the most benefit by efficiency and effectiveness from them and by showing them which factors are the most important for the employees when the issue is about being treated well as their perception. The factors those affect the HQT are determined by authors and ordered in a hierarchical way by method TOPSIS which was found by Yoon and Hwang in 1980. The factors have been determined by authors and from literature; then as weighting them, ordered with TOPSIS technique. The factors involve; working conditions which are workplace conditions, workload, quality of material used while working, working time; monetary conditions which are paying what the employee deserves as the salary which is called here as salary politics, promotion politics; off-days and annual vacations provided and social opportunities provided, job characteristics which are; job challenge, role clarity, performance appraisal fairness, work environment characteristics which are supervisory relationship and employee freedom, communication behavior type, management style person-organization fit, person involvement being fair, treating equal, respect, contribution to personal development and caring. Thus we have twenty-two factors here; and these factors are investigated and weighted under three conditions which are called here as criteria those are physically, psychologically and socially. Weighting is made by consulting a firm and by authors’ views. While ordering the factors by TOPSIS technique according to three criteria, because each factor shows difference as being weighted based on criterion; a rank that managers can benefit from, as they learn which factors they should pay more attention when they treat their employees in a quality way.

3 - A data-driven approximate reasoning model for multi-attribute analysis

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The evidential reasoning (ER) rule has been established recently to combine multiple pieces of independent evidence conjunctively. Through taking into consideration both the bounded sum of individual support and the orthogonal sum of collective support on weighted belief distributions in a rational way, the ER rule advances the seminal Dempster-Shafer (D-S) theory of evidence and it constitutes a generic conjunctive probabilistic reasoning process or so-called a generalised Bayesian inference process. To implement the ER rule to multi-attribute analysis effectively, this study aims to explore a few key issues of developing an approximate reasoning model from data.

First of all, it is important to consider the representation of attributes. Attributes can usually be categorised as qualitative or quantitative in the context of multi-attribute analysis. A qualitative attribute can usually be characterised by a set of mutually exclusive and exhaustive linguistic terms, as widely implemented in decision and risk analysis. Whilst a quantitative attribute can be discretised in order to capture the characteristics of its distribution roughly without making explicit assumptions. Discretisation is the most commonly used way in probabilistic inference, and however it loses the ability to differentiate values within a discretised interval. Thus a set of referential values can be sampled from domain data to construct the prior distribution for each quantitative attribute. As a result, each antecedent attribute can be profiled by a belief distribution consistently.

Secondly, after all attributes are represented by the belief distribution, it is necessary to model the causal relationship between the antecedent attributes and the consequent in order to perform further reasoning. Very often, there is no or insufficient prior knowledge about how each attribute influences others. Therefore it is difficult to construct a complete conditional probability table (CPT) for Bayesian inference. This study attempts to model the causal relationship between each antecedent attribute and the consequent separately, and then combine the consequent belief distribution supported by individual antecedent attribute approximately using the ER rule.

Thirdly, an optimal learning model can be constructed to train prior parameters, such as the referential values of antecedent and consequent attributes and the approximated belief degrees in causal belief matrices, in the approximate rea-

soning model when data are available.

The above proposed approximate reasoning model holds an additive complexity on the number of referential values of antecedent attributes in contrast to the multiplicative complexity in Bayesian inference, and therefore it can be easily implemented to a range of multi-attribute analysis problems, such as fault diagnosis, risk and decision analysis. The antecedent attributes are implicitly assumed to be mutually independent, but actually the independence among attributes can be investigated in real applications.

4 - Parameterization of ELECTRE based stepwise benchmarking model

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Performance evaluation and benchmarking based on ELECTRE multi-level outranking (ELECTRE-MLO) method has several advantages. The outcome in the form of relation tree allows decision makers to determine performance levels of benchmarking units and as well as to establish development strategy in a stepwise manner by tracking intermediate targets/benchmarks on the route to the ultimate goal. This optimal sequence of intermediate benchmarks constitutes a recommended development path. Another important advantage over other methods is in less number of parameters to be determined. However, threshold values for concordance and discordance indices set by decision makers can affect the relation tree as well as the final decision on benchmarking path for less successful units. Therefore, the parameterization of the model needs to be accompanied with appropriate sensitivity analysis which will indicate the robustness of the result. For this purpose we introduce sensitivity coefficient as an additional measure that assists for final choice on development path.

★ TU-3- γ -HS2

◆ Model Building

Tuesday, 13:30–15:10 – Room HS 2

Session: IS-MB-PMI: Building MCDA Models:

Practical and Methodological Issues

Chair: Luciana Alencar

1 - Contractor's selection based on an additive-veto model

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Contractors have high influence in the success or failure of projects in the construction industry. In the procurement project management in civil construction, selecting contractors is one of the critical acquisitions and should be well structured in order to be in accordance with the overall objective of the owner. In this context, contractor selection is a vital part of the project management. Then, an additive-veto multicriteria decision model is presented and an application using this model for selecting contractors is presented. The veto is used when the performance of contractors for some criteria are found to be unacceptable, penalizing their evaluation.

2 - A Fuzzy Multicriteria Sorting Model to Cooperation Assessment

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People play a fundamental role in software projects and they determine the quality and productivity of a project. One of the intergroup conflicts that has attracted most attention in the literature in the area of IS and IT is precisely the clash between technology versus business. The model proposed in this paper combines the ELECTRE TRI multicriteria method and the fuzzy approach to classify the cooperation of those involved in IT projects. Moreover, the suggestion was made to use triangular fuzzy numbers for the decision makers evaluation, both for the reference classes and the levels of cooperation. A numerical application was presented to illustrate the proposed model. The results are of great interest to researchers and practitioners of IS area: the theoretical mathematical procedure helps the companies regarding cooperation, which is a critical factor success of IT projects.

3 - Evaluation of power generation technologies using PROMETHEE method with surrogate weights

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The identification of new technologies for power generation in the Energy Sector is an actual challenge in Brazil. This is a strategic problem that deals with multiple criteria within a context of imprecise information regarding the importance of criteria. In that perspective, this study proposes a decision model based on PROMETHEE multicriteria method integrated with surrogate weights to evaluate Technology Readiness for energy. This model, PROMETHEE-ROC (Rank Order Centroid), is shown to be an adequate approach for technology readiness assessment since the decision maker is able and feels comfortable to order all criteria by their relative importance.

4 - Flexible Elicitation procedure for Additive Models

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The paper deals with a new procedure for elicitation of weights for additive models, which is one of the most relevant issues in additive models. This procedure introduces a flexible and interactive approach in the classical tradeoff elicitation procedure. The tradeoff elicitation procedure is one of the approaches with strongest theoretical foundation for multicriteria models. This procedure is intended to reduce the DMs cognitive effort in the process of preference modeling. A Decision Support System is presented with an application in order to illustrate its use.

★ TU-3-δ-HS3

◆ Industry and Business Applications

Tuesday, 13:30-15:10 – Room HS 3

Session: Spatial Optimization and Decision Making

Chair: Mariana Madruga de Brito

1 - MCDM and GIS to identify land suitability for agriculture

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The integration of MultiCriteria Decision Making (MCDM) approaches in a Geographical Information System (GIS) provides a powerful spatial decision support system which offers the opportunity to efficiently produce the land suitability maps for agriculture. Indeed, GIS is a powerful tool for analyzing spatial data and establishing a process for decision support. Because of their spatial aggregation functions, MCDM methods can facilitate decision making in situations where several solutions are available, various criteria have to be taken into account and decision-makers are in conflict. The parameters and the classification system used in this work are inspired from the FAO (Food and Agriculture Organization) approach dedicated to a sustainable agriculture. A spatial decision support system has been developed for establishing the land suitability map for agriculture. It incorporates the multicriteria analysis method ELECTRE Tri (ELimitation Et Choix Traduisant la REalit) in a GIS within the GIS program package environment. The main purpose of this research is to propose a conceptual and methodological framework for the combination of GIS and multicriteria methods in a single coherent system that takes into account the whole process from the acquisition of spatially referenced data to decision-making. In this context, a spatial decision support system for developing land suitability maps for agriculture has been developed. The algorithm of ELECTRE Tri is incorporated into a GIS environment and added to the other analysis functions of GIS. This approach has been tested on an area in Algeria. A land suitability map for durum wheat has been produced. Through the obtained results, it appears that ELECTRE Tri method, integrated into a GIS, is better suited to the problem of land suitability for agriculture. The coherence of the obtained maps confirms the system effectiveness.

2 - A Model for Spatial Multicriteria Hierarchical Clustering

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Research on the problem of multicriteria territory partitioning is at its begin. This is mainly due to the fact that it involves tools from fields that are to this day still young. To answer this shortage, we propose an adaptation of a multicriteria clustering method that takes spatial con-

straints into account. Two variants are described and tested on an illustrative case. This example deals with the partitioning of the Walloon region in Belgium into clusters with a similar level of well-being as perceived by its inhabitants.

3 - Solving Land Reallocation Problem for Land Consolidation by Integrating GIS and Multi-Objective Optimization

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The motivation of the proposed research is to automate the land reallocation process for land consolidation by integrating Geographic Information System (GIS) and multi-objective optimization technique. In this case, the problem is being solved for the state of Uttar Pradesh (U.P.) of India, while the same methodology with slightly different rules can be used for other states also. This is a spatial optimization problem. GIS technology plays a very significant role by integrating artificial intelligence, operational research, and decision science in solving complex spatial optimization problems. Land reallocation is one such problem. Limitations of manual land consolidation process, in view of the involvement of large volumes of spatial and non-spatial data which are to be organized, managed, retrieved and used for complex queries, can be eliminated using GIS technology. The aim of land consolidation is achieved by successful reallocation of land of the stakeholders in a village. The whole reallocation problem has two broad objectives which need to be satisfied simultaneously. One is redistribution of stakeholders location and the other is partitioning of land. In redistribution problem, a stakeholder in the village is reallocated land in maximum of three sectors and minimum of one sector by minimizing the leftover land after relocation. Partitioning problem describes the process of finding the optimal shape and size of the parcels depending on the value of the stakeholder. In addition to these there are a large number of regulatory constraints on the reallocation process which need to be accounted while solving the problem. Due to the involvement of large number of non-linear and non-convex constraints and more than one objective function, evolutionary multi-objective

optimization technique is appropriate to solve these problems. The non-dominated solutions from evolutionary multi-objective optimization are analysed for proper decision making to make the process robust. The output of this research is an automated land reallocation system which is reliable, systematic, efficient, accurate and transparent thus having the potential to reduce the number of legal cases. The results obtained using proposed method are compared with the results of the conventional approach, i.e., manual consolidation by consolidation officers and found satisfactory.

4 - GIS-based landslide susceptibility mapping using analytical hierarchy process (AHP): a case study in Porto Alegre municipality, Brazil

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Landslides are one of the most devastating disasters among all natural hazards in Brazil, with nearly 3,355 fatalities between 1988 and 2013. Apart from the loss of lives, they also cause substantial economic losses. As an example, the mass movements that occurred in 2011 in Rio de Janeiro resulted in US\$ 2.8 billion in damage. Thus, in order to mitigate these hazards, it is essential to map the landslide susceptibility. A variety of techniques have been proposed to assess the susceptibility. Deterministic approaches require geotechnical data that are not readily available in lesser developed countries. Likewise, statistical methods demands detailed landslide inventories, which are still scarce in Brazil. On the other hand, heuristic approaches, based on multiple criteria decision making (MCDM) techniques, allow the use of existing data and are relatively easy to apply. These methods can deal with the knowledge arising from the participation of many decision makers as well as a large number of criteria. In this sense, the main goal of this research was to develop and apply a methodology for landslide susceptibility mapping in data scarce areas, using MCDM techniques. The approach was tested in Porto Alegre municipality (476.3 km²), which is the most affected region in Rio Grande do Sul State, southern Brazil.

The landslide susceptibility assessment was carried out based on the combination of maps in a GIS environment, considering the knowledge of local experts. The conditioning factors considered were: slope, lithology, flow accumulation, land use and distance from lineaments, which were processed in Idrisi Selva software. Af-

ter pre-processing, all layers were converted into raster format with 5 meters and standardized through fuzzy logic. The relative importance of each factor for landslide predisposition was defined with the support of the MCDM technique entitled analytic hierarchy process (AHP). This technique was chosen because it reduces complex decision problems into a sequence of pairwise comparisons of relative importance, which can be easily understood by decision makers. Two different scenarios were elaborated: the first with the natural and the second with man-induced landslide susceptibility. Once the weights were computed, factors were combined using the weighted linear combination (WLC) method, resulting in two susceptibility maps in a continuous scale. These maps were then divided into five classes, using the equal interval method. For validation purposes, an inventory including 107 landslides records, between 2007 and 2013, was used.

Results show that most of the study area belongs to very low and low susceptibility classes. The natural occurrence of landslides is very unlikely in these places. Therefore, future urban developments should preferentially be led to them. Moderate susceptibility class covers less than 5% of the study area in both scenarios. Though their natural conditions are not favorable to landslides, such processes should not be disregarded in these zones, since they can be unleashed by wrong human intervention. High and very high susceptible classes are concentrated in the Porto Alegre Ridge. These areas present extremely fractured igneous rocks, high density of faults and slopes higher than 30%. Thus, they should be subjected to close monitoring in order to reduce the risk.

The validation of the maps reveals that the predicted susceptibility classes showed good agreement with the past landslide occurrences. About 95% and 94% of the 107 landslides records lie within very high and high susceptibility zones, respectively for scenarios 1 and 2. Furthermore, no landslides were observed in the very low class. This indicates that the variables and weights were adequate.

Results demonstrate that the AHP can provide reliable and cost effective landslide susceptibility maps, exploiting the existing data and knowledge. This can help to reduce efforts in the early stages of risk management, enabling the decision maker to prioritize the most susceptible areas for detailed mappings. The results can be easily updated once better data becomes available, allowing the generation of new scenarios. Nevertheless, it should be noted that MCDM approaches strongly depend on the judgments of the experts carrying out the study.

★ TU-3-κ-HS4

◆ AHP/ANP

Tuesday, 13:30–15:10 – Room HS 4

Session: AHP/ANP: Advances in Theory 1

Chair: Alexander Mechitov

1 - Optimizing AHP incomplete comparisons using D-optimal design

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The purpose of this paper is to present the development of mathematical approach based on D-optimal design with linear modeling especially when AHP incomplete comparisons appeared during the experiment. D-optimal designs are one form of computer aided designs provided by an algorithm. The overall design depends on a selection of various criteria and some related design rules. In effect, based on the selection process the design is created. The various components that the design is based are: the candidate set, the design matrix, the information of the dispersion matrix and finally the proposed linear model. Analytic Hierarchy Process (AHP) is an established method for multiple criteria decision-making. The main characteristic is pairwise factors comparison and final classification based on a relative scale. Even though, AHP is powerful enough, many AHP experiments are not complete for several reasons making the decision problem a rather complicated process, time consuming or even low validity. For this reason, it is considered very important to select and know which comparisons to take into consideration in order to avoid repetitions and minimize result bias. In order to enhance the statistical analysis overall, a detailed comparison case study is presented which uses D-optimal design for further evaluation.

2 - The reconstruction of a pairwise comparison matrix from a base

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We introduce the notions of generators and of a base of a pairwise comparison matrix (a PC matrix). We discuss the relation between a subset of entries of a PC matrix with a relevant graph. We also present an algorithm of the reconstruction of a PC matrix from its base, illustrated by the examples. This attempt may be particularly useful when comparing all the objects with each other is expensive or even impossible, so the resulting PC matrix is incomplete.

3 - Reaching and checking the weak \otimes -consistency

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In the context of Pairwise Comparison Matrices (PCMs) defined over an abelian linearly ordered group (G, \otimes, \leq) with identity element e , several levels of coherence of the Decision Maker (DM) are proposed. Let $A=(a_{ij})$ be a PCM over (G, \otimes, \leq) and $X=\{x_1, x_2, \dots, x_n\}$ the set of decision elements such as criteria or alternatives.

The \otimes -transitivity, introduced by Cavallo and D'Apuzzo (2015b), is the minimal logical requirement that DM's preferences should satisfy; it represents the idea that when x_i is weakly preferred to x_j ($a_{ij} \geq e$) and x_j is weakly preferred to x_k ($a_{jk} \geq e$), then x_i is weakly preferred to x_k ($a_{ik} \geq e$); x_i is indifferent to x_k ($a_{ik} = e$) only when x_i is indifferent to x_j ($a_{ij} = e$) and x_j is indifferent to x_k ($a_{jk} = e$). The \otimes -transitivity is equivalent to the existence of a total order on $X=\{x_1, x_2, \dots, x_n\}$ with respect to the relation of weakly preference, called actual ranking.

The \otimes -consistency, introduced by Cavallo and D'Apuzzo (2009), represents a full coherence of the Decision Maker (DM), and it is condition stronger than \otimes -transitivity; the \otimes -consistency ensures that the vector $w \otimes (A)$, provided by Cavallo and D'Apuzzo (2012) as weighting vector, is a reliable vector for assigning a preference order on the set of the related decision elements. Unfortunately, if the \otimes -consistency is not satisfied then $w \otimes (A)$ may provide a preference order on X different from the actual ranking.

As the \otimes -consistency is hard to reach in real situations, Cavallo and D'Apuzzo(2015a) propose the weak \otimes -consistency; it represents a little step forward a further coherence, with respect to the \otimes -transitivity, and it is weaker than \otimes -consistency. The weak \otimes -consistency represents the idea that when x_i is weakly preferred to x_j (i.e. $a_{ij} \geq e$) and x_j is weakly preferred to x_k (i.e. $a_{jk} \geq e$), then x_i is weakly preferred to x_k with at least an intensity of preference a_{ik} equal to the maximum between a_{ij} and a_{jk} (i.e. $a_{ik} \geq \max\{a_{ij}, a_{jk}\}$); the equality to the maximum holds only when x_i is indifferent to x_j (i.e. $a_{ij} = e$) or x_j is indifferent to x_k (i.e. $a_{jk} = e$). The weak \otimes -consistency ensures that a large class of vectors, including $w \otimes (A)$, is reliable for assigning a preference order on the set of related decision elements.

Cavallo et al.(2009) and Cavallo and D'Apuzzo(2010) propose algorithms for building \otimes -consistent PCMs and checking the \otimes -consistency; now, we provide characterizations and algorithms for reaching and checking the weak \otimes -consistency.

For further references about PCMs, Analytic Hierarchy Process (AHP) and its applications, see Angilella et al.(2013), Barzilai(1998), Barzilai(1997), Bortot and Pereira(2013), Brunelli and Fedrizzi(2015), Cavallo et al.(2014), Chiclana et al.(2009), Ishizaka and Labib(2011), Koczkodaj and Szybowski(2015), Saaty(2008), Saaty(1977), Saaty(1988), Vaidya and Kumar(2006).

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4 - Ordinal Inconsistencies in Pairwise Comparisons: problems and solutions

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Real-life decisions are usually complicated by the existence of multiple, often conflicting objectives, criteria, or influencing factors. In spite of crucial differences in approaches, many methods dealing with multi criteria environments are based on subjective information about the relative importance of objectives and/or criteria to the decision maker (DM). Rather often this information is obtained through pairwise comparison of objects. One of the most popular approaches based on this type of information is Analytical Hierarchy Process (AHP) though it is used in some methods within Verbal Decision Analysis (VBA) as well as in many others. It is known that people may error in their judgments, thus question of eliciting consistent information is of utmost importance to the success of the decision aids. Lately, there appear publications stating that without ordinal consistency, cardinal consistency of the results is not possible and that striving for ordinal consistency is the first step to the success of the decision process. In this presentation we discuss the notion of ordinal consistency and analyze possible approaches to the resolution of ordinal inconsistencies. Simple Excel-based tools for the process will be demonstrated.

★ TU-3-σ-HS5

◆ Multi Objective Optimization

Tuesday, 13:30-15:10 – Room HS 5

Session: IS-EMO: Evolutionary Multiobjective

Optimization (EMO) 2

Chair: Karthik Sindhya

1 - An Effective Hybrid Evolutionary Algorithm for Bi-criteria Optimization Problems

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Evolutionary algorithm (EA) is a generic population-based meta-heuristic optimization method, which can find compromised optimal solutions well for complicated optimization problem. Moreover, multiobjective evolutionary algorithm (MOEA) has attracted attention with respect to multiobjective optimization problems (MOP) because of the global and local search abilities to generate many Pareto optimal solutions with incommensurable quality for decision makers. However, most of existing MOEAs cannot provide satisfactory results in both quality and computational speed. This paper designs an effective hybrid evolutionary algorithm (EHEA) framework which combines vector evaluated genetic algorithm and a new archive maintenance strategy to preserve both the convergence rate and the distribution performance as well as better computational speed. The EHEA is applied to solve bi-criteria benchmark MOPs to verify the efficiency and efficacy and numerical experimental results show that the MoHEA could get the better performances than existing MOEAs.

2 - Robust Parameter Tuning in Genetic Algorithm for a Robotic Cell Scheduling Problem

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In this paper, we consider a linear robotic cell scheduling problem in a flowshop environment. A single-gripper robot is used to load/unload the parts on machines and handle them through different stages in order to produce multiple parts. Each part has a number of operations to be pro-

cessed on the machines with different operation times. The amount of time needed to produce a Minimal Part Set (MPS) is called the cycle time. The objective is to determine the optimal 1-unit cycles with the objective of minimizing the steady-state cycle time. In order to tackle this NP-hard problem, especially in large-scale instances, heuristic or metaheuristic algorithms can be considered. The main advantage of these algorithms compared to exact optimization methods is their ability in handling large-scale instances within a reasonable time, albeit at the expense of losing a guarantee for achieving the optimal solution. Therefore, metaheuristic techniques are appropriate choices for solving NP-hard problems to near optimality. Since the parameters of heuristic and metaheuristic algorithms have a great influence on their effectiveness and efficiency, parameter tuning and calibration has gained importance. In this paper a new approach for robust parameter tuning of heuristics and metaheuristics is proposed which includes three main steps: 1) In the first step, key parameters of heuristic or metaheuristic algorithms, as well as their possible levels, which have a significant effect on the efficiency and effectiveness of the search for solving the problem is determined. 2) In the second step, the Design of Experiment is employed in order to discover the effect of each parameter and determine their optimal levels by conducting minimal experiments. 3) In the last step, the proposed approach determines the optimal levels of parameters and to do this, simultaneously considers minimizing four objective functions of solution quality, overall runtime of algorithm and variance of these objectives. This is done by utilizing the Signal to Noise (S/N) ratio for combining the mean and variance of each objective, and then employing the Entropy-VIKOR as a multi-criteria decision making approach to combine the S/N ratios. In order to evaluate the performance of the suggested approach, a computational analysis has been performed on the Genetic Algorithm (GA) method, which has been used in solving the introduced problem. Extensive experimental results showed that by using the presented approach for parameter tuning of the GA, the problem can be solved in a reasonable time.

3 - Dynamic Resampling for Preference-based Evolutionary Multi-Objective Optimization of Stochastic Systems

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In Multi-objective Optimization many solutions

have to be evaluated in order to provide the decision maker with a diverse choice of solutions along the Pareto-front. In Simulation-based Optimization the number of optimization function evaluations is usually very limited due to the long execution times of the simulation models. If preference information is available however, the available number of function evaluations can be used more effectively. The optimization can be performed as a guided, focused search which returns solutions close to interesting, preferred regions of the Pareto-front. One such algorithm for guided search is the Reference-point guided Non-dominated Sorting Genetic Algorithm II, R-NSGA-II. It is a population-based Evolutionary Algorithm that finds a set of non-dominated solutions in a single optimization run. R-NSGA-II takes reference points in the objective space provided by the decision maker and guides the optimization towards areas of the Pareto-front close the reference points.

In Simulation-based Optimization the modeled and simulated systems are often stochastic and a common method to handle objective noise is Resampling. Reliable quality assessment of system configurations by resampling requires many simulation runs. Therefore, the optimization process can benefit from Dynamic Resampling algorithms that distribute the available function evaluations among the solutions in the best possible way. Solutions can vary in their sampling need. For example, solutions with highly variable objective values have to be sampled more times to reduce their objective value standard error. Dynamic resampling algorithms assign as much samples to them as is needed to reduce the uncertainty about their objective values below a certain threshold. Another criterion the number of samples can be based on is a solution's closeness to the Pareto-front. For solutions that are close to the Pareto-front it is likely that they are member of the final result set. It is therefore important to have accurate knowledge of their objective values available, in order to be able to tell which solutions are better than others. Usually, the distance to the Pareto-front is not known, but another criterion can be used as an indication for it instead: The elapsed optimization time. A third example of a resampling criterion can be the dominance relations between different solutions. The optimization algorithm has to determine for pairs of solutions which is the better one. Here both distances between objective vectors and the variance of the objective values have to be considered which requires a more advanced resampling technique. This is a Ranking and Selection problem.

If R-NSGA-II is applied in a scenario with a stochastic fitness function resampling algorithms have to be used to support it in the best way and avoid a performance degradation due to uncertain knowledge about the objective values of solutions. In our work we combine R-NSGA-II with several resampling algorithms that are

based on the above mentioned resampling criteria or combinations thereof and evaluate which are the best criteria the sampling allocation can be based on, in which situations. Due to the preference information R-NSGA-II has an important fitness information about the solutions at its disposal: The distance to reference points. We propose a resampling strategy that allocates more samples to solutions close to a reference point. This idea is then extended with a resampling technique that compares solutions based on their distance to the reference point. We base this algorithm on a classical Ranking and Selection algorithm, Optimal Computing Budget Allocation, and show how OCBA can be applied to support R-NSGA-II. We show the applicability of the proposed algorithms in a case study of an industrial production line for car manufacturing.

4 - Unified evolutionary multiobjective optimization algorithm for well distributed and preferred set of Pareto optimal solutions

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Evolutionary multiobjective optimization algorithms have been commonly used to generate a representative set of nondominated solutions that approximate the entire Pareto optimal front. Recently preference based algorithms have been proposed which consider the preferences of the decision maker to find only a subset of nondominated solutions that is preferable to the decision maker. However, in literature the two algorithms i.e. the one finding a representation of the entire front and the other finding only a preferred subset of solutions exist isolated. Here we propose a unified algorithm wherein the outcome would be both the set of nondominated solutions that approximate the entire Pareto optimal front and preferred region of the Pareto optimal front with a dense set of solutions. Such an algorithm has applications such as to construct an approximation of the Pareto optimal front e.g. by interpolating the nondominated solutions. Furthermore, the interpolated approximation can be used for interactive decision making.

★ TU-3- χ -HS6

◆ Environment, Infrastructure & Emerging Applications

Tuesday, 13:30–15:10 – Room HS 6

Session: Environmental Decision Making and Outranking Approaches

Chair: Corinna Krüger

1 - The consideration of uncertainty in PT-PROMETHEE by integrating scenarios

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One major aim of outranking-methods from Multi-Criteria Decision Analysis (MCDA) is to help the decision maker to elicitate his or her preferences (Belton, Stewart 2002; Roy 1996). However, experiments from descriptive decision theory shows that some of the underlying assumptions of MCDA-methods, e.g. with respect to utility-, value- or preference functions, do not represent humans actual assessment behavior. One theory which describes such actual assessment behavior is Prospect Theory developed by Kahneman and Tversky (Kahneman, Tversky 1979). Indeed, findings of Prospect Theory have been confirmed in various empirical studies and it represents a well-established theory to explain decision behavior. Two major elements of Prospect Theory are reference dependency and loss aversion, which represent rather humans actual perception and assessment behavior than a cognitive bias. Thus, integrating these elements into aggregation methods in order to give decision makers the opportunity to express preferences accordingly, seems to be worthwhile. An approach called PT-PROMETHEE has been developed to include reference dependency and loss aversion of Prospect Theory into the Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE). Based on the definition of an additional discrete reference alternative, the procedure of PT-PROMETHEE enables the decision maker to gain additional information by determining adequate reference values as well as to evaluate whether the underlying criteria-list addresses the overall goal. Additionally, the reference alternative can be interpreted as a benchmark in the ranking and thereby provide information on whether an alternative tends to fulfill the decision makers requirements. Furthermore, PT-PROMETHEE not only gives the decision maker the opportunity to decide whether loss aversion exists for each criterion but also to determine different levels of loss aversion if necessary (Lerche, Geldermann accepted 2015). Prospect Theory was originally developed as a theory concerning decisions under uncertainty. Therefore, it seems reasonable to extend also the modified approach of PT-PROMETHEE with the consideration of uncertain aspects, e.g. with respect to criteria-values. Existing research shows that scenario planning represents an adequate approach to address the aspect of uncertainty in MCDA-methods (Stewart 2005; Stewart et al. 2013; Montibeller et al. 2006). However, there exist various approaches for integrating scenarios into MCDA-methods. But, the procedure of these approaches differs with respect to several as-

pects, e.g. whether the probability that a certain scenario occurs shall be considered. Thus, those different approaches are discussed initially with respect to their suitability for incorporating uncertainty into PT-PROMETHEE. Furthermore, an extended approach of PT-PROMETHEE that implements scenarios is presented in detail. To test the described modification of PT-PROMETHEE by integrating scenarios and in order to gain additional findings about the application of this approach, a case study was conducted. The case study took place in cooperation with graduate students of Goettingen University, dealing with a decision problem concerning sustainable bioenergy concepts. The application of PT-PROMETHEE with scenarios followed a two-step procedure: In a first step, a group of students applied the original version of PROMETHEE to identify a sustainable bioenergy concept. Thereby, the students were also asked to include scenarios to incorporate uncertainty. In a second step, an additional workshop was conducted. Within this workshop, the concept of PT-PROMETHEE with scenarios was introduced to the students. Afterwards, the extended version of PT-PROMETHEE has been applied on the decision table, which has been previously developed by the students. To receive additional feedback concerning the modified approach of PT-PROMETHEE with scenarios, a questionnaire was handed out to the participants. The results of the case study as well as the findings regarding a suitable design of an approach that integrates scenarios into PT-PROMETHEE are presented and discussed.

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2 - Scenario-based application of PROMETHEE for Decision Support in the Extension of Low Voltage Grids in Germany

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Due to political regulations, the Renewable Energy Act (EEG), and environmental impacts, power generation and power consumption in Germany have changed in recent years. The share of renewable energies for power supply in Germany is intended to increase to 80 percent by the year 2050, along with a reduction of primary energy consumption by 20 percent compared to 2008 (Federal Government of Germany 2010; EEG 2014). The installed peak power of photovoltaic plants has significantly increased in recent years. Photovoltaics (PVs) are subject to large fluctuations in their power generation. Therefore, distribution system operators (DSOs) are confronted with greater problems to prevent the overload of grid components and to keep the voltage range within given constraints (DIN EN 50160). Network operators have to find a sustainable way of how to expanse their low voltage grid. In recent years, DSOs normally react to the new challenges with conventional grid extension by increasing cable cross-section, laying parallel cables and increasing the power capacity of the transformer. Another alternative is the innovative Voltage Regulated Distribution Transformer (VRDT) for regulating the voltage level of distribution grids. This case study analysis in close collaboration with one of the largest German DSOs whether sustainable grid expansion due to the increasing PV penetration can be achieved by conventional grid expansion or by the integration of a VRDT. As in many business decisions about investments, a large number of criteria have to be taken into account: besides the economic criteria, also environmental, technical and social criteria might be decision relevant. The overall potential of the grid expansion alternatives has to be evaluated for the entire low voltage grid of the DSO depending on different enforcement levels. The challenge is the heterogeneous structure of the low voltage grid making it impossible to evaluate the alternatives for the entire low voltage grid uniformly. Therefore, the scenario-based application of the PROMETHEE method is developed and applied: First, the required grid expansion of the entire low voltage grid of the DSO is calculated for both alternatives, conventional and VRDT. The low voltage grid of the investigated DSO consists of 13,000 local grids. Analyses of

the entire low voltage grid show that it can be mapped with high accuracy by 172 different synthetic local grids. The synthetic local grids differ in the following system parameters: performance of the local transformer, specific transformer capacity per household, branch cable length, number of secondary branches, and the number of households (Lhn et al. 2014). The combination of all system parameters creates synthetic local grids that mimic the real existing low voltage grid of the DSO. The required grid expansion of both alternatives, conventional and VRDT, is calculated for these 172 synthetic local grids and different enforcement levels of PV. Afterwards, the calculated grid expansion is extrapolated to the entire low voltage grid of the DSO. Due to the combination of the large number of synthetic local grids and PV enforcement levels a large number of decision situations have to be evaluated. Second, the PROMETHEE (Preference Ranking Organisation Method for Enrichment Evaluations) method invented by Brans et al. (1986) is used to evaluate the large number of decision situations. In several workshops with brainstorming sessions and group discussions, 15 criteria and attributes for the evaluation of grid expansion concepts were defined by project participants from the DSO and the participating researchers. For each local grid and each enforcement level of PV, an evaluation matrix is computed providing the data basis of the multi-criteria analysis. The calculation of the evaluation matrices and the multi-criteria analysis of the decision situations are implemented in MATLAB. The large number of decision situations makes it difficult for the DSO to evaluate the overall potential of a grid expansion alternative. Therefore, a key performance indicator is defined estimating the overall potential of a grid expansion alternative. The potential of the grid expansion alternatives are calculated depending on the grid characteristics and the PV penetration. For network planners, it is of great importance to have decision rules to identify which grid expansion concept should be implemented depending on the grid characteristics. The results show a high overall potential of the VRDT in the investigated grid area of the DSO. Due to the high overall potential of the VRDT, the senior management of the DSO is recommended to include the grid utility VRDT into its portfolio of grid expansion measures. The associated DSO supplies mainly rural areas and the obtained high potential is linked to the individual grid topology of the investigated DSO. However, the scenario-based PROMETHEE can also be applied to other DSOs by including the individual grid topology of the DSO. In general, the modified PROMETHEE method can be applied for the evaluation of investment alternatives in the field of infrastructure (for example telecommunications sector, gas distribution system, water network), in which a few alternatives in a large number of individual network struc-

tures and scenarios have to be evaluated.

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3 - A multi-criteria multi-period outranking approach: methodology and application for sustainable project selection

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Project selection in sustainable development context is one of the major concerns of governmental departments whose are seeking to develop best approaches and innovative methods to deal with such complex decision-making problem. This work is concerned with sustainable project selection, which must guarantee a long-term balance between the integrity of the environment, the social equality and the economic efficiency. For this context, we propose a novel multi-criteria multi-period outranking approach which solves multi-criteria decision-making problems, considering not only their immediate consequences but also their future impact in the short, medium and long term horizons. More specifically, the paper objectives are twofold.

The first objective of the paper is to provide a comprehensive state-of-the-art survey on sustainable project selection. The number of related scientific papers were growing rapidly in the past five years and the multi-criteria decision aid (MCDA) appears as the most common used approach. A deep analysis of literature shows first that the great majority of papers considers only two of the three dimensions of sustainable development (economic and environmental). The social dimension of sustainable development is rarely considered. Second, they do not consider neither the long term perspective related to sustainable development nor the unforeseen events that may impact future evaluations of projects. Although sustainable development consists of achieving a balance between the short and long-term horizons, existing research

do not evaluate the long term impact of projects. These results motivate our research focus on developing a multi-criteria multi-period approach for solving this kind of problems.

The second objective of the paper is to propose a novel multi-criteria multi-period outranking approach, which supports project selection under sustainable development context. The proposed approach consists of the following three phases: i) problem structuring and preference modeling, ii) multi-criteria aggregation at each period using an outranking method and iii) multi-period aggregation using a measure of distance between preorders in order to aggregate the results of the multi-criteria aggregation phase at each period. The proposed approach can be used with all outranking methods. In this paper, we illustrate the approach using ELECTRE II but any other outranking method could be used alternatively.

The proposed approach is then applied for sustainable forest management decisions. Sustainable forest management is well suited as an application framework for this research. Indeed, the selection of sustainable forest management options is designed to balance several perspectives such as conservation of biodiversity, soil conservation and water, maintaining the productivity of forest ecosystems, maintaining the multiple socio-economic benefits, and consideration of the values and needs of the population. In addition, the consequences of the different forest management options are evaluated over a horizon of 150 years (an evaluation each 5 years). Thus, the multi-criteria and the multi-period aspects of the problem should be considered simultaneously. The proposed approach is applied in this context and the main results are discussed.

4 - Supporting Sustainable Decisions in Agricultural Industries: An Application of Regularization Robustness in Multi-Objective Optimization

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Horticulture industries in Europe provide 44% of the worldwide production of flowers, bulbs and potted plants. Every year plant nurseries have to decide a production plan, determining in what ways plants are raised, e.g. how much peat is used. Usually, plants grow up in peat growing media inside of planter pots made of plastics, but there are alternatives both for peat and plastic pots which are possibly more sustainable.

The resulting real-world decision problem corresponds to a multi-objective integer linear program which contains two types of uncertainty. First, parameters of the model are uncertain, meaning that values of parameters are not known at the time the problem is solved. Initial investigations of parameter uncertainty in multi objective optimization can be found in the literature, e.g., Deb and Gupta (2005) and Ehrgott et al. (2014). A second type of uncertainty which has to be taken into account is variable uncertainty. Variable uncertainty accounts for the fact that computed values can not necessarily be put into practice. For instance, a computed amount of peat to be used can not be carried out exactly, since employees of nurseries will fill pots only within some accurateness. In single objective optimization this kind of uncertainty is addressed in the research area "regularization robustness", see e.g. Lewis (2002).

To the best of our knowledge there exist no studies on regularization robustness in multiobjective optimization until today. Therefore, in this talk we develop an extension of the framework of single-objective regularization robustness to multi-objective optimization. To this end we identify each solution with a solution set, which contains all possible realizations of the solution. For instance, a solution $x=3.78$ might be considered as the interval $[3.7, 3.8]$. Consequently, the objective values of solutions are sets, which have to be compared in objective space in order to find non-dominated solutions. We present different possibilities to compare sets, which are based on set-valued optimization.

Whenever applied to a single-objective problem, our concept is identical to the classical single-objective definition of regularization robustness. Furthermore, our formulation of multi-objective regularization robustness fits into the framework of Ehrgott et al. (2014).

Apart from the new concept we present first theoretical results and indicate solution techniques which allow for variable uncertainty in multi-objective optimization. As a consequence, our theoretical results can be applied to the production plan decision problem at a central Italian nursery, which is modeled as a multi-objective integer linear program containing parameter and variable uncertainty.

Due to increasing awareness of environmental protection in European society and first experimental results, a plant nursery in central Italy faces the question how many plastic planter pots should be replaced by biodegradable pots and/or how a partial replacement of peat by compost would affect the profit and sustainability of the business. There are several reasons why alternatives to large-scale usages of peat and plastic pots should be considered. Peat is a natural resource but the regeneration rate of peat is much lower than the current harvesting rate. As a consequence the worldwide area of peatlands, which are important living spaces for plants and

animals, is decreasing. Furthermore, there are different reasons to consider alternatives to the usage of plastic pots in horticultural industries. It is estimated that more than 11,000 tons of non biodegradable plastics are landfilled as a consequence of current horticultural practices every year. In contrast to plastic-made planter pots, biodegradable pots are able to decompose when planted into the soil or can alternatively be composted after use.

In our study, we develop a decision model for a nursery in central Italy, which has four options of raising plants: plants can either be grown in plastic pots filled with peat or in plastic pots filled with compost or in bio-pots filled with peat or alternatively in bio-pots filled with compost. The Italian nursery desires an annual production plan, determining how many pot-soil combinations of each of the four types are to be produced. As objective functions the model considers the profit and global warming potential in terms of CO₂-equivalent emission. All assumptions are based on experimental data.

This results in a bi-objective integer linear program. The goal is to determine all feasible solutions, i.e. production plans, which are not only pareto optimal with respect to the two objectives profit and global warming potential but also robust with respect to the two types of uncertainty included in the model.

Parameter uncertainty arises mainly from the usage of natural resources and can be handled with methods developed in Ehrgott et al. (2014). More importantly, variable uncertainty is also taken into account by our model. For instance, the theoretical amount of peat or compost put into each pot and thus the total amount of peat/compost used is computed with a high accuracy which can not be put into practice exactly.

Therefore, we are able to characterize desirable solutions to our real-world bi-objective integer linear optimization problem, which are both robust efficient in the sense of Ehrgott et al. (2014) and regularization robust efficient with respect to our concept.

Tuesday, 15:40–17:20

★ TU-4-β-HS1

◆ Decision Aiding

Tuesday, 15:40–17:20 – Room HS 1

Session: Advances in Decision Aiding Methods
4

Chair: Marko Bohanec

1 - Evaluation of multicriteria methods

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Often times different MCDA methods may yield different answers for exactly the same problem. There is no exact way to know which method gives the right answer. This situation leads to the question of how evaluate the performance of different MCDA methods. Since the appearance of the multicriteria methods, the researchers were questioning about the reliability of the results provided by them. Many research works has been realized to study the performance of some of these methods, including: AHP, the multiplicative model, Electre etc. These studies showed a remarkable weakness in the definition and stability of the best alternative and the overall ranking of alternatives [1], [2], [5], [6]. E. Triantaphyllou, during years of joint study and research, has devoted himself to the development of many tests based mainly on some mathematical properties that appear centrally in the famous theorem of Arrow [1], [2], [5], [6]. This reflection seems to be logical; nevertheless, it met a severe criticism from B. Roy [7]. On the same way we made a critical study allowing to evaluate the performance of Triantaphyllou tests [5], [6]. First, a stability study of some methods to the application of the first test is proposed. Then, a series of numerical examples elaborated in order to criticize the performance of this test are defined. In the same order of idea, we gave a synthesis of the works measuring the capacity of the methods from various approaches to provide a complete and transitive ranking. This synthesis has led to some surprising results about the feasibility of the three tests of Triantaphyllou as well as the impact of the two tests of transitivity. Each party introduced in this work is consolidated by numerical examples and/or statistical studies illustrating the proposed results.

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2 - Meaningful monotonic normalization procedures as a basis for a modification of the TOPSIS method in a mixed data context: The MMD-TOPSIS

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The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method was developed by Hwang and Yoon in order to identify an alternative closest to the ideal solution and farthest to the worst solution. In practice, this method was appraised and successfully applied for solving many multi-criteria decision making problems. Or this method suffers from the lack of meaningfulness in the sense of measurement theory. Since, for any statement based on a calculation which uses numerical representation, it is important that its truth value remains unchanged when modifying the scale representation using admissible transformations. For this reason, we are interested in studying the meaningfulness of different monotonic normalization procedures proposed in the TOPSIS method and in showing the meaningful ones for each scale type. Based on these meaningful monotonic normalization procedures, we propose a modification of the TOPSIS method in a mixed data context. We illustrate the proposed modification using a supplier selection problem. This purchasing problem is a multi-criteria decision-making problem that is affected by several conflicting factors. Our modified TOPSIS method is referred to as the Meaningful mixed data TOPSIS (MMD-TOPSIS) method.

3 - Sensitivity analysis of promising target-based normalization methods in environment of materials selection problems

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In most MADM approaches, normalization is often necessary to allow diverse criteria to be directly compared by eliminating the different di-

mensional units. The accuracy of the normalization process is very significant in the case of materials selection problems because it must address target-based criteria in addition to cost and benefit criteria. Target criteria are used in different design selection problems, particularly in choices of materials (for example: biomedical material selection in which implant materials must have similar properties to those of human tissues). Some matters including capability in removing scales, symmetry in normalization for cost and benefit criteria, transforming other types of criteria to the benefit one, rank reversals, handling negative values are important aspects for evaluation efficiency of normalization methods. It is found that most of the current normalization methods have shortcomings in tackling all mentioned requirements. In this simulation experiment the performance of three promising target-based normalization methods in environment of materials selection problems were investigated. Simulation parameters are the number of alternatives, distribution of data and location of target criteria. The effect of parameters and normalization methods were examined using analysis of variance.

4 - Statistical Analysis of Qualitative Multi Criteria Decision Models, Developed with Qualitative Hierarchical Method DEX

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Multi Criteria Decision Modelling (MCDM) methods differ greatly in the ways how they obtain preferential information from the decision maker, how they represent it within a decision model and how they use it to perform the intended decision-making task: choosing, ranking and/or sorting decision alternatives, and analyzing and justifying the results. While most of MCDM methods rely on numerical representations, there is a class of qualitative MCDM methods which is gaining more and more recognition in Operational Research. These methods characterized by the use of symbolic, qualitative variables; value aggregation is based on decision rules and other non-numeric aggregation functions; decision maker's preferences are often acquired through examples of decisions, following the Machine Learning, Aggregation-Disaggregation and Robust Ordinal Regression paradigms. Examples of well-known MCDM methods that exploit these approaches are MACBETH, methods of Verbal Decision Analysis (such as ZAPROS and ORCLASS), DRSA (Dominance-based Rough Set Approach), some variants of UTA, and Doctus. DEX (Decision EXpert) is also a qualitative MCDM method. Conceived in early 1980's under the name DECMAX, it combined the approach of hierarchical MCDM with rule-based

expert systems and fuzzy sets. The name DEX was coined around 1990 together with the method's implementation in a form of an expert system shell for decision making. The method has three key characteristics:

1. It is hierarchical: a DEX model consists of hierarchically structured attributes or criteria. In this, it is similar to the Analytic Hierarchy Process (AHP).
2. It is qualitative: all variables (attributes and criteria) are symbolic, taking values that are words rather than numbers, such as "bad", "medium", "excellent", "low", "high".
3. It is rule-based: the hierarchical aggregation of values is defined with decision rules, acquired and represented in the form of decision tables.

Currently, the DEX method is implemented in freely available software called DEXi (<http://kt.ijs.si/MarkoBohanec/dexi.html>).

DEXi supports an interactive construction of the decision model, and evaluation and analysis of alternatives. Special emphasis is on aiding the decision maker in creating the model structure and defining decision rules. There are three principle ways available for the latter: (1) direct definition of decision rules, (2) employing the dominance principle, and (3) employing user-defined weights. DEXi attempts to monitor and maintain the consistency and completeness of rules. Three types of analysis are available in the evaluation stage: (1) "plus-minus-one analysis" of the effects of small changes to the outcomes, (2) "selective explanation" based on strong and weak points of alternatives, and (3) multi-way comparison of alternatives. Following the Expert Systems paradigm, DEXi can evaluate alternatives even in the case of incomplete input and preference data.

Applicability is one of DEX's strongest points. DEX has been used to support numerous complex decision processes in various problem domains, including health care, project management, quality and risk assessment, environmental management, data mining, and many more. Literally thousands of DEX models have been developed worldwide and used to solve real-life decision problems. The idea explored in this paper is that we can learn from DEX models developed in the past. We can analyze their characteristics, such as size and structure of the attribute hierarchy, types and scales of individual attributes, number and quality of decision rules. We can identify common patterns or frequent problems occurring in decision models. On this basis, we may obtain better understanding of the decision-modelling process and possibly develop better algorithms and tools in the future.

With these goals in mind, we have recently compiled a research database of DEX models. Currently, It contains 582 models developed in 140 decision-making projects conducted in the period 1979-2015. The collection is biased as it includes only DEX models that were available to the author of this study, who is also a DEX devel-

oper, and excludes models developed elsewhere. Nevertheless, we believe that the database is highly representative with respect to the addressed decision problems, decision makers involved, covered time period and observed model characteristics.

In the following, we present some basic statistics. In average, the 582 models consist of 26.1 attributes, of which 15.8 are basic (model input variables) and 10.3 are aggregated (internal and output variables). The largest model in the collection, which is aimed at evaluation of cropping systems in agronomy, has 219 attributes, 87 basic and 132 aggregated. The depth of hierarchies ranges from 1 to 10, the average is 3.54. Aggregated attributes have from 1 to 10 (average 2.53) descendants in the hierarchy. The average of considered decision alternatives per model is 6.67.

The models contain 16178 attributes in total. Most of the attributes (86%) are preferentially ordered (thus, they are criteria). Attribute scales contain from 0 to 12 values (average 3.38). There are 2944 decision tables, which indicate a substantial variety. Decision space size varies from 3 to 2187 (average 33.73). In average, 30.26 elementary decision rules are defined in each table, giving a remarkable average completeness of about 95%.

In the paper, we will provide further explanations and details on the measured characteristics, with special focus on the quality (completeness and consistency) of decision rules and common types of aggregation patterns. We will also analyze the development of model characteristics over time. On this basis, we will identify common patterns occurring in DEX model structures and decision rules, and formulate suggestions for further research.

★ TU-4- γ -HS2

◆ Model Building

Tuesday, 15:40-17:20 – Room HS 2

Session: IS-CPL-MCDA: Constructive Preference Learning in MCDA

Chair: Miłosz Kadziński

1 - Entropy-optimal weight constraint elicitation with additive multi-attribute utility models

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We consider the elicitation of imprecise preference information for the additive utility model in terms of linear constraints on the weights. We propose a framework for comparing holis-

tic preference elicitation questions based on their expected information gain, and introduce a procedure for approximating the optimal pair-wise comparison question. We extend the basic approach to generate reference alternatives that differ on only a few attributes, and to determine when further preference information is unlikely to reduce decision uncertainty. We present results from computational experiments that assess the performance of the procedure and assess the impact of limiting the number of attributes on which the reference alternatives differ. The tests show that the proposed method performs well, and when implemented in a decision support system it may substantially improve on-line elicitation using pair-wise comparisons.

2 - Inducing probability distributions on the set of value functions by Subjective Stochastic Ordinal Regression

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Methodologies for elicitation of preference model parameters based on the indirect inference technique can take into account one, several or all value functions compatible with the preferences expressed by the Decision Maker (DM). In general, the same relevance is given to all these value functions, but it is logically correct to assign a weight to each compatible value function depending on some extra preferences provided by the DM. In this paper, we propose a new methodology for sampling a certain number of value functions satisfying the monotonicity and the normalization constraints as well as the constraints translating Decision Maker's preferences expressed on some reference alternatives, and then assigning a weight (probability) to each of these value functions based on the DM's holistic judgments expressed with different levels of certainty.

3 - Second Derivative Restricted Value Functions for Efficient Non-Monotonic Preference Learning

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UTA methods are among the most well-known MCDA methodologies for learning preferences from decision examples. Most of the existing UTA-like methods assume a monotonic relationship between input attributes and the preferences, however this is not the case in many real world applications. Although some methodologies have been developed to address non-monotonicity in preferences, they are computationally expensive and only applicable to the small size datasets. We propose a new UTA-like method for learning non-monotonic preferences from a ranking list given by the decision maker. The extracted preference model is represented by a set of additive nonlinear (piecewise linear) non-monotonic value functions. The method estimates the value functions by solving a single linear programming problem, and a set of transformations to normalize the utilities, while preserving the ordinal relations among the initial estimated utilities. The method prevents arbitrary value functions shapes by restricting the second derivative of the extracted value functions. The restriction intensity is directly controlled by a parameter in the model, which is determined by cross validation. The method performance and efficiency is illustrated using a real world dataset.

4 - Scoring Procedures for Multiple Criteria Decision Aiding with Robust and Stochastic Ordinal Regression

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We propose several scoring procedures for transforming the results of robustness analysis conducted with ordinal regression methods to a univocal recommendation. We use a preference model in form of an additive value function, and assume the Decision Maker (DM) to provide pairwise comparisons of reference alternatives. We adapt single- and multi-stage ranking methods to select the best alternative or construct a complete ranking by exploiting four types of outcomes: (1) necessary preference relation, (2) pairwise outranking indices, (3) extreme ranks, and (4) rank acceptability indices. In each case, a choice or ranking recommendation is obtained without singling out a specific value function. We compare the proposed scoring procedures in terms of their ability to suggest the same recommendation as the one obtained with the Decision Maker's assumed true value function. To quantify the results of an extensive simulation study, we use the following comparative measures (including some newly proposed ones): (i) hit ratio, (ii) normalized hit ratio, (iii) Kendall's tau, (iv) rank difference measure, and

(v) rank agreement measure. Their analysis indicates that to identify the best true alternative, we should refer to the acceptability indices for the top rank(s), whereas to reproduce the complete true ranking it is most beneficial to focus on the expected ranks that alternatives may attain or on the balance between how much each alternative outranks and is outranked by all other alternatives.

★ TU-4-δ-HS3

◆ Industry and Business Applications

Tuesday, 15:40–17:20 – Room HS 3

Session: Strategy and Facility Location

Chair: David Olson

1 - Infrastructure Optioneering: An AHP Approach

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Engineers often recommend alternatives for a project that impact multiple stakeholders. A crucial problem in complex engineering projects is the ability to quantify human judgment. This paper evaluates application of AHP in infrastructure engineering projects, exploring its benefits and limitations. Project priorities can be objectively analyzed through AHP and a best suited alternative can be chosen objectively with all of the important criteria considered. The need for employing a Multiple Criteria Decision Analysis (MCDA) technique on an infrastructure engineering project arose from our work on the California High Speed Rail project. Evaluating options for grade separations along the high speed rail line in the Los Angeles metropolitan area (construction cost of approximately \$1 billion) challenged us to find methods that could scientifically structure the decision making process and build consensus on a singular engineering solution that would satisfy multiple needs. Southern California region is one of the largest markets for transportation projects. Usually, large projects get entangled in conflicting interests. In an effort to consolidate ideas and build consensus around a viable design option, there is a growing need for a scientific methodology or tool. This search for a viable MCDA technique led us to the Analytical Hierarchy Process Method. This research paper builds a framework for a typical infrastructure problem (Grade Separations for California High Speed Rail), decomposing tangible and in-

tangible decision problems into comprehensible hierarchies. A ratio scale was derived by pairwise comparison of a set of engineering options and criteria (traffic, safety, pedestrian access, transit access, environmental impact, economic impact, aesthetics etc.) utilizing the fundamental scale. Further, this paper highlights the importance of rank preservation and the best way to assure confidence in AHPs outcomes from best alternative to worst, particularly when selecting options for an infrastructure engineering project. Finally, the numerical priorities calculated for each of the decision options were compared to decisions made by engineering experts. In conclusion, we found that infrastructure engineers can offer their clients a method to unbiasedly determine the best alternative by quantifying each stakeholders needs and priorities.

2 - Logistics Center Location Selection Using the New Method SMAA-TODIM

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Logistics center is a customized multifunctional intermodal transport chain where all the activities regarding all logistics, transportation and good distribution both for domestic and international markets. Kayseri has been playing important role in Turkey economy so establishing logistics center is of the utmost importance. This paper presents a new stochastic Multi Criteria Decision Making (MCDM) model for acquire robust conclusions and it is applied to selection of logistics center location in Kayseri a city of Turkey. TODIM (an acronym in Portuguese of Interactive and Multiple Attribute Decision Making) can identify differences between any two alternatives by pairwise comparisons and considering reference criterion. Also the advantage of SMAA (Stochastic Multicriteria Acceptability Analysis) is to handle imprecise, uncertain criteria weights and measurements and allow for decision-makers to make more extensive comments. The proposed method SMAA-TODIM is a method integration of SMAA and TODIM methods and comprises the advantages of both. Besides it allows TODIM to be applied without criteria weights knowledge and with stochastic criteria measurements. SMAA-TODIM computes criteria measurements from arbitrarily distributed values for weights. The alternative locations and related criteria are defined; the consistent results SMAA-TODIM are demonstrated.

3 - Analysing a Case Of Vendor Selection Model for Indian Industries of All

Categories through known procedures of AHP

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The main objective of this paper is to capture both the subjective and the objective evaluation measures in order to solve vendor selection especially when different organizations like computer hardware, automobiles, process industries and machine tool industries of India have different combinations of qualitative and quantitative criteria and sub-criteria. This paper provides the basic guidelines to develop the vendor selection model based on AHP. Developing AHP model by identifying the selection criteria and determination of the most important priorities is briefly defined through this paper. This paper also provides basic ways to calculate the weights of each criterion and enable decision makers to examine the strengths and weaknesses of the vendors' selection by comparing them with respect to appropriate criteria and sub-criterias.

4 - Tradeoffs in Supply Chain Management Strategy

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The move to lean supply chain management has been ongoing for decades, resulting in improvements for many organizations. Sometimes local lean operations have been replaced by outsourcing. This study examines expected impact of alternate supply chain strategies in light of profit as well as other factors. Sound supply chain management needs to consider not only profit, but environmental and social impacts (the triple bottom line), as well as customer service. This paper presents a supply chain simulation model to demonstrate tradeoffs among the four criteria of profitability, quality as measured by defects, customer service as measured by stock-outs, and carbon emissions. It uses an inventory model of a supply chain using a basic system relying on EOQ replenishment, a basic system utilizing a full truckload policy, lean variants of both of those systems, and an outsourcing variant. Inputs were random over given ranges. Lean systems were contended to provide learning benefits over time, and measures of the four criteria are evaluated for the first year, fifth year, and twentieth year. The paper shows relative tradeoffs among the five simulated supply chain systems. No particular multi-criteria selection methodology is given, but any could be implemented by decision makers.

★ TU-4-κ-HS4

◆ AHP/ANP

Tuesday, 15:40–17:20 – Room HS 4

Session: AHP/ANP: Industrial Applications 1

Chair: Petr Fiala

1 - Multiple Criteria methodology for supplier evaluation and purchasing management

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In companies purchasing situations can vary from buying new products or services from new suppliers, or buying new products from approved suppliers, among many other possibilities. Supplier selection and evaluation are an essential problem in supply chain management, where the trend is to look for partnerships with few reliable providers. The increasing professionalism in purchasing demands flexible frameworks that can integrate and support the decision making problems that appear in real companies. Many products and suppliers need to be managed not only to qualify and select, but also to monitor with the objective to support strategic decisions. The problem of supplier evaluation has a multiple criteria nature since there is a wide number of objectives that need to be considered. Recent literature reviews on supplier evaluation and selection point out that the main individual and integrated approaches used to solve this problem are DEA, linear and integer programming, goal and multiobjective programming, AHP and ANP. There are other techniques such as fuzzy set theory, TOPSIS, SMART, PROMETHEE, genetic algorithms, neural networks, etc. Nevertheless, the literature has dealt mainly with the supplier evaluation for selection, instead of providing information about the most appropriate relationship with them. The purpose of this paper is to develop a framework in order to evaluate products and suppliers based on a multiple criteria and group decision making process. This framework should integrate all relevant quantitative and qualitative criteria for decision making in purchasing management. The proposed framework has been applied in a real

company, Roquette, a multinational company active in more than 100 countries and in several sectors such as food, pharmaceutical and chemical, among others. A two-steps process has been designed. Firstly, we defined the criteria that are specific of the products and secondly those related directly to suppliers, as well as their performance measures. In both cases, the criteria are grouped into two categories: critical criteria and strategic criteria. Critical criteria are mainly related to market, and strategic criteria are those affecting internal operation of the factory. In particular, safety and environment regulations, number of suppliers, delivery time and provisioning factor are critical product criteria. As strategic criteria of the purchases we considered the following: contact with the final product, stopping production of the factory, products that affect the image of the company and purchase volume. Firstly, a critical product index and a strategic product index have been calculated using PROMETHEE method and D-Sight software. The weights of criteria have been obtained by AHP, through a group decision making process involving decision makers and technical personnel of purchasing department. Secondly, the critical product index together with delays and several risk concepts have been used to determine a critical supplier index. In the same way, strategic product index in addition to claims and purchase volume are the criteria to calculate strategic supplier index. These two indexes permit the company to classify how critical and strategic their suppliers are and to establish the appropriate relationship with each of them (to eliminate or modify, partners, long term contracts or market policies). To our knowledge there are no proposals to monitor products and suppliers within the supply chain management which has been evolving from production efficiency towards development of business partners. Many particular problems that are dealt with in the literature appear in real companies simultaneously. They need to buy new products, look for new suppliers and at the same time carry out monitoring their performance. The framework developed can deal with evaluating products from one or several suppliers, qualifying suppliers for one product, classifying and selecting the best suppliers and also monitoring suppliers periodically. Another strength of this methodology is the flexible way to integrate all relevant quantitative and qualitative criteria from a group decision making perspective. The most used criteria for supplier selection have been cost, quality and delivery performance. Others, such as financial strength, past experience, claims, distance, safety and risk factors, can be found in the literature. Nevertheless, they have not been grouped to generate aggregated indicators to measure the critical and strategic nature of products and suppliers. In the case study some criteria used in the literature as well as new ones have been

considered. In the former case we can mention safety and environmental regulations, delivery time, purchase volume, delays and claims. The new criteria are some strategic criteria of products (contact with the final product, stopping the production of the factory, affect the image of the company), critical index of products, strategic index of products and several risk factors (commercial, supplier country and supplier billing). PROMETHEE method has hardly been used for supplier evaluation and selection, although it has been applied to many other areas, such as environmental, energy and water management, business and financial management, logistics and manufacturing. The results obtained by using PROMETHEE have been compared with the previous procedure used by the company and with a value function method, highlighting the drawbacks and strengths for the three approaches. Finally, this framework applied to Roquette factory in Spain can be implemented in other factories of Roquette group and other companies by defining their appropriate criteria and preferences. This methodology has improved supplier management system of the company, to allow developing strategic suppliers, better reacting to market changes or new products and controlling risks of the supply chain.

2 - In Search of Intelligent Algorithm for Securing Video Streaming Over Cloud Computing Infrastructure

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Audiovisual materials, in contrast to other formats, offer richer learning environment that could streamline learning processes. We have witnessed particularly in higher education level, growing interest in applying video streaming to enhance teaching and learning activities in the last decades. However, traditional client server model seems no longer effective to deal with growing needs of video streaming contents both delivered locally (LAN) as well as via the Internet. Adding more services immediately in responding such increasing demand is not simple and straightforward efforts which in fact, requires lots of time, extra works and also additional cost. Cloud computing, on the other hand, has great potential to overcome the issue of growing demand of multimedia services in the case of educational video streaming materials through its on demand and virtualization features. While cloud computing works perfectly to solve on demand problems, issues of security and privacy of video streaming are remain unsolvable and still considered as serious gap in current literature. In this paper, it is argued that cloud computing must be accompanied by third party solution such as intelligent video streaming algorithm in order to solve security and privacy problems. Intelligent video streaming algorithm is a logical

approach in the form of algorithm aims to enhance video streaming ability in responding to delay, data loss and jitter.

Our preliminary study identified a number of intelligent video streaming algorithms and classified them into several categories, among them one called Secure Media Streaming algorithm. Basically, each algorithm in this category looks at the problem of lack of security and privacy mechanisms on video streaming from different point of views and thus constructed unique algorithmic solution by using various approaches or techniques.

The main question to be addressed in this study is how cloud engineers as experts should determine the most applicable algorithm to realize secure video streaming solution based on cloud computing infrastructure. Decision makers need a comprehensive methodology that can integrate various perspectives, aspects and criteria both technical and non-technical issues of secure video streaming in order to select the best one among available alternatives of secure video streaming algorithm.

In this paper, a novel framework that facilitates decision analysis by a group of expert in network engineering field is established and exemplified to guide them selecting the best secure video streaming algorithm. As a methodological support, it employs one of the widely accepted multicriteria decision analysis called Analytic Hierarchy Process with group decision making feature. In short, the analysis is performed in four steps. The first one is structuring the problem into decision hierarchy of goal-criteria-alternative structure. Then it is followed by performing pairwise comparison of each element within each level by decision makers in the second step. The next step is calculating the inconsistency level of every preferences taken from the previous step. Finally, final weight of all alternatives will be obtained by aggregating all decision makers results. The final result shows that algorithm with the highest weight among other alternatives is the suitable one to be applied by network engineers in order to establish secure video streaming services over cloud computing infrastructure. The main contribution of this paper is two-fold, firstly, it proposes and demonstrates a novel group decision making in the field of network engineering and secondly, the study gives a new contribution into the multicriteria decision making literature.

3 - The MCDM and Changeable Space Theories Based Capacity Reconfiguration for Small and Medium Size TFT-LCD Fabs

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The small and medium size thin film transistor liquid crystal display (TFT-LCD) panel market, which accounted for 25% of the worldwide TFT-LCD market, surged rapidly during the past years due to the fast evolution of the smart handheld devices. However, the demand versus supply relation fluctuated significantly due to the fierce competitions in the small and medium size TFT LCD market. The appropriate expansion of the facilities and optimal allocation of the manufacturing of the manufacturing facilities require an evaluation mechanism of the equipment suppliers. Further, how the equipment can be configured to maximize and revenue and minimize the cost require the mathematical programming of the facilities. Although scholars aimed to explore either the supplier evaluation or the optimization of fab facility, very few scholars try to study both issues concurrently by an integrated research framework. Further, almost no scholars tried to introduce the theory of the changeable space for reconfiguring and appropriating the production capacity. Further, almost no scholars studied the above mentioned issues for the small and medium TFT-LCD fabs. So, the author aims to define a multiple attribute decision making (MADM) theories and methods based hybrid framework for resolving the problems. The research proposal will render a new research proposal for appropriating and expanding the production capacity of small and medium TFT-LCD fabs by both a hybrid multiple criteria decision making (MCDM) framework as well as a changeable space theory based multiple object decision making (MODM) framework. A hybrid MCDM methods based framework will be used to evaluate and select the TFT-LCD fab equipment suppliers. Further, a changeable space theory based MODM framework consisting the De Novo programming technique will be introduced for appropriating and expanding the capacity of a TFT-LCD fab. An empirical study based on the modification of real Taiwanese small and medium size TFT-LCD fab will be introduced for demonstrating the feasibility of the proposed analytic framework. In the future, the proposed framework can be used for appropriating the production capacity of any plant. Meanwhile, the empirical study results can be used as the basis for appropriating the capacity of a TFT-LCD fab.

4 - Multicriteria Project Portfolio Management under Risk

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Project management is the discipline of planning, organizing, securing and managing re-

sources to bring about the successful completion of specific project objectives. In an accelerating economic world, projects become tools for promoting the objectives of the organization. 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 use of project portfolio management is increasingly becoming a tool for promoting the strategy of the organization, which is a very important role. Using of standard methods or trying to design and apply sophisticated methods based on quantitative analysis is possible for portfolio management. Selection of project portfolio is a dynamic multi-criteria decision-making problem under risk.

The paper presents an approach for dynamic project portfolio management based on the Analytic Network Process (ANP) model. The ANP model consists of four basic clusters (projects, resources, criteria, time) with their elements and influences. An important factor of the proposed ANP model is time. The ANP method is suitable for the determination of priorities in network systems where there are different types of dependencies between the elements of the system. Time dependent priorities play an increasingly important role in a rapidly changing environment of network systems. Long-term priorities can be based on time dependent comparisons of system elements. Short-term predictions can be based on using of compositional data exponential smoothing. A hybrid procedure that combines the advantages of both approaches is proposed.

In each period, the portfolio of projects is reviewed in line with the strategic objectives of the organization. Management may decide to initiate new projects, but also to end of some others that are currently being implemented. Even if the organization has available funds, it is sometimes better to decide not initiate a new project and wait for better one. However, while the set of projects that are currently ready for implementation is clearly defined, it is not so easy to predict what new projects will appear in the future. The organization must decide under risk whether to assign all available resources to present proposals or to reserve a portion of the funds unused for some time and wait for better alternatives that may occur later. We propose to use a decision tree with multiple criteria and interactive multi-criteria analysis for solving this problem. The procedure is in two phases. In the first stage are selected effective strategies. In the second stage, using interactive multi-criteria method selected preferred strategy. The procedure is flexible and can be modified and generalized. The risk attitude of the decision maker can be modified. We propose to complete the dynamic ANP model by a decision tree with multiple criteria and interactive multi-criteria analysis for solving the problem of project portfolio management under risk.

Acknowledgement The research project was supported by the grant No. 13-07350S of the Grant Agency of the Czech Republic and by Grant No. IGA F4/54/2015, Faculty of Informatics and Statistics, University of Economics, Prague.

★ TU-4- σ -HS5

◆ Multi Objective Optimization

Tuesday, 15:40–17:20 – Room HS 5

Session: Multi Objective Metaheuristics

Chair: Michael T. M. Emmerich

1 - Diversity oriented local search for multi-criteria optimization

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The present work is a contribution toward advancing the state-of-the-art in computational technique for approximating Pareto fronts of multi-criteria optimization (MCO) problems. More specifically, we develop a generic stochastic local search algorithm adapted to MCO. Local search is a powerful heuristic technique for solving difficult combinatorial optimization problems. The basic step in local search is to compute the neighborhood of a given solution, the solutions which can be obtained from it by a single modification and selecting with high probability the neighbor with the optimal cost. In MCO, it is often the case that there is a set of non-dominated and mutually comparable neighbors. Any local search algorithm must choose one of these neighbors for exploration in the next iteration. Furthermore, there is an additional question of discarding or keeping the unelected candidate solutions. Our strategy maintains such solutions and can select them in subsequent steps. Another major issue concerning the MCO problem is the number of non-dominated solutions. In many real-life situations, the number of non-dominated solutions can be prohibitively large. Keeping such a large list of solutions as well as large list of candidate solutions may render the algorithm computationally inefficient. This is primarily due to the fact that the local search algorithm has to compare the cost of newly found solutions with those already present; the process often referred to as Pareto filtering. Furthermore, providing a very large set of solutions is not always productive as a decision making aid. Our algorithm employs a new parametrized diversity based reduction technique to maintain a small set of solutions and candidate solutions. This new diversity measure $D(c,P)$ estimates the contribution of a point c to the diversity of set of solutions in P . Intuitively, the more c is isolated from other points in P , the larger is $D(c,p)$. The salient fea-

tures of our algorithm are (1) A selection policy based on diversity-oriented measure; (2) Keeping track of minimal points that have not been selected and including them as candidate for future iterations; (3) Update policies that keep the sets of optimal and candidate solutions small.

We developed a generic tool for extending local search to MCO problems. The tool is written in a modular way where the specifics of the particular problem to be solved are separated from the ingredients and parameters of the local search algorithm. Hence, to apply the tool to a new problem it suffices to write some small code that specifies how costs are derived from a representation of a solution and how local move operators are defined. For experimental analysis, we applied our tool extensively to two classes of problems: the bi-objective 0/1 knapsack problem (bKNAP) and the bi-objective quadratic assignment problems (bQAP). For the bKNAP problem, we consider several groups of instances; uncorrelated instance, weakly correlated instance, strongly correlated instance and subset sum instance with large number of items. For bQAP problem we consider uncorrelated and correlated instances with large number of facilities. Pareto sets are compared using the hyper-volume unary indicator. For each instance, the reference set is obtained by comparing all the runs for that instance. Therefore, the outperformance of an algorithm A on some other algorithm B is based on the simple dominance of volume of A on B. First, we compare our selection procedure with the strategy that randomly selects solutions from local Pareto set (non-dominated solutions in the neighborhood). These runs are performed with unbounded set of solutions along with unbounded set of candidate solutions. We show that for the most of the instances of bKNAP problem, our method outperforms random selection. In case of bQAP problems, our method performs similar to random selection procedure for small instances with number of facilities equal to 25, but as the size of the problem increases, our selection outperforms random selection. The experiments suggest that random strategy is more biased towards the convex inner portions of the objective space, where it outperforms our selection strategy. On other hand, our selection strategy results in better extreme solutions. Additionally, the number of approximate Pareto solutions found by our strategy is more than the number of solutions found by a random strategy. And this difference increases with the size of the problem. Next, we compare our strategy with volume based selection where the preference is given to those candidate solutions which have larger dominated volume.

As the number of non-dominated solutions increases with the size of the problem, we turn to bounded set for solutions and candidate solutions. We compare our strategy with random strategy and clustering based techniques. In random strategy, a solution is randomly discarded

for the set of solutions such that the number of solutions remains bounded. In a clustering strategy, the solutions which are farthest from its corresponding cluster centroid are discarded. We show that our diversity based comparison outperforms both strategies using volume indicator and Hausdorff distance. We also show experimentally the effect of different thresholds on the size of the set of non-dominated solutions candidate solutions. To conclude, we developed a powerful framework for solving multi-objective combinatorial optimization problems. We tested it extensively for QAP and knapsack problems and it can be easily applied to other types of problems. We also introduced a new diversity based measure which can be used in combination with other variants of local search algorithms as selection and archiving strategy. Additionally, it can also be employed as fitness function and selection strategy for mating individuals in evolutionary algorithms.

2 - Multi-Criteria Scheduling in a Real Context Using Ant Colony System as a Computational Intelligence Tool

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Scheduling is one of the hard optimization problems found in real industrial contexts. Generally speaking, scheduling is a form of decision-making that plays a crucial role in manufacturing and service industries. According to Pinedo (2008), scheduling problems deal with the allocation of resources to tasks over given time periods and its goal is to optimize one or more objectives. This work focuses on the Scheduling process for a specific configuration of a mineral laboratory located in Barranquilla (Colombia), which is in charge of reception, identification, preparing and analysis on samples of coal and coke according to the customer requirements either for certifying the quality of the material and evaluating the feasibility to open a coal mine, or for selling the coal after mining, or even for knowing the physics and chemical properties of it for customer utilization, as in thermoelectric plants and steel companies. According to this scenario, the aim of this paper is therefore, to solve a multi-objective scheduling problem in a real context, which is a mineral laboratory. Objective functions are defined as the minimization of the total completion time of all jobs (makespan) and total weighted tardiness.

Before this work, the scheduling of samples in the laboratory was done in a manual way at the beginning of a day trip taking into account the

analysis in process and those that could not be completed on the last day trip and the availability of machines and workers. The analysis was done in this way because the laboratory had not a formal methodology that allowed performing this tasks in an effective way and thus, taking better decisions in the manner of assigning samples to the resources so that the laboratory can supply the demand, and at the same time increase the utilization rate of machines and decrease the idle time of this machines. Hence, taking into account the natural complexity of the process and the large amount of variables involved, the scheduling process was considered as a NP-hard problem in strong sense.

As in a large number of real-life optimization problems in economics and business, the NP-hardness of a scheduling problem means that it cannot be solved in an optimal manner within a reasonable amount of time. Thus, the use of approximate algorithms is the main alternative to solve this type of problems. According to Talbi (2009), approximate algorithms can be classified in two classes: dedicated heuristics and meta-heuristics. The former are problem-dependent and are designed and applicable to a particular problem. The latter are called meta-heuristics procedures and represent more general approximate algorithms applicable to a large variety of optimization problems. Meta-heuristics solve instances of problems that are believed to be hard in general, by exploring the usually large solution search space of these instances. These algorithms achieve this by reducing the effective size of the space and by exploring that space efficiently.

On the other hand, we use the Ant Colony System (ACS) approach to solve the multi-objective scheduling problem under study. A Multi-objective Ant Colony Optimization Algorithm (MOACO) is proposed. Ant Colony Optimization (ACO) is a meta-heuristic approach proposed by Colnani et al. (1991) and improved in later research (e.g. see Dorigo et al., 1996; Stützle and Hoos, 2000). The common behaviour of all variants of ant-based algorithms (including Ant Colony System) consists on emulate “real” ants when they find the optimal path between their nest and a food source. Several studies have applied ACO to solve different discrete and continuous optimisation problems including different scheduling problems, Tavares-Neto and Godinho-Filho (2013), Dorigo and Stützle (2004). For the particular case of a mineral laboratory, to the best of our knowledge there is no evidence of using metaheuristics for scheduling in this kind of configuration. However, for scheduling problems, the use of metaheuristics is very effective and widely used as in academic context like in real problems.

The computational experiments were carried out on a PC Intel Core i7, 2.9 GHz with 8GB of RAM. The proposed MOACO algorithm were coded using Visual Basic 6.0. Datasets employed

in our experiments were taken from the historical files of laboratory. We considered data from three months with high demand from July until September of 2014. These dataset employed samples (jobs) with different types of priority. A comparison of the proposed MOACO against both real or laboratory schedule, and the exact solution using a Mixed-Integer Linear Programming (MILP) model was performed. The MILP model was coded and run using AMPL®8.0 for Windows®. An overview of these preliminary results is presented in Table 1. Note that a negative value of deviation index means that the proposed MOACO algorithm outperforms the method against to what it is compared with. In Addition, regarding the performance of MOACO, results have shown that the quality of the solution is not affected when the number of jobs to be scheduled is increased. Further analysis is however required. This includes obtaining nondominated solutions, the evaluation of distance measures between two fronts, the coverage of the solutions of MOACO algorithm, the deviation with respect to a single objective, the deviation with respect to the best initial solution, and the computational time.

3 - Bi-objective TSP with nature inspired metaheuristics

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The interest of multi-criteria decision making in recent years have motivated researchers to develop and improve high-quality solution techniques to decision problems. Optimization concept which can be evaluated as a decision making process also draw attention, and decision makers effort to find effective solution approaches to optimization problems with multiple objectives. Solution techniques vary by problem, but can be classified as exact, approximation, and heuristic/metaheuristic methods in general. In this study, metaheuristics for the multi-objective optimization are investigated from a general framework; besides the main concern is given to the nature-inspired metaheuristics such as ant colony optimization and genetic algorithms. In the paper, traveling salesman problem (TSP) is chosen to evaluate performance of two different metaheuristics; a genetic algorithm (GA) and a max-min ant system (MMAS) algorithm.

TSP is the problem of finding the shortest route of a salesman in which each node is visited only once. In other words, TSP is the problem of creating the shortest Hamiltonian cycle in a graph. In TSP, the objective function can be minimization of the costs related with the arcs; such as total distance travelled, total cost of the tour, total time spent, etc. TSP is a well-known com-

binatorial optimization problem, and has the difficulty because of its computational complexity. There has not been found any polynomial time algorithm for the problem. Therefore, finding effective solutions to TSP in practice is still discussed, and stands as a challenging area.

TSP is a single objective optimization problem; but in the case of two objectives bi-objective traveling salesman problem (bTSP) is encountered. In the bi-objective case, two costs are associated with each arc. Experimental study of the proposed GA and the MMAS algorithms is implemented with twelve bi-objective instances of multiple-objective TSP. From the literature, symmetric TSP data sets with Euclidean distances are used in the computations, and these data sets are taken from the TSPLIB. Bi-objective instances are obtained from classical TSP instances with 100, 150, and 200 nodes. According to results of the experimental study, algorithms are found effective, and the study is concluded with the comparison and discussion of the algorithms.

4 - Solving Dynamical Vehicle Routing in Practice: Lessons Learned and New Challenges

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This talk is about the lessons learned when applying algorithms for solving the dynamical vehicle routing problem (VRP) in a real world setting. In [1], the fitness landscape of the vehicle routing problem was captured using expanded barrier trees, which sheds light on the complex search landscape of this problem with many local optima. To put the theory into practice, a

pilot-study was created based on the procedure of daily routing of a surveillance company in the Rotterdam area (The Netherlands). The company has between 300 to 400 scheduled jobs and an average of about 45 incidents per day, that need to be scheduled on-the-fly. Five vehicles are used to service these jobs. Multiple criteria and constraints need to be taking into account when solving such problems, including non-standard criteria that are specific to a particular application case.

In the talk we will focus on the question of how real world performance differs from benchmark performance (dynamical version Solomon's benchmark) which can be seen in [2] and what key issues need to be addressed when putting VRP algorithms into practice. By conducting a series of pilots, apart from answers to algorithmic setup questions, we obtained valuable insights into the question of what else matters when putting VRP algorithms into practice. From this case we have condensed our experiences to three key principles:

1. Iteration works. Theoretical benchmarks are a simplification of the real-world problem which contains various kinds of non-standard constraints. Hence, doing several iterations and making some adaptations in each iteration are necessary for a successful application of an algorithm.

2. Communication is key. In order to make a good implementation of an algorithm, it is important to build a bridge between algorithm experts, the company and a team of drivers, so that information can be delivered from users to the developers correctly. Drivers require feedback about their performance and the schedule should appear plausible to them.

3. People are important. End users such as customers and drivers should play an important role in the development. To make them feel comfortable with the system should be the ultimate aim of our implementation.

Although many improvements have been achieved in the pilot studies, still some challenges remain. A situation, such as the traffic jams can be anticipated and an emergency procedure should be introduced in the algorithm for such cases. Other topics could include regular checks on the feasibility of the current schedule, online adaptation of algorithm parameters, and providing appropriate feedback to drivers.

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★ TU-4-χ-HS6

◆ Environment, Infrastructure & Emerging Applications

Tuesday, 15:40–17:20 – Room HS 6

Session: AHP/ANP for Sustainable Management

Chair: Ririn Diar Astanti

1 - Ranking the barriers to the development of the renewable energy technologies in Colombia

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Colombia is one of the emerging economies of the South American continent. Besides, the energy demand is increasing faster than the energy production. On the other hand, a low carbon economy has been set as a strategic priority for the Colombian government.

To fulfil this objective, one of the main actions deals with the development of the use of the renewable energy sources, and those include conventional (i.e. hydropower) and the so-called non-conventional renewable energy technologies: solar photovoltaic, solar thermal, wind, mini-hydro, geothermal and biomass power.

However the non-conventional renewable energy technologies are encountering different barriers against their development. In this paper we identify them by reviewing the literature and interviewing different experts in the Colombian energy sector. Barriers are then classified into 4 cluster as follows:

1. Technical
 - 1.1 Electrical grid deficiencies
 - 1.2 Lack of equipment Certification
 - 1.3 Public officials with little practical training
2. Economical.
 - 2.1 Lack of assumption of externalities
 - 2.2 Insurance and Investment Management
 - 2.3 Financing difficulties
 - 2.4 Economies of scale
3. Social
 - 3.1 Not enough Foreign Investment
 - 3.2 Bad reputation of the non-conventional renewable energy sources
4. Institutional
 - 4.1 Lack of development planning
 - 4.2 Poor coordination between the public and the private sectors

A fifth cluster is added with the above mentioned six non-conventional renewable energy sources and, then, the Analytic Network Process (ANP)

is applied to the rank order of the barriers on the one hand and the energy sources on the other.

The ANP provides a framework for dealing with decision making or evaluation problems. It presents its strengths when working in scenarios with scarce information. ANP generalizes the problem modeling process using a network of criteria and alternatives (all called elements), grouped into clusters. All the elements in the network can be related in any possible way, i.e. a network can incorporate feedback and interdependence relationships within and between clusters. This provides an accurate modeling of complex settings and allows handling the usual situation of interdependence among elements in assessment scenarios.

As a result the main barriers are distinguished from the not so influential barriers. Therefore, recommendations can be drawn for a development plan of non-conventional renewable energy resources. Scarce public resources can be applied to the main barriers.

Besides, non-conventional renewable energy sources are ranked showing which are more influential, i.e. which ones are having the main problems with the barriers. Again this information would be of use for selecting the renewable energy technologies with more potential for development.

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2 - ANP and SNA applied to the assessment of the sustainability of the Cotopaxi Natural Park management

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The protected natural areas of Ecuador face several environmental threats; grazing is one of them in several national parks (NP) including the Cotopaxi National Park (CNP). National Park managers are proposing action alternatives to reduce grazing environmental impact while promoting social and economic development of cattle ranchers and the other stakeholders. For the success of any of these actions, as much consensus as possible is needed among all involved stakeholders.

In this paper, the Analytical Network Process (ANP) is used to modeling the decision problem and helping stakeholders to participate assessing the sustainability of the solution alternatives. In the presented methodology, a panel of experts in natural areas management was arranged to determine the decision model i.e. the network of criteria and alternatives structured into clusters. Ten criteria were set in 6 clusters: 3 environmental -atmospheric, soil and water contamination-, 1 social, 1 economic and 1 cluster of alternatives. The alternatives, included in the revision of the NP management plan, were: Physical delimitation of the park and control of the entering livestock, Development of productive alternatives to grazing, and Pasture subsidies.

The findings confirm that stakeholders hold different interests, approaches to sustainability and sensitivities. After ANP all stakeholders understand better their interests and the others'.

Then, the Social Network Analysis (SNA) is added to identify the relationships among all the involved stakeholders. Besides, the SNA results allow finding out who is supporting who, or who is against who. Finally, SNA can be used for ranking the influence of the stakeholders themselves. This way a better understanding of the decision processes is obtained. SNA results are used to assign weight to the stakeholders' preferences in the ANP.

Thus, an improved participation is obtained and consensus or at least general agreements are more likely. Also a better commitment to the overall objective is achieved as the decision model facilitates improving the alternatives design in order to lessen the possible burdens for specific stakeholders or the environment.

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3 - Methodological framework based on MCDM applicable to develop hydropower decision aid - A case of Nepal

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Hydropower exploration is extremely important in Nepal for its economic growth. With huge potential of 83,000 MW and 100 years of hydropower development history, country still missing a concrete decision framework applicable to hydropower sector. Earlier ad-hoc or donors dominance based practice of project selection is somehow changed and includes multi-dimensional aspects, but in fragmentation, after restoration of democracy in 1990. It is utmost important that all those possible goals and criteria applicable to hydropower decision making need to be reviewed and evaluated with due weightage simultaneously. This demand a framework to make project related decision, comparison or appraisal in the most appropriate way.

The objective of this study is applying multi criteria based approaches to develop the hydropower decision framework. This research begins from an “evidence based” identification of goals and criteria in practice. This needs reviews of secondary information relating hydropower with status update, development trends, economy, finance, policies & strategies, environment, social aspects, support infrastructure, countrys preparedness and associated risks etc. This step will result a Multi Criteria Decision Making (MCDM) first framework and will be used in second step of the research for the filed data collection. This framework is applied to some sample hydropower sites as an alternatives to analyze. Information comprising both ordinal and cardinal received is tabulated and further processed to test the applicability following simple scoring method. In next step, weightage applied is verified against each goal through questionnaire survey involving different stakeholders. Hence the scoring table obtained earlier is further analyzed with Analytical Hierarchy Process (AHP) by researcher as decision maker following pairwise comparison based on information in hand. This will cross check and validate the earlier results which ultimately assure the applicability of such tools in hydropower decision making. From the long list of criteria, appropriateness of those criteria is further tested through application of Preference Ranking Organization METHod for the Enrichment of Evaluations PROMETHEE. Initial long list of 44 criteria together with their weights seems applicable in context of Nepalese hydropower decision making. The study found 15, out of 44, criteria listed earlier do not influence hydropower decision and removed from the list. Hence the study confirms that the 29 number of criteria under five goals is sufficient to apprise, decide upon or rank hydropower projects in Nepal. In present country context highest weight is assigned to the economic goal followed in descending order by social, political, environmental goals and finally the overall uncertainty. The present research indicates that combining MCDM approaches like analytical analysis, simple scoring, AHP and finally Vi-

sual PROMETHEE is effective in developing a hydropower decision aid which could be used for decision making or prioritizing hydropower options exhibiting quite different features.

The multiple MCDM tools used to develop hydropower decision framework is the contribution of the paper. Methodologies followed in this research is easy to understand and apply, specifically in country like Nepal where data availability and reliability is critical. This research could be useful for hydropower stakeholders in general and policy maker in particular.

This full paper is organized in eight sections namely introduction, hydropower development in Nepal, problem definition, objectives, methodology, applications, results and discussion; and conclusion and recommendations.

4 - Ethnic Entrepreneurship Model Using Analytical Network Process: A Case Study among the Javanese, Chinese and Minangkabau in Yogyakarta, Indonesia

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Entrepreneurship is being recognized as an important vehicle of economic growth. Previous research demonstrate that entrepreneur traits consist of psychological, economic and social traits. Furthurmore, these traits are determined by market conditions, access to ownership and group characteristics. Using the ethnicity perspective, the purpose of this study is to identify the dominant traits that apply to the ethnic entrepreneurs in Yogyakarta, Indonesia. Findings of this study are expected to be used in order to develop an entrepreneur training module, as an endeavor to prepare young generations to become entrepreneurs that will not only contribute to the society and economic development, but also preserve the noble cultural values. There are three ethnics that are invloved in this study, which are Javanese, Chinese and Minangkabau considering that most of the entrepreneurs in Yogyakarta are from those three ethnic background. In this article the connection between enterpreneurship and ethnic identity is examined. We examined various approaches to explaining ethnic enterprise in Yogyakarta province. First, an inquiry of the origins of ethnic enterprise was conducted in order to understand the causes, nature, dynamics of ethnic enterprise, and the cultural values that

have been passed on from generations to generations in Yogyakarta. Second, an analytical network process (ANP) framework was employed to identify the dominant factor that explained the connection between entrepreneurship and ethnic identity. There are four clusters considered in the ANP framework, which are: 1) Market Conditions (underserved and abandoned market, market with low economics of scale, market with unstable demand, market with exotic goods), 2) Access to Ownership (inter-ethnic competition, state policies), 3) Group Characteristics (skills and goals, settlement characteristics, culture aspiration, resource mobilization), and 4) Entrepreneur Traits (Psychological Traits, Economic Traits, Social Traits).

Wednesday, 09:00–10:40

★ WE-1- α -HS1

◆ Behavioral Aspects, Group Decision Making, Negotiations, Interactive Methods, Software

Wednesday, 09:00–10:40 – Room HS 1

Session: Group Decision Making

Chair: Günter Fandel

1 - A Group Decision Making based Supplier Risk Assessment Framework for Multi-National Supply Chains

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In today's global competition, due to shorter product life cycles, cost and time pressure, companies adopt lean production concepts, global outsourcing and collaboration strategies. However, these strategies may make supply chains more vulnerable in terms of various supply chain risks. As a result of these changes, importance of supply chain risk management has inevitably increased. However, identifying and assessing the risks is still a challenge for multi-national supply chains due to their distributed and complex structure. Therefore, risk assessment process should be conducted by separately considering individual assessments of supply chain agents and aggregating them to obtain a unique risk assessment. In this study, a group decision making based risk assessment framework is developed for supplier risk assessment in multi-national supply chains. In the proposed framework, plant managers assess suppliers' risk by considering a number of criteria. Afterwards, TOPSIS technique is utilized to rank the suppliers according to their

risk. To obtain unique decision matrix, decision matrices of plant managers are aggregated. Weights of the criteria are determined by using entropy weighting method. In order to confirm the viability of the proposed framework it is implemented to a multi-national supply chain spread on Europe. The supply chain consists of several plants and suppliers. Plant managers evaluate each supplier according to their delivery performances calculated by using past order records. The assessments of plant managers are combined to obtain unique decision matrix. As a result of the implementation, the suppliers are ranked according to their criticality in terms of risk. The results reveal that plant managers can benefit from the proposed framework in revising supplier contracts and ordering strategies by considering risk.

2 - Negotiating proportions in division problems with multiple references

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Proportionality is a primary principle generally accepted when dividing a commodity between a set of agents who are evaluated with respect to a certain characteristic. When a single characteristic is considered, the proportional rule provides a result in which all the agents obtain the same proportion with respect to their reference.

When multiple characteristics have to be taken into account, there is no obvious way to define a proportional rule. In the approach proposed in this paper we incorporate the extensions of two crucial properties which are inherent to proportionality: the proportions obtained with respect to the different references cannot be improved simultaneously, and the result does not depend on the scale in which each of the references is measured.

In our approach, the problem of deciding a single allocation for the division problem is understood as a negotiation between parties each one "supporting" one characteristic. This fact enables us to define concepts of solution for the multiple reference division problem based on the axiomatic bargaining solutions.

3 - A conceptual framework for Multi Attribute Group Decision Making

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Group decision-making (GDM) has received increasing attentions in last decade and seems to continue growing exponentially. Especially the

application of multiple attribute decision-making methods to GDM problems, so called multiple attribute group decision making (MAGDM), occupies a vast area in the related literature. However, to our best knowledge, there is no framework for MAGDM methods that provides the basic concepts and their relation in a GDM process. This kind of a conceptual framework will help academicians and practitioners who need to develop new MAGDM method and/or apply a MAGDM method to a problem. A framework is important for understanding and analysing the MAGDM methods as well as evaluating the parts (of a MAGDM method) that need improvement. By this way, it will also support the development and design of new MAGDM methods and provides a useful guide and an effective tool for researchers that working in this area. This study aims to fill the gap in the literature by introducing a conceptual framework for MAGDM methods.

Literature analysis shows that the decision process in MAGDM methods consists of three major stages: Structuring and construction stage, Assessment stage and Selection/ranking stage. Therefore the framework is designed based on these three main stages.

In the first stage, the problem is structured as a MAGDM problem by identifying decision goal and forming a committee of decision makers (DM) or experts. Then importance weights of DMs may be assigned in this stage. Finally, the alternatives that will be evaluated in the process are identified. A MAGDM model is constructed through determining the alternatives, criteria, and performance values, which is the decision matrix in classical decision models. For MAGDM problems, however, the set of criteria may be different for the DMs, and in some problems criteria are not available where DMs evaluate the alternatives directly. Since the set of alternative should be the same for all DMs in a MAGDM problem, the identification of alternatives takes place in the first stage while determining criteria and performance values are placed in the assessment stage in the framework.

In the second stage, the alternatives are assessed based on the decision goal identified in the previous stage. The assessment is conducted with two main approaches depending on usage of criteria: Criteria based assessment and Alternative based assessment. Classically, in most of the MAGDM problems, criteria are explicitly presented. But in some problems DMs do not give information about the criteria; instead, they use and only provide their preference through the ranking or comparing the alternatives. In criteria based assessment, DMs may use an agreed set of criteria or their own individual sets of criteria. In the agreed criteria case, DMs provide evaluations of the alternatives with respect to the common criteria. In the individual criteria case, the DMs determine their own criteria or select the criteria from a predetermined set. In alternative based

assessment, DMs directly evaluate alternatives. Finally, if it is possible DMs preferences are aggregated to a decision matrix (for some agreed criteria cases). Otherwise, individual preferences of the DMs are calculated (for some agreed criteria cases, individual criteria case, and alternative based assessment) in this stage.

In the third stage, alternatives are ranked or selected through finding collective preferences and consensus process. Collective preferences are calculated according to the output of the second stage. For instance, if the individual preferences are supplied as ranking of the alternatives, a social choice function can be used to find a collective preference. If a decision matrix is the output of the second stage, then a classical multiple attribute decision-making method can be used. After calculating a collective preference ordering some methodologies apply consensus process, which is defined as a dynamic and iterative group discussion process, coordinated by a moderator helping experts bring their opinions closer. In this process, initially, the degree of existing consensus among DMs opinions is measured. If the consensus degree is lower than a specified threshold, the moderator would urge DMs to discuss their opinions further in an effort to bring them closer. Otherwise, consensus process is finalized. In some methods the consensus measure is used to obtain importance weights to DMs. After designing the conceptual framework, we have also analysed top cited papers in the related literature according to framework in order to show the state of the art and to identify future research directions. Key results of this analysis are summarized as follows:

Because of the uncertain, incomplete, unreachable information, the application of fuzzy techniques in GDM is increasing rapidly. Especially we have seen a significant increase in intuitionistic fuzzy information and their application to MAGDM over recent years.

The consensus process is necessary to obtain a final ranking or selection with a certain level of agreement between the decision makers. However, the literature considering consensus process is scarce. Future research on this topic will be valuable to MAGDM literature.

Most of the articles use illustrative examples to show applicability of their methods. Application of current methods to real life problems will highlight the practical advantages and disadvantages of the methods. The number of methods for alternative based assessment and methods that enable the use of experts own criteria are very low. In some real life GDM problems, especially in pluralistic problem situations, experts may prefer to use their own criteria based on their expertise. The development of methods that permits individual criteria instead of agreed criteria may be a challenging research direction.

4 - The effects of trust variations on inspection procedures

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In our paper we expand the considerations of Fandel/Trockel (2011) to an analysis of a dynamic trust behavior of the strategic players. The trust parameters that determine the level of the additional payoffs in the case of trust are now time-dependent with respect to the number of repeated rounds of the inspection game. The basis of modelling is a logistic function that describes the trust expansion among the strategic players. Unfortunately there exists the hazard that the inspectee will prey the inspectors trust if the inspectors trust level increases and exceeds a threshold. The inspector wants to prevent this situation. This is modelled by a stochastic term which expresses the percentual loss of trust of the inspector that may occur, so that a reasonable boundary of a threatened exploitation is not realized. However if this occurs, the calculated equilibrium in the next round of the repeated game will be the Nash solution without any trust. In the following rounds trust will maybe increase again and develop in a similar way as before. Based on a simulated structure of the chronology of the players payoffs one can estimate the level of mistrust the inspector should never underbid, so that error-free payoff-series without trust variations occur that dominate the Nash solution in games without trust, but simultaneously decrease the value of hazard the inspector may be exploited by the inspectee.

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★ WE-1-β-HS2

◆ Decision Aiding

Wednesday, 09:00–10:40 – Room HS 2

Session: Decision Aiding for Information and Security

Chair: Iryna Yevseyeva

1 - A novel dual-time frame MADM model for improvement planning compromised between short-term and long-term prospects

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The mainstream management domain often criticizes the “short-termism” nowadays, such as in the Harvard Business Review [1-2], which encouraged business to pursue the enduring interests for the long-term (i.e., long-termism). After the recent financial crises, even certain policy makers have noticed the issue, such as in France, to support long-term investors with more voting rights [3]. However, management teams of the public-listed companies have the pressure to meet markets’ short-term expectations [3], which also cannot be overlooked in practice. A clear guidance based on decision makers’ judgment/preference to compromise between short-term and long-term prospects is highly required, also an underexplored issue in decision science. Therefore, the aim of this study attempts to explore the contexts and core attributes for both time frames: the long-term and the short-term, and develop a hybrid multiple attribute decision making (MADM) model to support management teams for improvement planning. This study proposes a hybrid approach to obtain the contexts/core attributes associated with each time frame by the dominance-based rough set approach (DRSA) at first (learned from historical patterns); in the next, the core attributes associated with each time frame are adopted to construct two sets of influential weights by the DEMATEL-based ANP method (termed as DANP) [4, 5], and the two sets of criteria (attributes) are integrated to compromise for the ideal improvement plan based on a decision maker’s preference at the final stage. A group of life insurance companies in Taiwan are to be analyzed, from 2009 to 2013. The contexts/decision rules associated with each time frame that lead to superior financial performance would be obtained, and the directional influences among the two sets of core attributes would be explored to form the directional flow graph (DFG) [6], which is easier for decision makers to comprehend. Finally, a case of five assumed improvement plans would be illustrated to compromise between the short-term and long-term prospects, to obtain the best alternative (i.e., improvement plan) for an insurance company. The present study thus contributes to the understanding of the complexity in a real world business environment with implications for both academia and practice.

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2 - Advancing the Maturity of Information Security Expenditure Calculations with Multi Criteria Decision Making

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Uncertainty is present in everyday life, in the decisions we make as individuals and the decisions we make within an organisation. Unfortunately, some decisions are more important than others, and a misinformed decision can affect yourself as an individual, or the organisation you're working for or even the information you trust to an organisation. As Information Security becomes a more discussed topic, the ways in which organisations are ensuring the safety of their Information also becomes a topic in the foreground, and there are severe penalties for organisations that are unable to guarantee security for their customers, or stakeholders. There are a number of Information Security solutions available to organisations, from simple off the shelf anti virus software to advanced firewalls. The selection of a Security solution that is both appropriate for the organisation, in terms of the threats it is likely to sustain and the nature of the organisation, as well as being cost effective. Current methods to evaluate financially the different Information Security solutions are very subjective, unpredictable and non repeatable. The methods are ad-hoc and not standardised. The application of Multi Criteria Decision Making, namely Multi Attribute Utility Theory and fuzzy and grey theory can create a mature framework for assessing the suitability of an Information Security solution. The large number of metrics, with different units and degrees of accuracy can be handled. This work presents a novel, extended version of Multi Attribute Utility Theory that incorporates fuzzy and grey theory to handle uncertainties and incomplete information in order to evaluate Information Security solution expenditure.

3 - Bayesian Inference and the Evidential Reasoning (ER) Approach for Multiple Criteria Analysis

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The Evidential Reasoning approach was originally developed for multiple criteria decision analysis under uncertainty. In this paper the relationship between Evidential Reasoning and Bayesian inference in the context of Multiple Criteria Analysis (MCA) is examined on the basis of the recent establishment of the evidential reasoning (ER) rule. In recent research, it has been proved that 1) the ER approach is a special case of the ER rule in which the weight of evidence exactly reflects or equals to its reliability and 2) Bayes rule is a special case of the ER rule when each piece of evidence is fully reliable and the probabilities for and against each proposition are summed to one. Therefore, Bayesian inference is a special case of Evidential Reasoning in the context of MCA as follows:

1. While prior distribution is a pre-requisite in Bayesian inference, evidential reasoning is a kind of likelihood inference and does not depends on prior distribution.
2. The performance of an alternative on each criterion is expressed by using a set of mutually exclusive and collectively exhaustive propositions ($h_1, h_2, \dots, h_i, \dots, h_n$) and evaluated as a belief distribution over the set of propositions with $p(h_i) + q(h_i) + r(h_i) = 1$, where $p(h_i)$, $q(h_i)$ and $r(h_i)$ are probabilities of h_i being true, not true and not known.
3. A probability distribution in Bayesian inference is a special case of belief distribution in evidential reasoning when $r(h_i) = 0$ for any i .
4. The individual assessment or partial performance of an alternative on each criterion is regarded as a piece of evidence which is used to update the overall performance of the alternative, in which no prior performance of the alternative is assumed in addition to its assessments on all criteria
5. The ER rule is used to combine multiple pieces of evidence (multiple criteria assessments) to generate an overall assessment for every alternative on all criteria.
6. The overall assessment of an alternative provides a solid foundation for further decision analysis such as ranking and formation of improvement strategies.

While Bayesian inference has been used for data analysis, the ER approach enhanced by the newly established ER rule can be applied to support multiple criteria analysis of big data, in which missing data (the veracity) and messy data (the variety) can be handled under the same framework consistently. In this presentation, several case studies are discussed on how the enhanced ER approach has been applied to

support multiple criteria analysis of big data in several areas such as healthcare and finance.

4 - Adaptive Soft Influence for Information Security

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When it comes to security the traditional approach to influence decisions is a requirement to comply with the security policy of the company. However, in practice, employees of companies rarely follow the security policy of the company, even when they are aware of it. Moreover, they may override or ignore security policies that are felt too restrictive [1]. Previous research shows such a situation is common due to the lack of employees awareness of security threats and vulnerabilities, and (often presumed rather than actual) hindering of productivity when acting more securely. For instance, in order to complete an important task, many people opt for connecting to a fast but insecure Wi-Fi network, rather than trying cumbersome and time-consuming ways to connect to a secure network. When working on their own devices employees actually have the right to make their own decisions. Moreover, they may be better positioned to make decisions when compared to their employer, especially when it comes to accounting for a dynamically changing environment. In such situations forcing compliance to a company policy may be counter-productive, and a hands-off approach may be still not secure enough.

In our work, we propose an alternative to a forced compliance and hands-off influence strategies for an employer: a soft influencing suggested to employees at the moment of making a security related decision. This strategy frames the choices towards decisions favorable to the employer without restricting other choices. It takes into account higher uncertainty of the employer when compared to the up-to-date information about the environment of the employee at the moment of decision-making and potentially conflicting security and productivity criteria.

Here we adapt influencing peoples choices by modifying the context of decision making in a way that some choices become easier to make. This approach is called nudging and it was popularized by Thaler and Sunstein in [2]. Nudges were successfully applied, for instance, in healthcare [3] and social policy design [4]. These examples show that small changes in the presentation

of alternatives make big differences in terms of choices.

In [5], we have taken a formal approach to model influence with agent-based model and in [6] we proposed a decision-making model based on multicriteria decision analysis for aiding influencing in security context. To extend those works, we propose here an approach to extract the preferences of a decision maker needed to design some adaptive influence. Indeed, being able to monitor the behavior of their employees and to study their preferences, an employer may design influence in a way that suits better their employees, who are groups of decision makers with different preferences. In addition, we aim at designing adaptive influence mechanisms that take into account the “habituation effect”, with which people who are influenced are getting used to subtle nudges and stop noticing them after some time. We apply the proposed influencing model for decision-making to derive optimal policies for the selection of Wi-Fi networks. This is a common scenario in which a device user has to choose between several Wi-Fi networks available for working outside the office in a cafe or in other public places. The graphical user interface of the device may present choices so as to influence the decision of the device user. In this case, the decision makers represent the device users and employees of a company, which wants to influence their choices.

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★ WE-1- γ -R401

◆ Model Building

Wednesday, 09:00–10:40 – Room 401

Session: Recent and Emerging Topics

Chair: Alexandre Leoneti

1 - Optimal measurement design for geotechnical laboratory experiment using a Monte Carlo approach

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Numerical simulations become an increasingly utilized tool for predictions of soil behaviour in geotechnical engineering. These simulations, however, require accurate soil parameters that have to be determined by conducting laboratory experiments. Nevertheless, the optimal measurement design of the laboratory experiments is of great importance for a successful determination of the soil parameters. This work illustrates the procedure of a measurement design for a loading apparatus on a soft soil with unknown parameters. The apparatus is numerically simulated using a finite element code and the soil parameters are firstly identified through an initial measurement design and a back analysis technique. Subsequently, a Monte Carlo simulation is conducted for optimizing the measurement design.

2 - Combination of conversations protocols for new web services configuration using the formalism of finite states machines

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The main goal of our work is to ensure a precise configuration of Web services complexe. We use the protocols of conversation to model the exchanges between the different entities (supplier, consumer, intermediaries). Our work is based on the technology of Web services and the finite state machines to define our approach of services configuration. In this work, we present an improvement of an existing algorithm of consumer-server composition. Then, we develop two new algorithms of composition: series composition and parallel composition of Web services.

3 - Choice Experiments for Decision Making on Multi-attribute Product Profiles

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Understanding choice behaviour of consumers for any financial product is an important area of consumer research in marketing science. Decision makers upgrade their product and build the marketing strategy based on estimation of utility value of that product. This utility value is a cognitive value that consumers obtain from a product and cant be measured from outside. Human choice behaviour between different products is based on different realization of certain attributes making those products. However, finding the effects of different attributes is not easy through direct measurements since utility of a product is non-measurable. It is thus a challenge for the researchers to quantify the effects of each attribute for the choice behaviour of the products. Discrete choice experiments are a standard tool in marketing research for quantifying consumer preferences. In a discrete choice experiment, levels of different attributes are combined or considered jointly in a product profile or alternative. These profiles describe either existing products or hypothetical or potential products. A choice experiment consists of a selected number of product profiles grouped into choice sets. Such a group of choice sets is called choice design. The number of profiles in a choice set is called choice set size. Each choice set represents a virtual market from which respondents indicate the product that they prefer. A better choice design helps us to obtain better estimation of underlying parameters.

In this talk, I will first discuss about some basics of multinomial choice model based on random utility theory and show how to approximate the utility value of a product though it is non-measurable. Design of discrete choice experiment is an important area of marketing research. Respondents often find cognitive burden in a choice experiment with large number of choice sets or large number of attributes in a choice experiment. I will present some of our recent findings to solve this problem of obtaining minimum number of choice sets, using orthogonal designs and other combinatorial techniques. I will start with paired choice (choice set of size 2) designs and then successively develop general results of optimal designs with choice set of any size.

★ WE-1-δ-HS3

◆ Industry and Business Applications

Wednesday, 09:00–10:40 – Room HS 3

Session: Optimization in Networks 1

Chair: Katarzyna Krupińska

1 - A Brief Survey on Multi-objective Optimization Methods Applied in Wireless Mesh Networks

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Wireless mesh networks are a type of communication networks. They have emerged from other communication networks in recent years, because their flexibility allows them to jointly operate with other kinds of networks such as cellular networks and DSL networks. Designing the wireless mesh networks can involve considerations from node placement, routing, scheduling, energy conservation, channel assignment and link quality requirements. But typically only a subset of them are considered simultaneously. For example, the design of a cost-effective and reliable wireless mesh network involves multiple conflicting objectives such as maximizing the performance of the network and minimizing the energy consumption subject to constraints such as the connectivity of the network and the bandwidth requirements of data flow. In this talk, we present a survey of how multi-objective optimization methods are applied in designing wireless mesh networks. Based on an overview of relevant literature, the survey begins with a discussion on the challenges in wireless mesh networks and the needs of applying multi-objective optimization methods in addressing the challenges. Next, a review of the contributions in the area is presented for the multi-objective optimization approaches in network planning and routing strategies. The review considers the methods applied originating from both approaches of multiple criteria decision making and evolutionary multi-objective optimization. As a summary for the survey, possible future research directions in applying multi-objective optimization are identified.

2 - Making Routing Decision in Wireless Sensor Network using Multi Criteria Decision Analysis

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Wireless sensor network (WSN) is a self-organizing wireless network system which enables densely deployment of nodes. WSN is a

prominent technology in collecting data from remote locations by interacting with the physical phenomena and depend on the collaborative effort by huge numbers of low cost sensor nodes.

These sensor nodes collect, process and send the data to a base station. Basically these sensor nodes gather the environmental data. These data are collected and routed to the destination via other intermediate nodes. The data packets are received and passed from the data source to the base station. In case of multi-hop communication, route finding is the key support for network transmission technology. In a WSN, an efficient routing algorithm is very important. But the realization of the same is not so easy because of many routing parameters of the network and the limited resources of the sensor node. The various constraints of the WSNs lead to set optimization problem in designing energy-efficient routing algorithms. For most of the existing routing algorithms, next hop is selected randomly or based on residual energy, node density or distance from the sink node. If next hop is selected based on residual energy, this node may be located far away from the sink node compared to other neighboring nodes. In this case end-to-end delay will increase as the path length (i.e. hop count) increases. Similarly, if next hop node is selected based on the shortest path (i.e. minimum hop count), then similar type of problem arises. A node near to sink node, but with low residual energy may get selected as the next hop. Hence single criterion does not always provide efficient routing decisions. So the decision, for selection of an ideal next hop, is made using multiple criteria. Handling of multiple criteria to decide about the next hop is solved by multi criteria decision analysis (MCDA).

We have proposed an algorithm which maintains balanced energy consumption among the nodes with consideration of minimum hop count using multiple criteria together. Weighted Product Model (WPM) is applied for solving the routing decision making problem. Instead of addition, this method uses multiplication to rank the alternatives. Each alternative is compared with others by multiplying a number of ratios, one for each criterion. Each ratio is raised to the power equivalent to the relative weight of the corresponding criterion. We have preferred WPM because it can be used in multi-dimensional decision process, as it is dimensionless. Here three different criteria are considered. Each of the criterion has different dimensions. Thus, WPM is appropriate to combine these values. It can accommodate benefit criteria as well as cost criteria simultaneously during decision making.

We have considered three different criteria i.e. residual energy, frequency of packet transmission and hop count to determine the product value applying WPM. Here, first one is the benefit criterion and other two are cost criteria. A neighbor table is maintained by every node. It contains following four fields :(i) Neighbor node, (ii)

Residual energy, (iii) Frequency, (iv) Hop count. Information in the neighbor table is used to make the routing decision. During the routing decision, product value is calculated for each of the neighbors. A neighbor node with highest product value is selected as next hop node. One particular node cannot always remain the next hop node. Next hop node is changed dynamically based on this product value. It implies that dissipation of battery power is balanced across various nodes. Thus, network lifetime is enhanced in this proposed algorithm.

In the MCDA assisted routing decision, weights are assigned to the criteria based on application requirements. We adopted three techniques for weight assignment. Weights may be assigned using relative rating method based on specific applications. Each criteria is rated relative to the others in satisfying a particular interest. Also, weights may be calculated using information entropy. Higher the entropy, weight of the particular criteria is lesser and vice versa. Network heuristics properties may also be taken into account to assign weights using fuzzy inference rules. We take three heuristic properties (i) node density, (ii) number of dead nodes, (iii) delay as input crisp values and defined as low, medium and high membership functions. Several fuzzy inference rules may be defined for making the decision about rank of the parameters. We have formulated several rules for implementation. The rules are applied dynamically based on the state of the heuristic properties. We may try to involve more criteria for making the routing decisions and more heuristic properties for weight calculation.

The routing scheme is implemented and tested in real-time. We have used TinyOS 2.1.1, open-source operating system for WSN and Crossbow's TelosB sensor-motes as a hardware platform. All the TelosB nodes are installed with the routing scheme and deployed in such a manner that multi-hop communication may occur. For implementing the routing scheme, it was required to develop the appropriate code separately in nesC language. Apart from this, some of the existing codes are modified to enable the proposed scheme.

3 - Multi-objective design of reliable ring tree networks

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In this work we introduce a multi-objective optimization approach for partially reliable network design. Our model generalizes the capacitated ring tree problem (CRTP), which asks for a network topology that connects given customers to a central distributor by combined ring and tree

structures. Customers are grouped in two classes with different security requirements and are assigned to rings or trees such that a minimum required security level is guaranteed. Customers that are located on a ring experience an enhanced security regarding a network breakdown since they are still serviced in the case of a single edge failure. One relevant field of application for the CRTP is the design of telecommunication networks, in which reliability is a crucial matter. The base CRTP objective is the minimization of the overall edge costs. However, in order to improve the reliability conditions of tree customers, we develop alternative criteria in this work. More detailed, the network reliability is quantified with regard to different single edge failures. In particular, we take into account (I) the minimization of the overall tree edges, (II) the minimization of the number of subtree customers and (III) the minimization of the maximal hops from a tree customer to a ring. We present a mathematical multi-commodity formulation that measures (I)-(III). Based on this formulation, we approximate the Pareto front with an epsilon-constraint method. Besides the study of the interplay of the objectives we perform a structural analysis in which we identify the usage frequency of arcs and nodes in Pareto-optimal networks. The latter is suggested for decision support. We apply our techniques to a series of literature instances and provide extensive computational results.

4 - Preferential description of robust paths in oriented graphs

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We present the problem of a shortest path in a directed graph in which costs connected to arcs are uncertain. We consider two different descriptions of uncertain arcs costs: in the first, to each arc is assigned a vector of costs related to a finite set of scenarios, in the second description, uncertain cost may be any number from an interval of possible values. We define a binary relation on the power set of the set of arcs and, in each case of uncertainty, we search for preferred paths which may be considered good in the sense of predefined requirements listed as some properties satisfied by the preference relation. We also try to give an operational description of a predefined concept of a robust preferred path.

★ WE-1- κ -HS4

◆ AHP/ANP

Wednesday, 09:00–10:40 – Room HS 4

Session: AHP/ANP: Industrial Applications 2

Chair: Fikri Dweiri

1 - Fuzzy AHP-Fuzzy Promethee Approach in Evaluation of E-Service Quality: Case of Airline Web Sites

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In conjunction with the technological innovations in information and communication world, the services submitted by internet build up over time and the competition between sectors has been transported to electronic environment. In recent years that internet access facilities have become widespread, firms are obliged to use their web sites effective as well as to compete and reach their customers easily. For this reason, so as to increase the quality of services presented over the internet, the organizations must attach importance to the notion of electronic service (e-service) quality. The e-service quality stands out from the point of measuring whether the services provided in electronic environment is qualified to respond customer expectations and if the firms are able to gain competitive advantage in sectors they situated. Because the e-service quality is a relative notion it is hard to measure and the use of fuzzy decision making methods that enable to assess in the circumstances involved uncertainty like this, presents an efficient solution. In this context, the aim is to measure the e-service quality of web sites by fuzzy multi criteria decision making methods. Firstly, the level of significance of e-service quality dimensions is determined by Fuzzy Analytic Hierarchy Process approach as a consequence of the surveys which are applied to expert team. After the level of significance determined, as a result of the surveys that are applied to customers, the e-service quality of websites of the airlines corporations performance is assessed by Fuzzy Promethee method. In this study, it is profited by 12 expert opinions that consist of five academics, four aviation industry employee and three information technology employee and the customers that used identified four airline web sites are surveyed. In this application, the websites of four Turkish companies which are operated in aviation industry, Onur Air, Pegasus, SunExpress and Turkish Airlines, are taken in consideration.

2 - An Analytical Network Process approach for measuring influence of stakeholders in a project

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1. Introduction

The Project Management Institute (PMI) defines a project with the attributes temporary, novel, target-oriented, dynamic and complex. Among the ten knowledge areas of Project Management one of them is Stakeholders' Management [1]. The International Project Management Institute (IPMA) defines project's stakeholders as "people or groups, who are interested in the performance and/or success of the project, or who are constrained by the project" [2]. Today we know that a great deal of the complexity concerns the stakeholder problematic because a project's environment involves a broad array of stakeholders that need to be regarded when it comes to decision-making processes. This leads us to the aim of a Stakeholder Analysis (SA) in project management, which is to gain a comprehensive overview of all the players in the environment of a project [3]. Although SA provides a variety of techniques they do not allow determining an individual value of the influence of each actor in a decision-making process. For that, in this paper we propose a new methodology to measure the influence that stakeholders exert on the project based on the multicriteria decision making tool Analytic Network Process (ANP) [4]. It will allow obtaining an individual index of influence for each stakeholder which could be used to weight their judgments in case we want to consider unequal importance of voters [5]. As far as we know, ANP has never been applied to analyze the influence between stakeholders in a group or social network.

2. Literature review to define "influence"

Stakeholder literature provides some approaches of how to deal with this issue, to be more specific, different sets of criteria that finally define influence. Therefore, a state of the art literature research was carried out in order to find out all the different criteria proposed to measure "influence" of stakeholders. The following list shows a summary of the results. The criteria were grouped into 4 clusters: Knowledge, Social Skills, External and Assets:

- K1: Expert Knowledge [6] [7]
- K2: Professional Competence [6][7]
- K3: Experience [6]
- S1: Representativeness [3][7][8]
- S2: Affiliating with others [3][8]
- S3: Manipulating others [3][8]
- A1: Financial Security [6]
- A2: Providing Resources [3][6][8]
- A3: Providing Financials [3][6][8]
- E1: Dependency to External Factors [8]
- E2: Public Image [8]
- E3: Hierarchical Position [6]

3. Approach of the methodology proposed

The proposed methodology was divided into four phases: 1. Definition of PM Experts 2. Fixing ANP model 3. Passing questionnaires to experts 4. Analysis of the results. The realization of the model requires the consulting of experts in project management and/or of experts of the particular area of expertise. In order to demonstrate the goodness of the methodology proposed it was applied to a particular Project Management case study: the implementation of new efficient energy saving measures for a four star hotel of 200 rooms located at the beach of a city of the province of Valencia, Spain. The project management team is integrated by four stakeholders: Hotel maintenance director (St1), Hotel director (St2), Technical director of the hotel chain (St3), Owner of the hotel chain (St4).

4. Results

According to the results regarding the criteria: the criterion which exerts the most influence, by a large margin is Experience with 18,8. This means that in this certain project that is the most important characteristic a stakeholder can possess. According to the results regarding the influence of the stakeholders: Stakeholder 3 (technical director of the hotel chain) with a percentage of 36,1% is the most influential one, closely followed by Stakeholder 4 (the owner of the hotel chain) with 35,1% of the influence. These two actors of the project are the ones that exert the most influence and therefore should be paid more attention.

5. Conclusions

The main conclusion we have obtained in this work is that it is possible to use ANP to analyze the influence among stakeholders in a Project. Nevertheless, this is not an easy task. The main problem is to define the concept of "influence" when the stakeholders have to face a project. And then analyze with the help of some Project Management experts how all the criteria that define this concept are related to each other. The results show different influence intensities for the four stakeholders, which should be considered when weighting the experts in a participatory decision making process.

6. References

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3 - Determining the Factors of Reputation Management by ANP Method

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Reputation is "the overall estimation in which a company is held by its constituents" and reputation management is "to systematically influence the perceptions that form this estimation". Since reputation is a significant determinant of marketing's influence in businesses, reputation management gets more important issue and has been used to reduce the risk of negative interaction outcomes in this globalized world. It is believed that a model of company reputation management needs to reflect the continual interplay and accumulation of the many consumer networks as a dynamic ongoing and interconnected process. Though reputation has usually been seemed as public relations' job; nowadays it is understood that it is related with competitive success for all corporation. A good reputation has many advantages such as a good reputation is significant because of its value creation potential and the fact that its intangible nature makes it hard for competing organizations to copy and do the same so has numerous positive implications for a company. It can protect the firm in crisis times and furthermore keep it away. For employees, a good reputation means high morale and productivity; and increasing the possibility for them to show their talents. In the views of competitors, it is a powerful way of differentiating the company from them and stimulating the purchases. For customers, it means the "attraction" and affecting their buying behavior and charging the price how the firm would want. For suppliers, it means a willingness to build up partnerships with that well-known in case of reputation-firm. Also it facilitates the investors' decisions in a positive way; and establishes customer cross-buying intentions by enhancing expected service quality of customers, reducing information costs and increasing trust and affective commitment. A good reputation can add value to a firm in lots of ways while failure of it can cause the alienating the

customers; thus it is such a hard task to manage it. Managers who are in charge with reputation management needs to know what factors play important roles in this management side. By giving what weights each factor deserves, managers can manage reputation more effectively and can be successful about it. For every company whether it is a product or service company and for every culture these factors can change but here the aim is to present general factors derived from literature and authors' views and order them in a hierarchical way. Though there are some researches about reputation management, mostly which are conceptually, we have met two of which studied reputation management with Multi-Criteria Decision Making Models as we would like to study in this research. First of these studies have been done in evaluating the reputation in airline market and ordered the factors about reputation and corporate image of airline companies by using AHP method in fuzzy technique. Though the main criteria such as moralities, managements, economics, services and conveniences seem dependent on each other, the authors preferred to choose AHP method instead of ANP. The other study is made by determining 5 factors of online reputation management, then ordered them by the method DEMATEL based ANP method which is called as DANP; though the factors are so few to be satisfied as an academic research. In this research, a model is built by finding the factors determining the reputation management for a manufacturing company from the literature and authors' views. Factors are firstly divided into five main sections as products, management, employees, economics and customers. Because these main factors are considered as dependent on each other, interdependency of main factors is measured by the method which has been developed by Saaty in 1996 and called as ANP method then; per each factor; sub-factors are determined and made a weighting among these sub-factors by using AHP method which is developed by Saaty. The first main factor which is 'products' involves the sub-factors those are; quality, variety, pricing and significance. Second main factor which is 'management' involves the sub-factors those are managing style, being in CSR projects, way of treating employees and on time performance. The third one that is 'employees' constitutes the sub-factors which are behaviors to customers, professional skills, handling complaints and problems. Fourth one, the economics involves; physical assets (building), financial situation of the firm, selling channels, promotion activities and position in the market. And the last one which is 'customers' involves; popularity/place of firm in minds, culture of society, personalized preference and temporal sensitivity. The factors which affect the reputation management of a typical manufacturing firm have been determined by both authors' views and basing on the literature search. The factors are firstly di-

vided into five main categories and investigated by the technique called ANP because of their dependency on each other; and then the sub-factors, twenty at total, have been found their global weights and ordered by using the technique called AHP.

4 - Third Party (3P) Warehouse Location Selection in a Lube Oil Company: An AHP Approach

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Warehouses are most crucial components of most modern supply chains: they are likely to be involved in various stages of sourcing, production and distribution of goods. From handling of raw materials to work in process through to finished products as the dispatch point serving the next customer in the chain, they are critical to the provisions of high customer service levels. The objective of this paper is in two folds, first we will identify and rank third party (3P) warehouse selection criteria for lube oil company in Pakistan and secondly, we will rank alternatives using Analytical Hierarchal Process (AHP).

★ WE-1- σ -HS5

◆ Multi Objective Optimization

Wednesday, 09:00-10:40 – Room HS 5

Session: Multi Objective Optimization for Society

Chair: Amin Chaabane

1 - A Framework for Natural Disaster Mitigation Decision Making

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Australia is exposed to natural disasters on a recurring basis, which have significant financial, economic and social costs. The impacts and costs of such disaster events can be expected to increase in the future with population growth and expanding urbanisation in coastal and bushland areas. Current government funding arrangements are heavily weighted towards disaster recovery, which reduces the economic incentive for state and local governments to mitigate disaster risk. As such, natural disaster costs have become a growing liability for governments. Effective planning and mitigation of natural hazard risks by reducing exposure and vulnerability to hazards is thus an essential task for government. One step in the mitigation "value chain" is the selection of the best mitigation options for a set

of locations exposed to natural hazard risk. This paper describes the approach taken to develop a transparent and robust decision support framework to support this decision within the Australian emergency management community. The aim was to produce a model to evaluate and compare potentially suitable alternative options to ensure consistent and reliable decision making in the face of limited financial resources. The decision maker is ultimately likely to be a committee of high-level public servants tasked with recurrently (annually, say) allocating funds from a finite budget to a project set. The decision is likely to have to be repeatable (i.e. annual allocations) and scalable (i.e. different levels of jurisdictions), so a single model with common criteria was desired, to ensure temporal and spatial consistency.

The overall objective was a prioritisation of a number of potential mitigation projects, based on criteria entailing

- risk reduction to the community (largely in line with consequence categories detailed in national emergency risk assessment guidelines, and relating to the reduction in threat to human life, losses of buildings, infrastructure and property, and business losses), and
- social benefits to the community, i.e. those with social, or environmental impacts (such as loss of community amenity or species habitat, and reduction in the perception of risk).

Whilst it is desired to minimise the social and environmental impacts of a project (or better still, improve them, if this is possible), at the same time it is desirable to maximise risk reduction and positive economic impacts.

The framework makes use of cost-benefit analysis (CBA) suitable for analysing financial costs and benefits as one criterion in a multi-criteria decision analysis (MCDA), which is better suited to analysing qualitative costs and benefits, such as some social and environmental costs and benefits.

A value tree, comprising four sub-trees from the four established disaster recovery domains

- Social domain
- Environmental domain
- Built domain
- Economic domain

was built iteratively and in conjunction with a high-level decision task team responsible for framing the decision process. A group of experts in community resilience and recovery policy and funding debated and arrived at appropriate criteria weights, as well as suitable value functions for the attributes describing the criteria.

Finally, a portfolio of mitigation projects was determined from the prioritised set using a linear programming model, with constraints representing budget and diversification requirements.

Apart from discussing the development of the model, this paper will describe the reaction to the decision framework from high-level policy specialists and subject matter decision makers

who had not been exposed to formal models of a complex decision problem in this field before, as well as discuss some practical implementation issues.

2 - Applications of preferences, utility functions and multiobjective optimization methods in insurance companies.

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This work illustrates the applications of decision making process in insurance companies from the first step of taking risk to the final analyses of the occurred losses in order to reach a better results in future estimation process. The paper shows the mechanism of preferences of the decision makers who wishes to make a reasonable choice by taking a better risk. Using a set of axioms for coherence among preferences, it shows the existence of utility function, defined on the set of choices and maintaining the individual's preference ordering. Also considering examples when a decision maker has to choose among the different kinds of utility functions to determine the maximum premium the policyholders have to pay to get a full coverage. The work also deal with the problems when several functions are proposed to obtain a necessary claim amount to be paid and a multi objective optimization procedure is used to obtain the appropriate parameters using statistical data of the company and to find the best function to approximate. The main goal of the paper is to find the best combinations of the applied methods to reach significant results in risk assessment.

3 - A multi-objective goal programming model for maritime search and rescue location analysis

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Location-Allocation problems are basic models for several important applications, including the location of ambulances, police cruisers, fire stations, distribution centers and so on. Optimizing the efficiency of resources is always a major concern. Maritime Search and Rescue, categorized as a public emergency response activity, is a potential application of Location Analysis to deal with managing resources and their locations. This problem becomes more complicated when we are faced with several criteria for assessing decision outcomes, some of which may be conflicting as well. There is a rich and diverse literature in the area of emergency location analysis, but some gaps still exist, particularly in the case of maritime search and rescue resource

planning. Usually, research in this area considers only a single objective while in the real case there is more than one criterion that decision makers care about. Coverage, cost and average access time or response time are widely used in multi-criteria location analyses as model objectives. This study considers several criteria as objectives in the mathematical model.

In this research we build a framework of mathematical models to optimize the Location/Allocation of Maritime Search and Rescue Resources with regard to several criteria such as primary and backup coverage, mean access time and service equality. Atlantic Canada serves as the area of the study and the Canadian Coast Guard has provided the necessary datasets and information. The general methodology utilized in this study is to build a goal programming multi-objective model to optimize the location and response allocation of SAR resources in order to achieve greater response effectiveness and resource utilization. The number of feasible solutions is much more than can be easily handled by traditional multi-attribute decision making methods. Therefore, we need to utilize multi-objective optimization methods to model our problem. Sensitivity analyses are performed on variable objective weights and goals values to examine their impact on the optimal solution.

Results of this study could be useful for guiding decisions with regards to Search and Rescue vessel acquisitions and placement in order to improve the efficiency of resources and increase the service level. More specifically, the outcome of this study could provide the Canadian Coast Guard with some beneficial insights for future resource capacity planning including fleet recruitment planning and appropriate stations for placing new vessels. Also, it can be helpful for managing current operations to increase the resource utilization and effectiveness of their services. Several operational rules can be extracted from the model solution for best resource allocation policies.

4 - Sustainable Closed-Loop Supply Chain Design: a Multi-objective Optimization Approach

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Introduction

For many years, the common belief of supply chain management was associated with the flow of material from suppliers to costumers. Closed-Loop supply chain focuses on taking back products from customers and reuse modules, components, and parts. Closed loop supply chain management (CLSCM) is the design, control, and operation of a system to maximize value creation

over the entire life cycle of a product with dynamic recovery of value from different types and volumes of returns over time (Govindan et al., 2015). Today, CLSCM practices are shifting toward the integration of sustainability objectives. Companies need to be responsible for the impacts of their products on environment and the whole society. Moreover, government legislations have been widely expanded to force corporations to minimize their environmental impacts. In addition, customers mainly prefer to buy their products from companies which care about the environment. Last but not least, return products might be important from a financial point of view as they are cheap resources to fulfill customer's demand. Majority of operation research-based papers related to closed-loop supply chain network design have not focused on the social side of sustainability. Accordingly, this analysis clearly points to a research gap regarding social pillar as well as the overall integration of the three sustainability performances. Thus, this study focuses on the social side of sustainability in closed-loop supply chain design. However, the main questions that need to be answered in the current work are: (1) what are the impacts of social performances on main objectives, profit and environment of a supply chain network, and (2) how do social indicators govern and apply to a vast array of decisions in closed-loop supply chain network. Literature review In the past decade, closed loop and sustainable supply chains have received a lot of attention among researchers. Dehghanian and Mansour (2009) applied an Analytical Hierarchy Process (AHP) to handle the social aspect of sustainability into a recovery network of end-of-life products. Moreover, Chaabane et al (2012) introduced a mixed-integer linear programming to design a sustainable supply chain network of aluminum industry to evaluate the trade-off between economic and environmental objectives. Elhasia e al (2013) applied a discrete-event simulation model of sustainable supply chain in order to analyze a cement supply chain operations and find the best scenario that demonstrates the best economic, ecological and social performance. In this paper, we use the mathematical formulation proposed by Devika et al. (2014) as a benchmark. We apply different social indicators to the proposed model to assess how social parameters could affect decision variables and objective functions in the supply chain network. Model description The multi-objective mixed-integer linear programming (MOMILP) formulation associated the minimization of costs, waste minimization and the maximization of social responsibilities with the weights associated with social criteria. The MOMILP consists of ten echelons with considering four types of facilities in the reverse network: (a) Recovering; (b) Remanufacturing; (c) Recycling and (d) Disposal. The main decisions should be made in this model are: determining the type of technologies of manufacturing center; assigning the customers

to distribution centers and collection centers; the amount of products which have to be produced at each plant and the flow of materials.

Results

The model is developed in GAMS 23.5 and solved with CPLEX solver. However, different social indicators have been applied to the model in order to compare the results. Generally, increasing the social activities results the maximization of net return and the minimization of wastes. Moreover, some of decision variables are influenced by social activities and various indicators have different impacts on decision variables. For instance, the indicator “number of job opportunities” affects the decision variables associated with establishing facilities. Consequently, centers which need lower opening costs create more job opportunities.

Conclusion

In this paper, we developed a mathematical formulation proposed by Devika et al. (2014) with various social indicators in order to assess the impact of social activities on objective functions and decision variables. However, the results represent that investment in social activities is able to increase profit and reduce the environmental impacts in the supply chain network. As a result, it is crucial for managers to discover the optimum level of investment in social activities as it could lead to economic benefits and waste reduction for businesses.

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★ WE-1- χ -HS6

◆ Environment, Infrastructure & Emerging Applications

Wednesday, 09:00–10:40 – Room HS 6

Session: IS-MCDM-LATAM: New Developments and Applications of MCDM in Latin

America

Chair: Luiz Flavio Autran Monteiro Gomes

1 - Industry Risk Assessment in Brazil with the WINGS Method

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Due to the increasing importance of the financial market over the past decades, credit risk has become a paramount issue in investment, loan spreads, corporate solvency, trends and prospects, etc. Credit risk evaluation models may be classified in two broad categories: quantitative and qualitative. Quantitative models seek to analyze information from financial statement and indexes, while qualitative models focus on the analysis of intangible variables that affect global business. These models typically follow a top-down approach by analyzing the industry risk, competitiveness and peer comparison and management. The aim of this paper is to present an industry risk assessment model based on multicriteria analysis methods that can measure the strength of variables that affect the industries of Brazilian economy, as well as the influence between them. The model is based primarily on the Weighted Influence Non-Linear Gauge System method. Concerning human judgements about the variables, the model is founded on the use of the Analytic Hierarchy Process method. The result from the model is presented through risk levels, applied to fourteen industries in the Brazilian economy. The paper closes with a discussion of results, as well as with an outline to future research directions.

2 - The Hellinger TODIM for Ranking and Comparing Performance of Evolutionary Algorithms

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In order to compare algorithms performance it is very common to handle such issue by means of statistical tests. In this paper, we present an alternative method based on TODIM (an acronym in Portuguese for Interactive Multi-criteria Decision Making) to solve this kind of problem. When multiple algorithms are applied to multiple benchmarks as is common in evolutionary computation a typical issue rises, i.e., which algorithm presents the best, the second best, or in some cases, the worst performance among the

suite of benchmarks?. It is a standard procedure in evolutionary computation that the algorithms are executed several times and then the mean value and the standard deviation are calculated. In this case, the alternatives consist of the algorithms and the criteria are the benchmarks. Since the standard TODIM is not able to handle the stochastic nature of evolutionary algorithms, we employ the Hellinger-TODIM, which uses the Hellinger distance. Examples are used to illustrate the method for evolutionary algorithms but the approach is of general purpose. Simulation results show the feasibility of the proposed approach to find out the ranking of algorithms under evaluation.

3 - Improving Systems Usability through Multicriteria Classification: the TODIM-FSE Method

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TODIM-FSE is a new multicriteria classification method that combines the prospect theoretical-based TODIM technique with the Fuzzy Synthetic Evaluation approach. This paper shows how TODIM-FSE can support decisions on where to invest in order to improve systems usability. The case study of the intranet of a Brazilian university illustrates the application of the technique. The alternatives taken into account in the analysis are constructs related to each of the following metrics: ease of learning; ease of remembering; error control; efficiency; effectiveness; and satisfaction. The criteria are five and their valuations range from total dissatisfaction to total satisfaction of users. For this case study data on users preferences are surveyed. The resulting figures point out which are the most impacting metrics for the university's intranet system. The analysis with TODIM-FSE leads to the most relevant constructs that minimize the costs to improve the usability of the system. Numerical comparisons between the application of TODIM-FSE and the use of the Choquet integral are provided in the paper. The fuzzy measures used in this paper were determined by using varimax rotation in principal component analysis in order to classify the variables that were considered. The paper closes with indications of the most important constructs for some major metrics for this case study. Conceptual differences between TODIM-FSE and equivalent methods such as ELECTRE-Tri and UTADIS are also commented in the closure of the paper.

Wednesday, 11:10–12:50

★ WE-2- α -HS1

◆ Behavioral Aspects, Group Decision Making, Negotiations, Interactive Methods, Software

Wednesday, 11:10–12:50 – Room HS 1

Session: Group Decision Making: Negotiations and Fuzzy Approaches

Chair: Murat Erkoç

1 - Modelling Scenarios of Sensitivity Analysis in a Fuzzy Multi-Criteria Group Decision Making Environment

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Sensitivity analysis plays a crucial role in decision making support systems. In group decision making settings, it becomes handy in testing for the reliability and stoutness of the preferences made by decision makers. This paper presents novel scenarios of sensitivity analysis in a Fuzzy Multi-Criteria Group Decision Making Environment to analyse the congruent effect of certain changes on the final ranking or selection of a best alternative. Using numerical examples of fuzzy TOPSIS and PROMETHEE Multi-Criteria Decision Making Methods, a demonstration of modelling critical changes to (1) criteria weights (2) alternatives ratings (3) exclusion and inclusion of decision makers are presented. The various scenarios presented are generally considered adaptable to other MCDM methods.

2 - Aggregation of preference information using neural networks in group multiattribute decision analysis

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In this paper, we deal with group multiattribute utility analysis incorporating preferences of multiple interested individuals. Since it is difficult to repeatedly ask them questions for determining

parameters of a multiattribute utility function, we gather preference information of them by asking not difficult questions to answer, and develop a method for selecting an alternative consistent with the preference information. For a given set of single-attribute utility functions, assuming multiattribute utility functions to be in the multiplicative form, we evaluate trade-off between attributes by utilizing neural networks. Using the preference information actually gathered in an application study (Hayashida et al., 2010), we verify the effectiveness of the proposed method.

3 - An Integrated Fuzzy Multi Criteria Group Decision Making Approach for Software Selection Problem

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Any software in market can not exactly perform the expectations and requirements of firms, because firms lead its trade with different goals and strategies. In order to carry out an achievement software project in firms, it is essential to select an appropriate software system because it is a difficult and expensive process for firms. This study presents a new decision framework that could deal with the interdependencies among different criteria and to indicate how to select the most appropriate software alternative in software evaluation project. This study provides a hybrid fuzzy multi-criteria group decision making model to evaluate alternative software. Firstly, fuzzy extension of AHP is employed to compute the weights of criteria and sub-criteria in a software selection problem systematically in a vagueness environment. Fuzzy extension of AHP is suggested in this study because of little computation time and much simpler than other fuzzy AHP procedures. Then, the result of the fuzzy PROMETHEE model can be employed to define the most appropriate alternative with regard to this firm's goals in uncertain environment. Not only the used method, which is known as a fuzzy form of PROMETHEE, maintains advantages of PROMETHEE, but also supports to make a decision in a vagueness environment. It ensures the chance of selection decision makers preference functions. All the stages of suggested methodology are implemented to ensure an analytical tool in an electronic firms software evaluation project. A number of decision makers interact to achieve unique decision in group decision making. Each decision maker might have special goals, opinions, and different evaluation process, although they aim to select the best alternative. The decision makers have to define their preferences by using a set of numerical values. The utilization of same preference by all the

decision makers has been a widespread implementation in group decision making but it can't generally be possible in actual implementation because of special characteristics of each decision maker such experience, abilities, and knowledge. There is no study about software selection using integrated fuzzy AHP-fuzzy PROMETHEE approach with group decision making. Software selection process includes defining of expert decision makers to make selection, determining suitable software alternatives, determining criteria that examined in evaluation phases, weighting the criteria and evaluation of alternatives phases. Software selection procedure begins to assign the three experts committee comprising of software and academic experts. We identified cost, technical specifications, vendor specifications and ease of use as the main criteria in an appropriate software selection problem through opinions of experts and literature review. Cost criteria covers two sub-criteria like purchasing fee, updating fee, and technical specifications criteria covering five sub-criteria like interface, functionality, module framework, software reliability, supporting data files, and vendor specifications criteria covering three sub-criteria like training and consulting services, vendors reputation, references, and ease of use criteria covering five sub-criteria like speed, learnability, suitability for user, software ergonomics, reporting. The consistent ratios (CRs) of the pair-wise comparison matrix for main and sub-criteria have been observed as smaller than 0.1 so that the assessment procedures are rather enough consistent. CRs for each decision makers are calculated. When the CR exceeds this number, the assessment procedure must be reconsidered in order to improve consistency. Furthermore, the importance degrees of decision makers can be quite influential in group decision making so that weights of three decision makers in this study have been determined. Our recommended methodology is intended to ease group decision making in the software selection process. Results indicate that our methodology allows decreasing the information loss in group decision-making and thus, ensures a robust solution to the firm.

4 - A Game Theoretic Approach for Multiobjective Energy Policy Making

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In this paper, we propose a two-stage decision making model on how a government should build and incentivize its energy policy across multiple

objectives of economic concerns, environment, and energy surety over a finite time horizon. We introduce a Game Theoretical setting between a governmental institution and a power generating company, where the former one sets penalties and limits for the latter one to build and incentivize policies regarding power generation and capacity investments. In the proposed setting, the governmental agency moves first and determines the allowable limits for different types of greenhouse gas emissions, and incentives for increasing the ratio of energy generation from renewable and sustainable sources. The power generating company responds by choosing its energy investment and production strategies. The governmental agency is motivated by multiple conflicting concerns, namely, economic well-being of its constituencies, environment, and energy surety, whereas, the power company aims to minimize its investment and production costs. The power company minimizes its cost under constraints enforced by the government in terms of penalties and limits. Inferring on the power companys best response, the agency needs to set its limits and penalties that leads to energy generation policies striking an optimal balance among the conflicting objectives.

The governmental agency has three distinct objectives: i) minimization of energy generation cost; ii) minimization of greenhouse gas emissions; and iii) maximization of energy surety. The agency needs to take the energy generation costs into consideration in developing its policies since higher costs usually are reflected on the energy bills of the industry and residents that are part of the agencys constituency. This objective coincides in most part with the objective of the power company. However, having a much broader stakeholder base, the agency is concerned of other issues as well. The second objective addresses the environmental concerns, where the agency has responsibility to protect the environment for its citizens and thus, needs to curtail the greenhouse gas emissions. The last objective ensures uninterrupted availability of energy for its citizens. This objective involves stochastic elements due to uncertainty regarding the yield in renewable energy generation.

The valuation of the agencys conflicting objectives changes with the perspectives of various stakeholders. Some emphasize the cost and production efficiency and as such, consider renewable energy an inefficient and overrated alternative in power generation. Such perspectives may be motivated by the political structure, pressures from lobbyists, and a governments large endowment of huge resources of conventional energy. On the other hand, environment-conscious citizens and organizations pressure governments to encourage renewable energy to minimize pollution and dependency to mineral resources. Thus, the governmental agency is compelled to cope not only with multiple conflicting objectives but also with conflicting valuations of these objec-

tives. Consequently, the agencys problem is in fact addressed by multiple decision makers representing different viewpoints.

The two stage decision process is modeled as a leader-follower game. In order to find the equilibrium employ backward induction and derive the best response function of the power company based on its optimization model with single objective function. Next, we map the companys response function into the governmental agencys multiobjective decision model. To solve the agencys model we use the Successive Weighted Sum (SWS) method proposed by Kucuk et al. (2010). The SWS method makes use of vector optimization and applies multiple weight vectors to solve multiobjective optimization models. The main purpose of vector optimization problems is to find optimal elements of a given set in partially ordered linear spaces. The weight vectors in the SWS approach are applied successively to the solution of the model. Each weight vector narrows down the solution space by generating subsequent subsets. The use of multiple weight vectors enables us represent differing views of the stakeholders. Since there are multiple decision makers in our problem, the solution necessitates multiple preference orders, which are captured by multiple weight vectors used as part of the SWS procedure. In contrast to conventional weighted sum methods, the SWS method guarantees convergence to a unique solution by use of consecutive weight vectors that are perpendicular to each other. Since the number of weight vectors is limited by the number of objective functions, three vectors representing three different viewpoints are assumed in this study. The vectors are ordered based on the importance of the decision maker and/or the viewpoint influencing the agencys solution.

Using both analytical and numerical analyses, we investigate equilibrium conditions and derive managerial insights regarding the energy policy making problem. We demonstrate the effectiveness of our approach with a case study from the State of Florida, USA. We conduct a sensitivity analysis by investigating different cost structures and varying orderings of the weight vectors. In a broader sense, our work provides a novel framework for policy making on energy that integrates incentive compatibility by means of Game Theory, conflicting objectives by means of multi-objective modeling, and differing viewpoints by means of the SWS method. It also is a stand-alone demonstration for the application of SWS method in a practical context.

★ WE-2- β -HS2

◆ Decision Aiding

Wednesday, 11:10–12:50 – Room HS 2

Session: Ranking and Sorting

Chair: Özgür Özpeynirci

1 - Studying synergies between Data Envelopment Analysis and Multiple Criteria Decision Aid: the case of PROMETHEE methods

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Data Envelopment Analysis (DEA) and Multiple Criteria Decision Aid (MCDA) are two important research areas in Operational Research (OR). These domains are both based on the evaluation of “objects” according to multiple “points of views”. This common feature leads to think that synergies exist between the two fields. Due to their successful application in finance, health care, transportation, water management, etc. we focus ourselves on the PROMETHEE multicriteria methods. In this work, we will investigate two potential combinations between DEA and PROMETHEE. Firstly, we will study how DEA can be applied to constraint weight values in PROMETHEE VI. Within the MCDA framework, choosing the most appropriate weights for the different criteria often arises as a problem itself for Decision Makers (DMs). As a consequence, researchers have developed original methodologies to help them during the elicitation phase. Sensitivity analysis tools, like PROMETHEE VI, allows to determine the impact of ranges of weight values. In this work, we suggest an extension of the so-called “decision maker brain” used in the GAIA plane. The underlying idea is based on the computation of weights that are compatible with the DEA analysis. Secondly, we address the problem of weight restrictions in DEA. These questions were initiated with the goal of making DEA outputs more reasonable. Indeed, in classic DEA models, some inputs/outputs can sometimes be characterized by arbitrarily low or high weight values. These can be in contradiction with a priori information leading to counterintuitive interpretations. The aim of this research is to investigate a new weight restricted DEA approach based on a MCDA methodology. To achieve this goal we use the stability intervals based on the PROMETHEE II method as weight constraints in DEA. As expected, these restrictions improve the discrimination power of the model. As well, in the new DEA approach, the unicriterion scores matrix is used instead of the initial evaluation matrix. In this way, we already integrate preferential information in the DEA process. By construction, the obtained results are compatible with the PROMETHEE II ranking. Both models are illustrated by means of real examples.

2 - A temporal extension of

PROMETHEE methods

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A temporal extension of PROMETHEE methods
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PROMETHEE & GAIA [1] are well-known multicriteria decision aid methods. They have been applied in hundreds of applications such as water management, human resources, industrial location, investments, finance, health care, etc [2]. This success is partly due to the simplicity of the methods, the existence of user-friendly software (like D-SIGHT [3]) and the availability of visual interactive tools that allow to better structure and understand decision problems. Nevertheless, current PROMETHEE methodology relies on the assumption that data are not time dependent.

Several multicriteria applications are characterized by temporal evaluations. To illustrate this point, let us consider the case of a hospital where physicians want to monitor the health of many patients. These are evaluated by time dependent criteria such as the level of cholesterol, pulse, temperature, etc. After a given period, a ranking of all patients present in the medical unit has to be established in order to evaluate the treatment efficiency.

In this work, we present an extension of PROMETHEE which takes into account the fact that alternatives and preferences may evolve over time. Hence, this model is based on a specific aggregation operator [4] which requires the elicitation of the decision maker weighting time vector [5]. It also investigates how the GAIA plane can be extended in order to display dynamic evaluations with respect to given criteria.

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3 - Multi criteria methods used for assessing for companies' attractiveness

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Many researchers have studied about attractiveness of a company in business domain but survey after survey, reveals that there is always room for improvement. In this paper, human reasoning extraction is investigated to evaluate the attractiveness of each company resident in Belgium. The term attractiveness refers to the case that a company X pays attention only to customers preference to boosting employee satisfaction, help the company retain personnel and attract new employees. This leads to brand name improvement which allows the company to increase the sales of their products or services, remain competitive in the market and increase the employee productivity. These effects can be achieved if the company will focus and improve the factors that participants considered more important. Three Multi-Criteria Decision Making methods: Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Analytical Hierarchy Process (AHP) and Weighted Sum Model (WSM) were deployed to identify and order the most important factors that influence the company competitiveness based in customer satisfaction. The challenging part of this study is the exploitation of "pure" knowledge from participants, the comparison of results and finally, the aggregation of all accomplished evaluations, without expert knowledge and consequently without weights and criteria. To accomplish this goal, we customized TOPSIS and AHP methods to deal with participants' consensus, without using common voting methods but methods based on MCDM. 14.585 questionnaires were gathered from people in Belgium and 349 companies, which were resident in Belgium, participated in this research. It is important to note that the respondents didn't have any information about the name of each company. The most significant factors were selected from respondents on the assumption that they wished to choose a company X to be employed in. The questionnaire was divided into two parts, Data Set 1 (DS1) and Data Set 2 (DS2). In DS1, participants gave their preference value only to five of the seventeen factors that consider more important. In DS2, participants had not any limita-

tion for the factors' choice. Each participant had to split the amount of one thousand points to factors that they considered most important by giving more points to the most significant factor. Before ordering the factors, the first procedure was to clean the data in order to achieve the best results. As mentioned before, there is no knowledge about criteria, which are important to determine the ranking, especially in TOPSIS and AHP method. In this paper, each horizontal row of the decision matrix is allocated to one factor and each vertical column to one participant's opinion. All participants had equal importance so no weights were required. The results have shown that rankings of seventeen factors (of thousands of participants' opinions which were distributed in fifteen sectors), were similar in three methods. The five top factors that each company is interested to improve were at the top of the list. Since TOPSIS and AHP method was proved effective in our problem to rank properly the factors, we applied once again TOPSIS and AHP method to aggregate the people consensus in the final classification. In these cases, seventeen factors were used as an input (rows) in the decision matrix and fifteen sectors were inserted as columns and applied in DS1 and DS2. Fifteen rankings (one for each sector), that have been ordered with TOPSIS method, were aggregated into a final order, using TOPSIS method and other fifteen rankings that have been ordered with TOPSIS method, were aggregated into a single one, using AHP method. As noted in the final standings the top five factors or the most significant factors, are common in both different data sets. The purpose of the final ranking was to aggregate the common opinion (or else the consensus) and reflect the significant factors that need to improve when the company X cares about the attractiveness or wants to enhance the competitive advantage. The ranking of top 5 factors show that people prefer long term job security and competitive salary package more than offering of interesting jobs, financially sound and pleasant working environment. It also showed that people in Belgium prefer stability (long-term security) instead of jobs financially sound. However, this outcome is not surprising and it could be a direct result of the economic crisis.

4 - Inverse Multiple Criteria Sorting Problem

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Multiple criteria sorting problem (MCSP) is to assign objects evaluated with multiple criteria to one of the predefined and ordered classes. Assigning star-ratings to hotels, credit risk assessment of countries or individuals, letter grading of students at the end of academic semesters are all examples of MCSP. Multiple criteria sorting methods and their real-life applications are well studied in the literature.

In this study, we consider the inverse multiple criteria sorting problem (IMCSP) where we have the chance to modify the scores of the objects by taking a subset of the predefined actions, hence to change the final classification of the objects. Each action has a corresponding cost and impact on the scores of the objects under each criterion. In IMCSP, we consider different underlying sorting methods, level of information and types of problems. We assume the underlying sorting method is known and study three different methods: linear, UTADIS and MR-Sort. We consider two levels of information; (i) the sorting method parameters are known explicitly (simple version) and (ii) assignment examples restrict the set of compatible parameters (robust version). We study two types of problems; finding the least costly set of actions that guarantees the assignment of all objects to desired classes and improving the assignment of objects under a limited budget.

For each combination of sorting method, information level and problem type, we develop the necessary mathematical programming models. For the robust versions, we design algorithms to guarantee the desired classification to hold for all compatible parameters. We conduct extensive computational experiments on randomly generated instances and report the results.

During this study, the second and third authors were supported by the Scientific and Technological Research Council of Turkey (TÜBİTAK-2219 International Postdoctoral Research Scholarship Programme)

★ WE-2-δ-HS3

◆ Industry and Business Applications

Wednesday, 11:10–12:50 – Room HS 3

Session: Optimization in Networks 2

Chair: Michael Stiglmayr

1 - Multiobjective Optimization of Distribution Network Management in Deregulated Electricity Market

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Nowadays, the deregulation of electricity market is being developed over the world and electricity charges will be diversified due to newly participated retailers into the retail market. “Advanced metering infrastructures” such as smart meters, and “information and communication technology” to collect information of consumers’ electric consumption and also to offer the electricity charges to consumers from the retailer will be widely introduced into the demand side as well as energy management systems, e.g. HEMS and BEMS (Home / Building Energy Management System), which is for the efficient management of electric consumption of consumers by controlling electric appliance based on electricity charges. Therefore, a change of consumers’ load profile due to demand-side power savings and a load shift in responding to the electricity charges offered by retailers can be expected after the deregulation. After the electric generation, transmission, distribution, and retail sectors are separated by the deregulation, electricity purchased by retailers from the market is supplied to consumers through Transmission and Distribution Networks (TN and DN) managed by Transmission and Distribution Company (TransCo and DisCo). TransCo and DisCo are severely required to supply electricity with high power quality and reliability to the consumers. After the unbundling of sectors, however, the proper management of TN and DN can be harder due to the lack of the close cooperation of multiple sectors. Moreover, the change of the load curve and the power flow in TN and DN needs additional measures to adequately manage the networks. Particularly, the management of DN is significantly important because there are many DN in the electric power system. The characteristics of each DN depending on the geographical features, e.g. the length of line and consumers’ types, are different from each other. The different kind of consumers and diversified electricity charges can cause an inherent and complicated change of the load curve in each DN after the deregulation is realized. In conventional management of DN, equipment in DN such as transformers are generally operated based on the actual or presumed load curve as well as consumers capacity. The load curve before the deregulation is easily estimated because the impact of regulated electricity charges on the load curve is much smaller than other predictable factors such as temperature and weather conditions. Under the deregulated environment, on the other hand, the load curve cannot be always estimated due to the uncertainty of market conditions and the variation of the consumers’ responses to the electricity charges. The flexible consumers responses to the electricity charges utilizing HEMS and BEMS cause the large change of the load curve and, in that case, the conventional management way of DN by DisCo may not able to manage DN adequately after the deregulation. The novel management framework efficiently and adequately

managing the DN even in the deregulated power system is needed. Additionally, because DisCo is required to severely avoid an inessential investment for DN, DisCos operational goals such as power quality should be met utilizing existing DN equipment as much as possible. DN is generally operated as the radial structure utilizing section switches located on distribution lines to improve fault tolerance. Because the structure of DN can affect the power quality and line losses, the conditions of the section switches (opened or closed) are determined based on the characteristics of DN, e.g. consumers types and impedance of the distribution lines. Similarly, settings of the equipment in DN such as the transformers are managed based on the characteristics of DN including the structure, the consumer's types, and line impedance. When the load curve changes due to the deregulation, therefore, the reconfiguration of DN by operating the section switches may be required to meet DisCos desirable operational goals. However, the section switch cannot be operated frequently (repeated open and close actions) because the frequent operations rapidly deteriorate itself. Furthermore, the modification of the settings of the equipment according to the change of load curve and DN structure needs the cooperation with the conditions of the section switches. This cooperation sometimes needs additional works and costs in a part of DN which is undesirable for DisCo. For the efficient management of DN by DisCo, therefore, the optimal DN structure should be constructed taking into account the DisCo's operational goals, i.e. the distribution line loss, the power quality, the operation of the section switches, and the cooperation with other equipment located in DN. From this point of view, in this study, the multiple criteria optimization of DN structure based on DisCos operational goals in the deregulated electricity market is performed. The load curve after the deregulation is estimated by utilizing the market model in which the retailer and consumers sell and buy the electricity power. The reconfiguration of DN is generally dealt with combinatorial optimization problem of the conditions of the section switches (opened and closed) and it has strong nonlinearity with large search space. To efficiently find the pareto solutions corresponding to DisCo's desirable operational goals, NSGA-II (Non-dominated Sorting Genetic Algorithm II) is used.

2 - Bicriteria fixed-charge network flows - separating fixed costs and flow costs

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The fixed-charge network design problem is one of the classical network design problems. From a multicriteria perspective its objective function is the weighted-sum of a network flow objective and the sum of the fixed costs (i.e. design costs). Flow can only be routed through those edges

for which the respective binary design variable equals one. The single criteria flow problem is well studied in literature; a lot of different solution approaches have been developed and applied, including branch and cut, Lagrangian relaxation as well as heuristic methods like dynamic cost scaling. However, from an application point of view design costs and flow costs are not directly comparable. Usually the design costs are due a-priori, whereas the flow costs correspond to maintenance or operation costs which incur on a regular basis. In this talk we will present heuristic and exact solution approaches based on the two-phase method and ranking algorithms.

3 - Shortest paths with shortest detours: A biobjective routing problem

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A rescue service tries to reach its destination as fast as possible. The first guess is that it is optimal to choose the quickest route to get to the scene of the accident. However, this quickest route might be blocked by a fallen tree or traffic jam that was not known before. In order to bypass this incident, the rescue service has to change its route, go back to the last junction and choose a detour. Instead of traveling on the quickest route, it might hence be better for the rescue service to prefer a route that is a little longer but has a shorter worst-case detour.

We introduce a biobjective network optimization problem. The shortest path with shortest detour problem (SPSDP) minimizes the length of a path as first criterion and, as second criterion, the maximal length of a detour if the chosen path is blocked. More applications beyond rescue services are conceivable, e.g., modelling production chains.

The PSDP generalizes the classical shortest path problem: Although each arc has only one fixed cost, we consider two objective functions. The second objective function takes into account detours in a worst-case scenario.

We present a new polynomial time threshold algorithm that determines a minimal complete set of efficient paths for PSDP. Moreover, we prove that the number of efficient paths is bounded by the number of arcs in the network.

4 - Mathematical Model Based Heuristic Method for Two Objective Container Loading Problem

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In this work we study container loading (CLP) and assortment problem. Different size of containers are available and certain number of containers are available belong to container types. A set of rectangular boxes exists and has to be located in the containers. We propose a two objective mathematical model based heuristic method for CLP. Heuristic method includes two stages. A two objective 0-1 integer programming model is developed for the first stage and objective functions are formulated in the form of minimizing the unused space and number of used container types. In the second stage, objective is maximizing volume utilization in a certain container under some constraints. Different scalarization methods are used to solve the first stage of developed two-objective mathematical model based heuristic method and obtained solutions are compared.

★ WE-2- κ -HS4

◆ AHP/ANP

Wednesday, 11:10–12:50 – Room HS 4

Session: AHP/ANP: Advances in Theory 2

Chair: Salvatore Greco

1 - An optimization approach for the eigenvector method

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Pairwise comparison matrices play an important role in multiattribute decision making; they are applied to derive priorities or implicit weights for a given set of decision alternatives. Several approaches exist regarding how to derive a suitable vector of weights from a pairwise comparison matrix. Saaty proposed the eigenvector method in which the principal eigenvector of the pairwise comparison matrix serves as the vector of weights. Another class of approaches is based on optimization methods and proposes different ways for minimizing the difference between the pairwise comparison matrix and the consistent matrix constructed from the weights. In the talk, based on Perron-Frobenius theorem, we show that eigenvector method also can be considered from the aspect of the optimization approach. Namely, the principal eigenvector can be obtained as the optimal solution of a convex optimization problem. We show that this approach is very useful in the case of incomplete

pairwise comparison matrices. Computational experience is also presented.

2 - Analysis and comparison of Analytic Hierarchy Process by the implementation of fuzzy logic and Monte Carlo simulation

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The Analytic Hierarchy Process (AHP) is a methodology that is part of the Multi-criteria Decision Making (MCDM) that uses mathematical algorithms and selects the best alternative that meets multiple objectives or criteria established in the beginning. The aforementioned is achieved through a hierarchical structure that is supported by the opinions and preferences of experts to organize the criteria considered, that is, the success of this methodology lies in the construction of the problem and the different levels that make up the hierarchical structure. Therefore, many authors throughout the world have questioned the accuracy of this methodology, as it uses a qualitative scale where subjectivity depends on the opinions and preferences that experts give for the estimation of the relative weights for each element to the element of the next higher level of the hierarchy. As a result, the need to implement mathematical methods arises to reduce the imprecision and increase the security of the decision when AHP is used. For this reason, this paper analyzes the behavior of AHP with the implementation of two different mathematical methods. The first one is the implementation of fuzzy logic and the second one is Monte Carlo simulation. The mathematical model was programmed with each of the two mathematical methods in Visual Basic to make the necessary simulations and the respective validation through a case study that aims to identify and organize the selection criteria of MBA students at a university. This article will hopefully get a comparison of implementing AHP with each of the mathematical methods in relation to traditional AHP to determine the level of confidence and precision for final selection. Our results show that quantitative comparison is a tool for decision makers at the time of search and selection the methodology to use.

3 - Heuristic Rating Estimation - another approach to the ranking procedure in AHP

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Making choices is an inherent part of everyone's life. Therefore, people often have to make comparisons. In daily situations, for instance, when paying for a fruit in the market, everyone is trying to choose the heavier one. In reality, people have to compare, often by guess, things that are much more complicated than fruits. Even worse, usually there are many different items that need to be compared. In such a case, the pairwise comparisons (PC) approach comes to the rescue. It allows people to do what they do best – compare pairs – and then it helps them to compute a priority list using the set of collected comparisons (usually given in form of the PC matrix). AHP is one of the most popular multi-criteria decision methods. It is based on the mutual comparison between the considered alternatives with respect to each of the criteria. To prioritize the alternatives in relation to the given criterion, AHP uses an appropriately rescaled principal eigenvector of the PC matrix. In other words, the input to the prioritization procedure (with respect to the single criterion) is the PC matrix. The output is a vector of weights, indicating the importance of individual alternatives. This means that the priority of each of the alternatives is known at the end of the ranking procedure. Sometimes, however, it happens that the priorities of some alternatives are known to the decision-makers earlier. This extra knowledge can come from a variety of sources: market research, expert surveys, other rankings carried out in the past, etc. The aforementioned observation prompted the author to propose HRE (Heuristic Rating Estimation), which allows the ranking values of some alternatives to be initially known, while ranks for other alternatives have to be estimated [K. Kułakowski, Heuristic Rating Estimation Approach to The Pairwise Comparisons Method, *Fundamenta Informaticae*, vol 133, pp. 367 - 386, 2014, <http://dx.doi.org/10.3233/FI-2014-1081>], [K. Kułakowski et al., Heuristic rating estimation: geometric approach, *Journal of Global Optimization*, 2014]. To calculate the missing ranks, it is assumed that the priority of every single alternative can be determined as the weighted mean of the priorities of all the other objects. In the presentation, the HRE method and its close relationship with AHP will be discussed. In particular, it will be shown how AHP users can take advantage of the HRE approach. Theoretical considerations will be accompanied by numerical examples.

4 - Spanning tree pairwise comparison based prioritization for multiple criteria decision aiding

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We propose a multiple criteria decision aiding methodology based on pairwise comparison matrices related to the evaluation of alternatives with respect to a set of considered criteria as well as to the evaluation of the importance of the criteria themselves. Existing approaches like the Analytic Hierarchy Process usually condense the rich preference information contained in each pairwise comparison matrix into a single priority vector. By contrast, the spanning trees approach explores the entire set of prioritization vectors compatible with the originally provided information. Taking an approach similar to Stochastic Multi-criteria Acceptability Analysis, we propose using this entire set of prioritization vectors to determine the probability that any alternative is ranked in any given position. Moreover, for each pair of alternatives, we also compute the probability that one is better than the other. Since the number of spanning trees increases exponentially with the number of alternatives and the number of criteria, the number of compatible prioritization vectors can be extremely large and so analysing these vectors can become intractable. We propose a random sampling procedure to address this issue.

★ WE-2- σ -HS5

◆ Multi Objective Optimization

Wednesday, 11:10–12:50 – Room HS 5

Session: Interactive Methods

Chair: Ana Belen Ruiz

1 - Using a single objective optimization problem in an interactive method as a surrogate of a computationally expensive multiobjective optimization problem

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When solving multiobjective optimization problems e.g. in engineering applications, objective and constraint function evaluations often involve numerical simulation, which can be computationally expensive. In order to mitigate the computational cost, surrogate-based methods are commonly utilized in the literature. This means that a computationally less expensive problem known as a surrogate problem is built, updated and solved iteratively. One approach to build such a surrogate problem is to approximate each individual computationally expensive function using a metamodeling technique. Once all functions are approximated, a multiobjective surrogate problem is formulated.

In this presentation, considering a computationally expensive multiobjective optimization problem with box constraints, we discuss a novel surrogate-based method where a single objective optimization problem is introduced as a surrogate of the computationally expensive multiobjective optimization problem incorporating a decision makers preferences expressed as reference points. In this method, the multiobjective optimization problem is first scalarized using the achievement scalarizing function (ASF). Then, the ASF is approximated using a metamodeling technique in which decision variables of the multiobjective optimization problem and aspiration levels forming a reference point are treated as variables of the ASF. To accomplish this, a limited number of hyperboxes near the set of Pareto optimal solutions in the decision space and a hyperplane in the objective space are considered. Sample points for the decision variables and the aspiration levels are selected within the hyperboxes and on the hyperplane adaptively. The approximated ASF is accurate near the set of Pareto optimal solutions and inaccurate in other regions of the decision and the objective spaces. Once the surrogate problem is built, a reference point given by a decision maker is projected onto the hyperplane. Then, the surrogate problem is optimized using a suitable single objective optimization method where the projected reference point is utilized as a reference point for the approximated ASF. The obtained optimal solution of the surrogate problem is an approximation of the preferred solution corresponding to the given reference point. As a by-product, this method can also approximate the Pareto frontier in the objective space. The performance of the proposed method has been evaluated on benchmark problems in the literature, i.e. ZDT2, ZDT3, Kursawe and DTLZ3. The numerical results show that the proposed method alleviates the computational cost significantly in terms of reduced number of original objective function evaluations and provides preferred solutions for a decision maker accurately.

2 - A two-phase interactive approach to stochastic multiobjective allocation problem

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Various types of stochastic allocation problems are considered in the literature. For example, sensor allocation management as a stochastic dynamic programming resource allocation problem is considered in Johansson et al. (2005). Techniques for approximately solving a certain class of resource allocation problems that arise in the context of stochastic sequential decision making problems that are computationally efficient are considered in Hariharan (2009). The problem of allocation of a given quantity of a resource to several activities to satisfy stochastic demands occurring randomly was described in Mendelson et al. (1980). An application of dynamic resource allocation in wireless communication using stochastic optimization is described in Li (2012). A stochastic multiobjective allocation problem considered in our previous paper (Nowak and Trzaskalik, 2014) can be described as follows. A company has a limited amount of a particular resource that can be allocated to various projects. We assume that the decision maker has defined K goals that he/she would like to achieve. For each goal several levels of achievement have been specified. The problem is a stochastic one: if a given amount of the resource is allocated to a given project, a given level of goal is achieved with a given probability. Hence, we are to decide which projects should be implemented and what should be the intensity of their realization.

The single objective deterministic allocation problem, formulated as above, has been described and solved in Bellman (1957) and Bellman, Dreyfus (1962). A bi-objective allocation problem was analyzed in Trzaskalik (2008).

The allocation problem considered in the present paper differs from the previous one. We assume that all projects are similar and provide an identical financial return. However, the return depends on the way in which the resource is split among projects. Let (x_1, x_2, \dots, x_T) mean that x_1 units of the resource are allocated to project 1, x_2 units are allocated to project 2 and so on. According to our assumption, the financial return of the allocation $(x, 0, \dots, 0)$ is the same as for $(0, x, \dots, 0)$ and $(0, 0, \dots, x)$. Since the financial result, while important, does not always reflect strategic importance, we also take into account non-financial criteria. We assume that the degree to which the projects contribute in reaching strategic goals is not the same, even when the financial return is identical. Our goal is to propose a two-phase procedure for identifying the best allocation of the resource. Our method combines multiobjective dynamic programming and interactive approach. Since for most companies, finan-

cial result is of crucial importance, we propose to use a two-phase procedure. First, allocations are evaluated with respect to financial criteria using Monte-Carlo simulation. Then, non-dominated allocations with respect to financial criteria are identified using Bellmans principle of optimality adapted to the multiobjective problem. In the second phase experts are asked to evaluate non-dominated allocations with respect to non-financial criteria. In our paper we propose an interactive procedure for identifying the final solution of the mixed stochastic-deterministic problem.

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3 - An Interactive Approach for Two-Response Product and Process Design Parameter Optimization

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In recent years, an ever-increasing interest has been shown in developing high quality of products and processes through design. Several factors affecting quality of a product have to be considered simultaneously to determine optimal settings of controllable design variables to consistently produce high quality in each and every item produced. On the other hand, quality of a product is typically defined in multiple dimensions, i. e., there exist multiple responses of a product or process. In most cases, an optimal design solution for a response may not be optimal with regard to some other responses. This problem is referred to as the multi-response robust product and process design (or parameter design optimization) problem. Especially when there are multiple responses, using multi-response surface optimization approaches are preferred to solve these problems. These approaches first build empirical relationship functions as models of the relationships between responses (or performance measures) of interest and several controllable design variables, and then treat these functions as objectives or constraints in an optimization model. In these approaches, even if there is only one response of interest, there are at least two objectives (e.g., minimizing expected value of the response and minimizing variance of the response).

Most of the aforementioned approaches aggregate the objectives into a single one to optimize them simultaneously. Yet, in many cases, such aggregations fail to satisfactorily represent the decision makers preferences. In robust product and process parameter design problems, responses may statistically and preferentially depend on each other. Moreover, modelling and estimation difficulties are encountered in these problems due to limiting assumptions of the modelling approaches, insufficiency of data, representation of results in appropriate scales and multiple dimensions and so on.

In this study, to overcome many of those deficien-

cies, an interactive approach has been developed for two-response product and process design optimization problems. This approach takes into account preferences of the decision maker explicitly and the statistical dependency (correlation) between the responses. It uses a predefined set of objectives that are commonly encountered in the literature and industrial applications. However, instead of presenting all objective values at each iteration, a set of performance measures are used to represent the objectives in a way to communicate with the decision maker better. A significant part of this communication utilizes visual aids such as specification and prediction regions of a solution. Thus, the decision maker is able to decide better which objective can be sacrificed by how much in order to improve an unsatisfactory objective in the next iteration. Additionally, these performance measures ensure that possible correlations between the responses is considered. The developed approach is illustrated with examples and compared with some approaches from the literature. Issues for covering more than two responses and handling further problems on modeling and estimation are also discussed.

4 - NAUTILUS: Family of Interactive Trade-off-free Multiobjective Optimization Methods

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Interactive methods for solving multiobjective optimization problems typically iteratively generate Pareto optimal solutions. The decision maker directs the search for the most preferred solution by moving from Pareto optimal solutions to others and in this, one must allow impairment in at least one objective function to get new, more preferred solutions. In other words, interactive methods necessitate trading-off. This may lead to anchoring or premature convergence and to the situation where the most preferred solution is not actually found. The idea of NAUTILUS methods is to enable free search by starting the solution process from the worst possible objective function values and improving ev-

ery objective at each iteration according to the preferences of a decision maker. In this way, the decision maker does not have to trade-off and we avoid the limitation that past experiences affect decision makers' hopes. In NAUTILUS methods, starting, for example, from the nadir point, at each iteration a solution is obtained which dominates the previous one. This means that only the last solution is Pareto optimal. However, the decision maker never loses sight of the Pareto optimal set, and the search is oriented so that (s)he progressively focusses on the interesting part of the Pareto optimal set. NAUTILUS thinking is also suitable for a group of decision makers because all decision makers can gain, which is a fruitful setting for negotiations.

In this talk, we first present the original NAUTILUS method where new solutions are obtained by minimizing an achievement scalarizing function including preferences about desired improvements in the objective function values. Then we describe a more advanced version where the decision maker expresses preferences in the form of a direction of simultaneous improvements. Finally, we introduce a variant called E-NAUTILUS which has been developed for computationally expensive problems, in particular. The method consists of three stages and starts with a representative set of Pareto optimal solutions. No costly calculations take place in the second stage where the decision maker interacts with the method. Instead of only one point, a set of points is shown to the decision maker at each iteration and then (s)he can choose one as the preferable point. E-NAUTILUS can also be regarded as an interactive method for finding the most preferred solution of a set of solutions generated by any a posteriori method, like some evolutionary multiobjective optimization method.

★ WE-2- χ -HS6

◆ Environment, Infrastructure & Emerging Applications

Wednesday, 11:10–12:50 – Room HS 6

Session: Development of MCDM: Literature Analysis

Chair: Rauf Nisel

1 - Systematic Review and Statistical Analysis on Applications of Fuzzy Multi-Criteria Decision Makings

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This study reviews past development of Fuzzy Multi-Criteria Decision Making (FMCDM) application tools and discovered future opportuni-

ties in this field of research. The web of science search engine was used covering a time frame of 34 years from June 1980 to June 2014, zooming on the keywords “Fuzzy Multi-Criteria Decision Making”. We examined five journals with the highest publication in field of artificial intelligence, operation research, engineering, management and information technology and thus 142 articles selected, critically reviewed and analyzed. The articles were systematically reviewed and statistically analyzed in their publication, application, application area, applicant and organizational structure. The major findings indicate that: 1) integrating fuzzy set theory with Multi-Criteria Decision Making (MCDM) has significantly increased the speed of developing MCDM science especially from 2010; 2) FMCDMs are effective for selection, evaluation, ranking, forecasting, allocation, recommendation or comparison of decision alternatives; 3) the Application areas of FMCDM in order from the most to the least are supplier management, project/service management, environment, medical, military, location management, risk management, human resources; 4) managers are the most applicants of FMCDM. One-way analysis of variance (one-way ANOVA) of FMCDM application areas shows that, the value of $F(df = 5, 174, p < .05) = 43.32$ is significant. So, there is a significant difference among the application area in applying Fuzzy MCDM. The supplier management in the population has the most applying Fuzzy MCDM when compared to the other application areas.

2 - Past, Present and Future of MADM Techniques

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Multi-Criteria Decision Making (MCDM) is the modelling of real-life to solve problems we encounter. It is a discipline that aids decision makers who are faced with conflicting alternatives to make an optimal decision. For this purpose, two aspects have to be considered: preference structure and weights.

In order to deal with MCDM problems, first the problem has to be identified by figuring out how many attributes or criteria exist in the problem and how to treat the problem to obtain a solution. To reach a goal, a set of possible alternatives or strategies have to be determined. Next, appropriate data, performance values of alternatives or preferences for alternatives with respect to criteria, has to be collected to reflect the judgments of decision maker (DM) correctly. Finally,

an appropriate method to evaluate the possible alternatives is selected and the findings are obtained.

To facilitate systematic research in the field of MCDM, Hwang and Yoon (1981) suggested that MCDM problems can be classified into two main categories: Multi-Attribute Decision Making (MADM) and Multi-Objective Decision Making (MODM), based on the different purposes and different data types.

The historical origins of MADM can be traced back to St. Petersburg paradox. In 1738 Bernoulli gives a detailed explanation for the solution of this paradox in his book based on utility theory. In 1947, von Neumann and Morgenstern published their famous book, *Theory of Games and Economic Behavior*, to conceive a mathematical theory of economic and social organization in detail, based on game theory. There is no doubt that the great work of von Neumann and Morgenstern indeed opens the door to MADM. In 1960s, ELECTRE is developed by Bernard Roy. Zadeh introduced Fuzzy Set Theory in 1965, which will be integrated to MADM methods. In 1975 Roy founded the EURO Working Group “Multiple Criteria Decision Aiding” which has held two meetings per year since then. Saaty published a detailed study about Analytic Hierarchy Process (AHP) in 1980 and a study about the development of Analytic Network Process (ANP) in 1996. In 2004, Brauers wrote an article explaining the MOORA and MULTI-MOORA techniques.

Although various MADM techniques were developed for the problems encountered, their methodology is limited in modelling real-life. Moreover, objective results are hard to obtain, and the findings are generally derived from subjective data. Although, new and modified techniques are developed by presenting new approaches such as fuzzy logic; comprehensive techniques, even though they are better in modelling real-life, could not find a place in real world applications for being hard to apply due to its complex structure. These constraints restrict the development of MADM.

This study aims to conduct a comprehensive analysis of MADM techniques. For this purpose, a detailed literature review has been conducted, major techniques and their modifications are determined. These techniques are then classified through their characteristics; such as problem, information, aspect and scale. From this point, the algorithms of MADM techniques are derived, their advantages and disadvantages stated in order to guide decision researchers for their future studies in improving the MADM discipline. As Tzeng and Huang (2011) stated, “...for the past 50 years, scholars have proposed various functions to try to represent the true preference structure of a decision maker and the correct weights of criteria, and these efforts will certainly be ongoing for the next 50 years.”

3 - Multi-Criteria Decision Making Methods Application in Supply Chain Management: A Systematic Literature Review

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In the past decade, large number of research papers, certified courses, professional development programs and scientific conferences in the area of supply chain management are evidence of its significance and importance. Supply chain management is a multi-criteria decision making problem because in the entire supply chain management process, we have to consider different criteria related to each sub criteria of supply chain activities. Often, these criterias are conflicting in nature. Moreover, multi-criteria decision making methods have received much attention from researchers and practitioners in the field of supply chain management. The aim of this paper is to conduct a systematic literature review for published journal articles and provide useful literature review and insights in the application of multi-criteria decision making methods in supply chain management decision at strategic, tactical and operational levels. More specifically, this paper will analyze how Fuzzy decision making and its integration with Analytical Hierarchal Process (AHP), Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS), Data Envelope Analysis (DEA) and Analytical Network Process (ANP) can be applied at strategic, tactical and operational level decision making of supply chain management. A total of close to 60 papers, published between 2004 to 2014, met the selection criteria are selected and reviewed. The papers are then analyzed and categorized at different levels of decision making and different functions of supply chain cycle.

The review also revealed that most of the studies in sustainable supply chain management used a multi-objective or a multi-criteria methods to handle the conflicting objectives between the financial performance and the non-financial performance (environmental and social performances).

Finally, this paper will help supply chain decision makers to identify the most commonly used multi-criteria decision making method at each planning level of decision making and functions of supply chain management.

4 - Multicriteria Decision Making in Sport: A Comprehensive Literature Review

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Over the last two decades, fast advancements in data technologies and computer algorithms contributed to more interest on data analytics in sport. Managers, professionals and fans have applied many statistical tools and models in order to analyze sports data systematically. As a result of increasing need for more sophisticated techniques, multi-criteria decision models have also been widely utilized in various sport disciplines such as football, basketball, baseball, olympic games and so on. The purpose of this study is to present a comprehensive literature review on multicriteria decision making in sport. From the years 2000 to 2015, a total of 136 articles from peer-reviewed international journals were collected from reputed academic databases (ScienceDirect, Proquest, EbscoHost, Emerald, Ingenta, Taylor & Francis, and InderScience). Articles were categorized and analyzed according to several questions. Analysis and results showed that multicriteria decision making techniques were mainly used in many areas of sports for performance measurement, team or player evaluation and ranking, prediction of failure, scheduling, measuring technical efficiency, and sport marketing.

Wednesday, 14:10–15:00

★ WE-3- α -HS1

♦ Behavioral Aspects, Group Decision Making, Negotiations, Interactive Methods, Software

Wednesday, 14:10–15:00 – Room HS 1

Session: IS-INTER-SOFT: Multi Objective Optimization Software for Supporting Interactive Decision Making

Chair: Karthik Sindhya

1 - Using Interaction Techniques in Implementing Interactive Multiobjective Optimization Methods

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During the last 50 years, numerous methods have been developed for solving multiobjective opti-

mization problems. Among these, interactive methods have been found promising for solving real-world problems. Interactive methods involve a human decision maker (in practice e.g. a designer or an operator) in the iterative solution process of finding a most preferred Pareto optimal solution between the conflicting objectives. Despite the large number of interactive methods developed, surprisingly few implementations enabling their real-world applications are available. In the implementation of any interactive multiobjective optimization method, the graphical user interface plays a crucial role since it facilitates the interaction between the method and the decision maker, which is the essence of interactive multiobjective optimization. Therefore, in order to make interactive multiobjective optimization methods more widely used in practical decision making, there should exist well implemented interactive multiobjective optimization methods readily available for the decision makers to be used. Obviously, optimization method developers are not experts in visualization and interaction techniques (and other user interface techniques), so it is natural that they focus on what happens behind the user interface. This is why implementations of interactive multiobjective optimization methods may lack proper visualization and interaction techniques.

The visualization of information through graphical user interfaces has been studied in different disciplines, one of the emerging one being visual analytics which has been defined as “the science of analytical reasoning facilitated by interactive visual interfaces”. As far as visualization aspects are considered, the multiobjective optimization literature has mainly been interested in how to visualize the Pareto optimal solutions to the decision maker, especially, when more than three objective functions are considered. How the decision maker should process the generated solutions in order to provide updated preferences meaningfully, is not typically paid attention to. In other words, the focus has not been in how the decision maker could be supported in analyzing the available information to gain more insight in the problem and direct the search. Nevertheless, the decision making process can be further supported with appropriate interaction techniques.

In this presentation, we study how interaction techniques considered in visual analytics can be utilized in designing and implementing interaction between an interactive multiobjective optimization method and a decision maker. We think that visual analytics is useful in this context since it provides a technology that combines the strengths of humans and machines by using their respective distinct capabilities for the most effective results. The idea is to benefit from previous research and avoid re-inventing the same ideas. Our aim is to widen awareness and increasing the applicability of interactive methods for solving real-world problems. As a concrete approach, we discuss seven categories of inter-

action techniques proposed in the visual analytics literature and map them to the needs of interactive multiobjective optimization. We find that collaboration between developers of interactive methods and visual analytics experts can be fruitful in improving the user experience of interactive methods.

2 - Advancements and Trends in Simulation Process Integration & Design Optimization

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Analyze and compare engineering data at fingertips, trade-off conflicting design objectives, identify feasible design regions, capture multi-fidelity simulation processes, reduced margins and empowered consumers: The need to run your engineering process smarter and simultaneously reduce low added value tasks in simulation departments has never been more pressing. The next Optimus platform enables organizations to transform design exploration information into insight and insight into design decision. This presentation illustrates how to apply Optimus state of the art design space exploration capabilities and prescriptive analytic solutions to key engineering imperatives in order to deliver substantial value and ROI. You will gain practical know-how for implementing predictive models comparison, feasible region detection, multi-fidelity simulation workflow automation and simulation-based performance analytics with the next generation of Optimus.

★ WE-3-γ-HS2

◆ Model Building

Wednesday, 14:10–15:00 – Room HS 2

Session: IS-AUTOMAT: Automating decision-making

Chair: Sebastiaan Breedveld

1 - Using Description Logics for Automated-Decision Making

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Description Logics (DL) is a family of knowledge representation languages which corresponds to decidable fragments of First-Order Logic. Due to its desirable properties and well established foundations, it is commonly used in fields of knowledge representation and automated reasoning. It also embodies the formal foundation of the popular Semantic Web Ontology Web Language.

In this work, we combine DL with multi-attribute value theory and introduce a novel yet intuitive approach to representing multi-attribute decision problems and solving them in an automated decision making environment. The formalism allows us to modularly represent the distinct features of the decision maker such as what it knows, alternatives at hand, and a preference relation over multi-attributes. Moreover, our approach enables us to ontologically link all those features under an expressive logical language, so that the logical entailment can be employed as the basic inference service for automated decision making, while maintaining logical consistency. Moreover, given the decision and the knowledge base of the artificial agent, automated reasoning services i.e., abduction can easily be employed to provide minimal explanations for that decision.

In particular, what an agent (artificial) knows about the world is represented as an ontology, which corresponds to a list of logical sentences in DL. In particular, those logical sentences can encode two types of knowledge; terminological knowledge (concept hierarchy) e.g., “every roadster is a cabrio”, and assertional knowledge (membership axioms) “the car is in good condition”. Moreover, each alternative which is available to the agent, is represented by a set of assertional statements e.g., “the car has a blue colour” and “the car is a roadster” etc. Finally, a preference relation of the agent on attributes (e.g., colour and type) are represented over assertional statements “a blue cabrio is preferred to a red cabrio”. Given that preference, an agent which knows that “every roadster is a cabrio” can have a different ordering of alternatives than the one which does not.

At the remaining course of the work, we elaborate the taken approach further, and investigate its computational properties as well as expressivity in terms of preference representation from a decision theory perspective.

2 - A Lexicographic Optimiser for Fully Automated Multi-Objective Optimisation in Radiotherapy

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In multi-objective optimisation problems, various conflicting objectives need to be optimised simultaneously. When dealing with similarly structured problems, automated decision making may be considered. In this case, the decision making structure needs to be formalised so that the actions of the decision maker (DM) can be replicated using a suitable algorithm.

We recently developed the lexicographic reference point method (LRPM) for automated multi-objective optimisation. The LRPM is a generalisation of the reference point method, where multiple reference points are used to process the predefined lexicographic ordering of the objectives with their corresponding aspiration levels. Additionally, trade-off tuning can be implemented into the LRPM to obtain a better balanced solution. The reference points and trade-off configuration are processed into a single optimisation problem which guarantees to generate a Pareto optimal solution.

One of the applications of multi-objective optimisation where we attempt to automate the decision making is radiotherapy. For patients diagnosed with cancer and selected for radiotherapy as treatment, a CT scan is made to localise the tumour and surrounding healthy tissue. For a successful treatment, a sufficient dose has to be delivered to the tumour. Inevitably, the surrounding tissue is also exposed to the radiation. This needs to be minimised as much as possible. Typically, a treatment plan is obtained by minimising suitable treatment objectives (ranging between 10-25) towards aspiration levels in a prioritised order. Our current automated method solves a sequence of -constraint problems to find an optimal balance between tumour irradiation and tissue sparing. This strategy can be approximated using the LRPM, but then in a single optimization. The methods were tested on two sites: 30 prostate and 15 head-and-neck cancer patients. On each site, the aim is to configure the LRPM with a uniform set of input parameters, allowing fully automated treatment plan generation.

For both sites, we automatically generated the treatment plans using a uniform set of input parameters for the LRPM. All plans were found clinically acceptable meaning that for each patient, the tumour irradiation was sufficient while keeping the doses on the surrounding healthy

tissue at reasonable levels. The prostate plans obtained with the LRPM and with our current method were almost identical. However, the LRPM plans for the head-and-neck site frequently showed strong improvements for lower prioritised objectives at the cost of a small deterioration of higher prioritised ones. The LRPM plans were preferred clinically.

The LRPM includes lexicographic ordering of the objectives and allows a flexible trade-off configuration, while the computation time is relatively short compared to our current method. For the prostate patients, the average runtime decreased from 34.3 to 3.0 minutes using the LRPM. The LRPM was proven suited for fully automated treatment planning for prostate cancer and head-and-neck cancer patients.

★ WE-3- δ -HS3

◆ Industry and Business Applications

Wednesday, 14:10–15:00 – Room HS 3

Session: Engineering Applications

Chair: Djamel Chaabane

1 - Bicriteria Scheduling in a Multiple Part-Type Robotic Cell

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Multi-objective decision making approaches have been widely used in a variety of scheduling problems. However, in robotic cell scheduling literature, especially in single part-type systems, the number of studies devoted to optimizing multiple objectives is very limited. In this study, we consider a bicriteria scheduling problem in a flow shop environment. The cells consist of an input device, a series of (M) processing stages (M1, M2, ..., Mm), an output device, and robots for material handling within the cell. Robot activity A_i , consists of; unloading a part from M_i , traveling from M_i to M_{i+1} and loading the part onto M_{i+1} . The robots travel time between adjacent machines M_{i1} and M_i , equals δ , and it is additive. That is, the travel time between any two machines M_i , M_j is $|i - j|\delta$. 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 and different

due dates. 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 and exactly k parts are produced. We try to determine the robot move sequence along with the part input sequence in order to minimize the cycle time, as well as the total tardiness simultaneously. Tardiness causes the delay of payments, loss of customers, and lost sales costs. On the other hand, the benefits of cycle-time reduction can be remarked as increasing the average margin, throughput, productivity and reducing the break-even point of facilities.

We formulate the problem as a bicriteria mixed integer programming formulation and use the epsilon-constraint approach to determine set of non-dominated solutions. Since even the single objective minimization of cycle time is NP-Hard, the two criteria problem is also NP-Hard. Therefore, we developed a genetic algorithms base heuristic method to determine the set of non-dominated solutions.

In order to test the performance of the heuristic algorithm, we performed extensive computational studies with an experimental design on problem parameters. The results of the genetic algorithms are compared with the results of the MIP formulation. The results indicate that the developed method performs efficiently and finds high-quality solutions in reasonable CPU times.

2 - Bi-Objective Optimization Applied In Speech Denoising Signal

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In this paper, we study the problem of speech denoising signal. The objective is to achieve a compromise between noise reduction, signal distortion and residual noise and music. The spectral subtraction technique manages to reduce, considerably, additive noise but introduces, on the other hand, a residual noise (noise music) annoying to human perception.

Our goal, is the use of the operations research techniques, particularly, the multi-criteria optimization to reduce this type of noise while preserving the speech intelligibility. The problem can be considered as a bi-objective optimization problem, minimizing the noise reduction and preserving intelligibility of speech (minimizing signal distortion).

★ WE-3- κ -HS4

◆ AHP/ANP

Wednesday, 14:10–15:00 – Room HS 4

Session: AHP/ANP: Important Applications

Chair: Rafikul Islam

1 - Applying Analytic Network Process to Explore Consumer Adoption of Radical Innovation: a Case Study of Smart Home Technologies

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With rapid technology development, the boundary between industries becomes blurring, traditional industry has been transformed, and emerging industry are born. Firms in consumer electronics industry face fierce competition in product launch game. The success of innovation is essential to maintain competitive advantage and to expand business territory. The introduction of radical innovation can even change industry dynamics and consumer behavior. Since radical innovation is often new to the world, quantitative research approach (e.g. Survey) cannot deliver a reliable measurement of consumer demand while qualitative research method (e.g. focus group) often cannot converge opinions among participants. In addition, literature of radical innovation focuses on firm's innovation capability, performance outcome, commercialized decision, project management. Identifying factors that influence consumer adoption of radical innovation is neglected in literature. Therefore, the aim of this research to understand the key factors that influence consumer adoption of radical innovation product. We used the concept of smart home as the example of radical innovation, and, based on literature, we developed ANP with the following four criteria: control device, product design, product reliability, and market environment. Each criterion consists of multiple sub-criteria. The result shows that portable control device, user-friendly interface, aesthetic product design, personal information protection, and product compatibility affect consumer adoption of smart home applications most. This research contributes to literature by understanding consumer adoption in the era of internet of things, and by extending ANP to marketing research.

2 - Assessing and Ranking HALMAS Parks in Malaysia: An Application of Importance-Performance Analysis and

AHP

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In 2007, Ministry of International Trade and Industry, Malaysia, had set up a unit named Halal Industry Development Corporation (HDC) to spearhead the government initiatives towards evolving Malaysia into a global hub. One of the main activities of HDC is to develop and promote halal parks. It selects an operator who is entrusted to run a particular park. On the other hand, tenants occupy the parks to carry out manufacturing, service activities, and various logistics operations. HALMAS is an accreditation status given to the operators, logistics companies, and other tenant companies upon successfully meeting the requirements set in HDC Halal Parks Development Guidelines. HALMAS status enables its beneficiaries to enjoy incentives made available through and managed by HDC. Tenant companies from seven HALMAS Parks participated in this study and expressed their expectations and satisfaction on running the parks. An importance-performance analysis (IPA) approach was adopted to come up with the Importance-Performance Matrix which enables HDC to focus on areas that need remedial actions. The study also highlights the necessity of a ranking system for HALMAS Parks. In consultation with the tenant companies and independent evaluators, the ranking criteria have been identified and absolute measurement process of AHP has been applied to complete the ranking exercise.

★ WE-3- σ -HS5

◆ Multi Objective Optimization

Wednesday, 14:10-15:00 – Room HS 5

Session: Optimization in Healthcare 1

Chair: Serpil Sayın

1 - Multi Criteria Decision Problem of Assigning Specimens to the Pathologists for Assessment

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In the Department of Pathology and Laboratory Medicine (DPLM) at The Ottawa Hospital, each day a number of specimens (pathology requests) arrive from operating rooms and clinics to be examined by pathologists. In this department, at the beginning of each month clinical managers must assign expected daily pathology requests to available pathologists based on the following requirements:

- Pathologist's specialty

In DPLM, there are 36 pathologists, each with a set of sub-specialties defining the types of specimens that a pathologist is trained to analyze. There are in total 26 sub-specialties in the department such as liver pathology, breast pathology or neuropathology.

- Pathologist's availability

Pathologists' availability on a given day is measured based on the pathologists' "full time equivalent (FTE)" fraction (i.e. for pathologist working full time in a given day, the FTE value is 1). It incorporates absences due to vacation, maternity leave, research, or teaching.

- The service weight of each type of pathology request

The length of time it takes to analyze a given specimen is measured using predefined service weights that are different for each specimen (i.e. a service weight of 2.0 for neuropathology indicates that all neuropathology specimens in a given day can be processed by two pathologists). Values of the service weights were established by the DPLM based on historical data.

Apart from the above requirements, the following criteria are important to consider when making decisions about assigning specimens to the pathologists:

- Consistent assignment in a week

It is desirable that within a given week a pathologist is assigned the same specimen each day.

- Assume rotation to maintain sub-specialty requirements

In order to maintain his/her expertise, each pathologist should rotate through the list of specimens for which s/he is meant to be competent.

- Prioritization of the specimens

The requests to analyze the specimens come with different priorities for processing. This implies that any assignment must first ensure the completion of high priority requests before moving on to less urgent requests.

Currently the clinical managers at DPLM use a manual approach to assign daily pathology requests to the pathologists. Since the size of the pathologists' assignment problem is large, finding a feasible assignment manually is a time-consuming process that takes a number of iterations over a number of days to complete. Moreover, every time there is a need to revise the schedule, new assignments need to be developed. In this research we have created a decision support tool for managing this problem by developing a multiple objectives optimization model and

embedding it within a spreadsheet-driven decision support tool to help managers in the DPLM to determine the optimal monthly pathologists' staffing schedule.

The multiple criteria correspond to consistent assignment in a week, rotation of the tests between the weeks, and prioritization of the specimens. These criteria were converted into a single weighted sum objective function because of a requirement that a single solution needs to be given to a clinical manager and in the DPLM setting there was no opportunity to try interactive programming techniques. The resulting mixed integer programming model has 43649 variables and 52057 constraints. The constraints force the model to provide a schedule based on the pathologists' specialties, availabilities and the service weights of the pathology requests.

The model was solved using IBM ILOG CPLEX Optimization Studio. Responding to the clinical manager request that interactions with a model should be spreadsheet like we embedded the model within a customized Microsoft Excel platform that provides a user-friendly interface. The resulting scheduling system was called the Automatic Pathologists' Scheduler (APS) system.

The APS system has the following components:

- Editing: allows the clinical manager to update and revise the pathologists' availabilities and subspecialties, add a new specimen type or remove a type from the list, update the list of pathologists working full time or part time, and set a day as a holiday.

- Management control: allows the clinical manager to change the service weights of each type of pathology request based on daily demand forecasts, revise volume of pathology requests by type and day, for a given pathologist change the daily workload restrictions, and make explicit assignment of pathologist to specimen for a given day.

- Optimization control: allows the clinical manager to change the weights in the objective function to evaluate different assignment scenarios.

The system has been validated at the DPLM of The Ottawa Hospital. The results of this validation showed that the APS system is effective in developing a schedule that meets about 80% of all the scheduling criteria and therefore represents a step forward in simplifying pathologists' assignment problem for the clinical managers. The APS system developed in this research can be customized and ported to other pathology departments providing that there is data available to revise model's parameters.

2 - Grid-based Algorithm to Generate Well-dispersed Nondominated Solutions for Multiobjective Optimization Problems: Application to Radiation Treatment Planning

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The solution to a multiobjective optimization problem (MOP) consists of the efficient set that portrays all relevant trade-off information to a decision maker. In general the efficient set is not an easy set to deal with. Thus, instead of obtaining the entire efficient set, generating a finite discrete subset of the efficient set, which is called representation, can be more preferable by the decision maker. Generally, a representation with well-dispersed solutions over the non-dominated set (mapping of the efficient set in the outcome space) is desirable since it eliminates redundancy and represents each part of the nondominated set with an equal degree. In this study, we present a grid based search algorithm to generate well-dispersed representation of the nondominated set for MOPs. In this algorithm, we subdivide the outcome space into p -dimensional grid cells where p represents the number of objective functions. Our aim is to address the nondominated solutions in grid cells to generate well-dispersed representation and we utilize achievement scalarization to attain the solutions. The subproblem does not guarantee to find a nondominated solution in the grid-cell. In the way we define the parameters of the subproblem, it has an incentive to find such a solution. The subproblem can also be used to find a nondominated solution that targets the specified grid-cell where it is defined by the given bounds on the objectives based on decision makers preferences. We use the grid-based algorithm to generate treatment plans for external-beam radiation therapy and obtain single treatment plan by considering the bounds on the objectives that are given by clinicians.

External-beam radiation therapy is to use computer-controlled linear accelerators to deliver precise radiation doses to the tumor while sparing the critical organs and healthy tissues. The treatment planning for the radiation therapy requires considering several conflicting objectives. Hence, inverse planning problem can be considered as an MOP. Here, we show the test results on one of the locally advanced head and neck cancer cases. Test case includes three planning target volumes (PTV), (primary PTV, high-risk PTV, low-risk PTV). The organs-at-risk (OAR) are left and right parotid glands, and oral cavity. Finally, critical organs are brain stem and spinal cord. Subproblems are solved by using IBM CPLEX 12.5.1 (Barrier Optimizer). In the first test, we consider the problem as three-objective linear programming problem. First objective function minimizes the maximum variation from the prescription doses over all target volumes. Second and third objective functions aim to minimize overdose to OARs and

critical organs respectively. We test the algorithm with error levels 0.4, 0.2 and 0.1. The numbers of solutions in the representations, i.e. number of treatment plans, are 18, 47 and 182 respectively. In the second test, we consider the problem as eight-objective linear programming problem. First three objectives minimize the maximum variation from the prescription doses for three target volumes. Fourth, fifth and sixth objectives aim to minimize mean dose to the OARs. Seventh and eight objectives minimize the maximum dose to critical organs. Since the complexity of the algorithm is exponential in the number of objectives, instead of generating several plans we target a single plan by considering the bounds on the objectives that are given by clinicians. The resulting plan by the subproblem achieves uniform dose for all targets while as much as 22% improvement in OAR sparing comparing to clinical plan.

★ WE-3- χ -HS6

◆ Environment, Infrastructure & Emerging Applications

Wednesday, 14:10–15:00 – Room HS 6

Session: Applications in Higher Education

Chair: Mehmet Kabak

1 - Determination of Synthetic Indicators of University Quality through multicriteria analysis: Ranking of the Spanish Universities

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The different methodologies presently used to perform rankings of universities are a controversial issue. This fact is due to both the indicators that are considered, and the methodology used to aggregate them. In this work, we propose a methodology, based on multicriteria techniques, to determine a synthetic indicator of university quality, making use of a series of single indicators, classified into different categories. The methodology used allows us to consider indicators of different nature, measured in different scales. Subjective judgments can be included both in the assessment of the relative importance of each criterion, and in the determination of reference levels for them. The study is complemented with a sensitivity analysis on

these subjective parameters. Finally, different compensation levels among indicators are considered, ranging from total compensation (weak scheme) and no compensation (strong scheme).

2 - A MCDM Approach to Evaluate Universities Distance Education Websites

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Purely economic, social, military, political or cultural development for societies is not enough to be successful or survive in today's global and diverse economy. Societies need permanent developing knowledge related with these issues to be able to reflect the achievements to production. Societies' ability to produce knowledge is directly related to the competencies and educational level of the individual. The concept of lifelong learning shows itself at this point. On the other hand, the traditional educational model forces students and teachers to share the same physical space and requires being together in the class. Individuals who work full-time work at present cannot allocate adequate time for training to further personal and professional development. In such instances, another educational model different from the traditional one is needed. An education model that doesn't require student and teacher at the same place and time can be defined as distance education or distance learning. The distance education model can provide education at a distance via technology, especially the internet. Many universities or organizations use internet and prepare websites to get the main advantages of distance education. In this study, a MCDM approach related with forming a distance education website is proposed for universities. Four major criteria are determined, namely system quality, information quality, service quality and attractiveness with a total of 25 sub-criteria based on the literature review and experts' opinions. 25 different sub-criteria under 4 major criteria are weighted using the analytic network process (ANP). The most three important sub-criteria are the information sharing, the security and the social network compatibility, respectively. In the following step, the TOPSIS method is applied in order to rank the 15 different distance education website alternatives. 8 sub-criteria are quantitative ones and alternatives are evaluated by certain numbers, the others are qualitative ones and linguistic variables are used for evaluation. Outcomes of the results in this study can provide guidance to system designers in identifying the key factors facili-

itating distance education website development, and find the ideal policy for improving website effectiveness.

Thursday, 09:00–10:00

★ TH-1

◆ Plenary Session

Thursday, 09:00–10:00 – Aula

Session: Plenary talk: Carlos M. Fonseca

Chair: Francisco Ruiz

1 - Subset Selection in Evolutionary Multiobjective Optimization

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The potential of evolutionary algorithms in multiobjective optimization was identified early in their history. That potential has been realized over the years with the development of increasingly elaborate Evolutionary Multiobjective Optimization (EMO) algorithms that have found many important applications in the real world, and have contributed significantly to the growth in popularity of multiobjective optimization in general.

Although EMO has traditionally emphasized the approximation of the whole Pareto-optimal front in an a posteriori articulation of preferences setting, preference-driven EMO algorithms capable of handling interaction with a Decision Maker (DM) were proposed early in their development. While the identification of a most preferred solution is usually seen as the ultimate goal in practice, recognizing that the search for diverse sets of alternative solutions to be presented to the DM (whether in a progressive or an a posteriori articulation of preferences scenario) implies some sort of set-oriented preference for diversity has been a turning point in EMO algorithm development. State-of-the-art algorithms such as IBEA, SMS-EMOA, MO-CMA-ES and HyPE, for example, implement multiobjective selection based on a notion of set quality that is then used to infer the quality of the individuals in the population and to introduce bias towards the better ones at the parental and/or environmental selection stages. However, the issue of how to combine such set-oriented preferences with the more traditional search for a single most-preferred solution remains largely open.

This talk focuses on the problem of selecting a diverse subset of non-dominated solutions from a larger set of candidate solutions according to DM preference information. The expression of

set-oriented preferences by the DM, their incorporation in EMO algorithms, and computational aspects of the resulting subset selection problems are considered. Existing quality-indicator and decomposition approaches are reviewed and discussed, and an alternative perspective is introduced where set quality is not specified by the DM as such, but is inferred from the uncertainty associated with DM solution-oriented preferences instead. Recent results obtained by instantiating this idea in the form of a portfolio optimization problem are presented and discussed, and opportunities for further work are outlined at the end.

Thursday, 10:30–12:10

★ TH-2-β-HS1

◆ Decision Aiding

Thursday, 10:30–12:10 – Room HS 1

Session: Decision Aiding: Emerging Applications 1

Chair: Jian-Bo Yang

1 - Exploring NFC technology adoption for creating the best educational institution based on new hybrid MADM model

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With the advancement in mobile devices and the concept of Internet of things (IOT), the use of near-field communication (NFC) technology has increased constantly in recent years. NFC technology will create new intelligent environments for creating the best educational institution to safely transfer information or service. In the educational institution, the decisions to adopt NFC technology are multiple attribute decision making (MADM) problems requiring multi-criteria decision analysis that involves the interdependence and feedback effects among the criteria/dimensions. However, most traditional decision models cannot capture these complex interrelationships. This paper proposes an evaluation model that could explore and improve NFC technology adoption for creating the best educational institution. In this evaluation model, the interdependence among criteria/dimensions, the best alternative selection, and systematic improvement can be addressed by using a new hybrid MADM model, which combining decision

making trial and evaluation laboratory (DEMATEL) technique to construct the influential network relation map (INRM), find the influential weights with DEMATEL-based analytic network process (DANP), and use the modified VlseKriterijumska Optimizacija I Kompromisno Resenje (modified VIKOR) for reducing the performance gaps based on INRM. Furthermore, an empirical case of evaluating and improving NFC technology adoption is used to verify the proposed model.

2 - Consumer preference prediction to support New Product Development (NPD)

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In the context of new product development (NPD) it is important for companies to launch products with characteristics which meet the consumer preferences. Hence, one of the most important processes which support NPD decision making is consumer preference prediction. The literature illustrates a wide range of methodologies employed for predicting liking: from statistical methodologies e.g. multiple linear regression to non-statistical approaches e.g. artificial neural networks (ANNs), support vector machines (SVMs), and rough sets. The Belief Rule-Base (BRB) methodology has also been tested in this field: for consumer preference prediction and target setting. Moreover, BRB was proven to hold technical and conceptual advantages over the aforementioned alternative approaches. This paper is set to introduce further advantages and applications of the BRB methodology for consumer preference prediction.

The presented features/ advantages were selected in response to the challenges raised by the two case studies addressed in this paper. The methodology has been tested in the fast moving consumer goods (FMCG) industry: the personal care sector. Some of the main challenges were identified to be: the high number of potential predictors, the uncertainty present in the inputs, the outputs which are presented as distributions, and the optimal model structure selection.

First of all, the addressed case studies presented

a large number of potential inputs. One of the addressed industrial applications offered over 1000 instrumental measurements, all of which could represent potential predictors. For managing this challenge, two major directions have been proposed: predictors' selection through step-wise linear approach or data reduction through either principal component analysis or Autoencoder. Each approach was found to have its own set of advantages and drawbacks; especially in terms of overall accuracy and interpretability of results.

Secondly, some of the instrumental measurements conducted in the case studies have implicit machine error. These errors along with their conceptual implications are generally disregarded. However, in this paper, the flexible structure of the BRB has been adjusted to accommodate for such errors.

Thirdly, it has been observed that the outputs are fundamentally distributions, as they are captured through questionnaires. The majority of the above mentioned methodologies, summarize such outputs by their averages. This paper comes to argue that averaging data leads to information loss and to analyse the conceptual advantages of employing the distributions through BRB models.

Finally, in the modelling phase, one of the most prominent interests raised by the practitioners concerned the model's validation and over-fitting. The paper proposes a heuristic approach which can support BRB model structure selection and can avoid over-fitting. The number of referential values for both outputs and inputs is evaluated based on two objectives: maximizing the prediction accuracy and minimizing the model complexity. The approach generates the Pareto front of optimality/ efficiency. Moreover, an automated approach for selecting the optimal model structure is proposed. Whilst the Pareto front can offer valuable insight, it is important to provide a prescriptive approach capable of indicating which specific model structure is best to be selected.

3 - Application of Evidential Reasoning Rule to Decision Making in Financial Investment

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Decision-making in financial investment is a very complex issue where an investor chooses assets to invest in with three important criteria: return, risk, and time horizon. The objective of a financial investment is to achieve high returns with low risks in a reasonable horizon. One recent advance in decision theories is the development of the Evidential Reasoning (ER) Rule, which generalizes the Dempster-Shafer Theory to allow for different weights and reliabilities on the evidence to be combined to enable a consistent combination of potentially conflicting evidence. Here a succinct investment strategy is presented which uses a model of Efficient Information Combination (EIC) based on the ER Rule to aggregate the opinions of financial analysts for synthesizing investment portfolios. Experiments were carried out to backtest the investment strategy using data of historical stock prices and analyst reports from the China Stock Market & Accounting Research (CSMAR) Database for the four-year period between 2009 and 2012, containing more than 270,000 research reports published by more than 4,600 financial analysts. It is demonstrated that the risk-adjusted returns of the strategy with varying parameters significantly outperform the market returns of CSI300 index for investment horizons of around six months, with p values from Student's t-test being as low as 0.13%. The annualized excess returns obtained average up to 14.6%, compared to the average return of 6.7% above market performance by hedge funds, according to one estimate published by Penguin Group. The research serves as the first application of the ER Rule in the finance field, providing a new and effective method for decision-making in financial investment. Backtesting shows high risk-adjusted returns within a reasonable timeframe compared to the market. Further studies are warranted to explore the use of the ER Rule in the finance field to enhance the accuracy and effectiveness of information fusion from various conflicting sources of evidence.

★ TH-2- γ -HS2

◆ Model Building

Thursday, 10:30-12:10 – Room HS 2

Session: IS-MB-RISK-MAINT: MCDA Models in Risk, Reliability and Maintenance Contexts

Chair: Cristiano Cavalcante

1 - Multidimensional risk evaluation in natural gas pipelines: sensitivity analysis of model parameters based on a Monte Carlo simulation

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This study presents the sensitivity analysis module of a Decision Support System (DSS) developed to support evaluating multidimensional risks in natural gas pipelines. The multidimensional risk evaluation model uses Multi-Attribute Utility Theory (MAUT) to incorporate the decision maker's (DM's) risk behavior, and analyzes each section of a pipeline network. Three risk dimensions are considered: human, environmental and financial. As a result, the model produces a ranking of pipeline sections in terms of risk, where a risk hierarchy between each pipeline section is obtained by comparison. In the sensitivity analysis step, the focus of this study, a Monte Carlo Simulation is applied in order to vary the parameters of the model according to probability distributions. Additionally, Kendall's correlation coefficient is used to measure the association between rankings resulting from each replication. Thus, it is possible to check variations on parameters that lead to changes in ranking positions, and therefore, to establish the correlation with the original ranking. Finally, in this module, these variations can be illustrated by means of graphical visualization, thereby enabling a more complete analysis of the information.

2 - An MCDM model for preventive maintenance planning in a water supply system

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Due to issues of non-planned urban development, as well as shortage of drinking water, a water supply system may not be able to feed all consumers simultaneously. Some urban areas are supplied through wells and requiring continuous rationing. The rationing works according to a preset schedule by the supply company. This situation gets worse due to interventions in implementing equipment maintenance services. Thus, this paper presents a decision model to evaluate multiple criteria in order to establish when preventive maintenance should be performed on such equipment, which means to define the most suitable time interval for performing preventive maintenance actions in such environment. Availability and cost has been evaluated in the decision. The most suitable time interval was considered based in the tradeoff between avail-

ability and cost by considering an aggregation process based on Multi-attribute Utility Theory (MAUT). From this model the maintenance engineering has a time interval for preventive maintenance actions in order to reduce operating costs and to improve the welfare of consumers by increasing the availability of equipment.

3 - MCDM Models in Maintenance Research

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The use of multiple criteria and multiobjective models in maintenance research has increased in recent years. The need to consider more than one aspect so as to optimize different objective functions simultaneously can justify the more frequent use of these approaches. Typically, in the maintenance context, there is an evident trade-off between cost and reliability. In such situations, optimal solutions for only one objective function cannot express the decision maker's expectations. The objective of this paper is to analyse the connection between MCDM and the main features of maintenance decisions based on a literature review. The maintenance decisions considered include preventive maintenance, condition-based maintenance, outsourcing, spare parts, redundancy allocation, design selection and maintenance planning. A discussion on fundamentals of multicriteria in maintenance modelling and some directions for supporting the choice of suitable multicriteria are given, based on previous applications. An overview and insights are provided in order to guide researchers to understand the potential of multicriteria and multiobjective models in the most relevant problems from this area.

4 - An MCDM/A model to support the definition of opportunistic maintenance policy

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This paper puts forward a multicriteria model to support decision-making related to maintenance policy that takes into account the opportunities brought by other parts of an operational system. The article is an extension of previous studies that were developed from the optimization perspective. It generates a broader view for the decision maker who can now consider the consequences of different maintenance actions (minimal repairs, opportunistic repairs, and preventive maintenance) under two different dimensions: cost and availability. Cost studies of

opportunistic maintenance models are well documented. Multicriteria models for an opportunistic maintenance policy are less well developed, and the contribution of this paper to this area is to contextualize an application for a highly relevant sector. Our policy has a high potential impact in practice because it not only determines when to carry out maintenance but also helps the decision maker to determine what type of maintenance to carry out.

★ TH-2-δ-HS3

◆ Industry and Business Applications

Thursday, 10:30–12:10 – Room HS 3

Session: Industrial Decision Support

Chair: Piotr Sawicki

1 - Multicriteria modeling and tradeoff analysis for oil load dispatch and hauling operations at Noble Energy

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Noble Energy produces and sells tens of thousands of barrels of oil a day in the Denver-Julesburg Basin in Northeastern Colorado, one of the largest natural gas deposits in the United States. This talk presents a new mathematical model that was built and implemented to support the company's business decisions regarding its current and future sales, dispatch, and transportation operations. The corresponding multicriteria optimization model is formulated and solved as a multiperiod, multi-objective mixed-integer program that considers the maximization of revenue and sales, and the avoidance of temporary production shut-ins and sell-outs to guarantee long-term contractual obligations with its partnering well owners, haulers, and markets. A theoretical tradeoff analysis is presented to validate model decisions with current operational practice, and a small computational case study on an original data set demonstrates the use of this model to find efficient dispatch schedules and gain further insights into the tradeoffs between the different decision criteria.

2 - Methodology to support decision-making about of prioritization of improvement plans in the agricultural sector: A case of study

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Decision making in Agricultural sector management, as well as the allocation of financial resources in developing countries to projects, is usually made without evaluating the concepts and perceptions of industry experts, and it is simply limited to the evaluation of quantitative, criteria-related production. This paper proposes a multiple criteria methodology in which quantitative and qualitative criteria for prioritization of horticultural products in Center of Colombia were mixed in order to allocate financial resources to the implementation of logistics strategies to increase their competitiveness. The expert method and the method for planning, implementing, and evaluating capacity development in agricultural chains of International Service for National Agricultural Research (ISNAR) were used as a basis for developing this methodology. The expert method analyzed qualitative criteria with which the logistic potential index (LPI) of each product was determined, while the assessment of quantitative criteria for determining the competitiveness level index (CLi) of each product was based on the indicators used in the ISNARs method. Finally, the results of both analyses were merged and presented in an array called the prioritization matrix. Each quadrant of this matrix determines the importance of the product in the area evaluated. With the proposed methodology, agricultural products (vegetables and/or fruits) for each zones was prioritized; furthermore, it allowed us to explicitly incorporate the preferences of experts to assess farm management options in the horticulture chains. These results are the first stage of the project "Design and implementation of a logistic model as basis for the value integration in horticulture chain at Tolima-Colombia" and they are the basis for providing continuity with diagnosis of agricultural chains selected and design of improvement plans.

3 - Multi-objective simulated annealing for collision avoidance in air traffic management

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The increasing demand in air traffic operations

requires improved systems for automating aircraft maneuvers. This paper addresses the conflict detection and resolution problem. Conflict detection and resolution is one of the most widely studied problems in the air traffic management field. A conflict situation occurs if, according to their flight plans, two or more aircraft within the same specific aerial sector do not keep a safe horizontal or vertical distance. It is a combinatorial optimization problem that is resolved by deciding the best global strategy for avoiding conflicts through the modification of the aircraft configurations (velocity, altitude or angle of direction). The approach that we propose allows each individual aircraft to choose an order of preference among above three different maneuver options on the basis of different criteria, such as fuel consumption efficiency, passenger comfort or changes in the original aircraft path. If deemed appropriate, the preferred maneuvers can be modified by the system; for example, if infeasible situations crop up, like trying to solve a conflict between aircraft that are flying in opposite directions by performing a velocity change maneuver.

We propose the use of multi-objective simulated annealing to derive a large number of efficient configurations (Pareto or non-dominated solutions) on the basis of a geometric model that can predict the existence of such conflicts and their magnitude. The system takes into account different general or maneuver-dependent objectives, such as reducing the number and magnitude of maneuver changes, minimizing collision risk or forcing a return to the original flight configuration. Besides, as the approach is designed to work as part of a continuous execution system (reactive process waiting for queries), an important objective is to reduce the total number of maneuvers of a single aircraft as of when it begins to be managed by an air traffic controller, i.e., when it enters the respective aerial sector. The proposed approach is original in different ways. Firstly, we consider a model accounting for the three possible maneuvers that an aircraft can perform (velocity, altitude or angle of direction) as opposed to other proposals in the literature, which consider only one or two of them simultaneously. Besides, we tackle the problem from a multi-objective perspective, deriving a set of efficient solutions rather than a single solution. The solutions are then shown to users, who select the one that they prefer.

Note also that we have optimized a multi-threading parallel software implementation to efficiently solve the problem. This implementation focuses on creating a real application with an industrially usable execution time, which is crucial in this particular context.

4 - The concept of the multiple-objective business process optimisation

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In the paper a problem of business processes optimisation is considered. The concept of a business process has been recently discussed in the literature, however, a consensus has been still not found. Based on the literature analysis the author of this paper has proposed a novel process definition giving a base for its understanding and further optimisation. The process is assumed as a structured set of activities, which are performed using the necessary resources that allow the conversion of input elements into the expected results. In this meaning the process performance is a result of triple interactions, including internal relations among activities in the process (dynamic interaction), relation with another processes in organisation (dependencies between results, stochastic nature of the results), as well as relation of the process and its environment (customers expectations, competition, technological advances). Taking into account the nature of the process the author of the paper has proposed a concept of multiple-objective interactive optimisation procedure. This procedure is composed of six interdependent stages using several concepts and techniques, including process modelling, mathematical programming, simulation, data mining and rule generation.

In the stage 1 the considered process is identified (in case of existing solution) or designed new one (in case of process setup). As a result of stage 1 the process is modelled to formalise its description. To this end one of the existing language, e.g. EPC (event driven process chain), BPMN (business process models and notation) or UML (unified modeling language) can be applied. The final decision in this issue has to be made on user perception and software availability. In the stage 2 a predefined catalogue of potential process changes has to be considered. The catalogue is a set of all practice-based changes in the specific group of processes. Only those changes that are reliable under certain business conditions can be selected for further consideration. Next, during stage 3 of the procedure, a comprehensive, i.e. multiple criteria, mathematical model is constructed. The objectives resulted from a process essence are the basis for its performances evaluation. The multiple-objective stochastic and dynamic formulation has to be applied to express all the phenomena of the considered process nature. In stage 4, the simulation model is constructed and a set of simulation is carried out. Its purpose is both, to reflect the process run, and to obtain the numerical representation of conversion of parameters and variables of the considered process into the set of final results. The simulation model is built with respect to the nature of criteria defined at stage 3. To create stage 4 of the procedure, ExtendSIM simulation package has been applied.

In the stage 5, the set of simulation results generated previously (at stage 4), is evaluated. The extraction of Pareto solutions is carried out and

the decision regarding the continuation or discontinuation of seeking a compromise solution is made. In the absence of a foundation for further exploration the procedure is stopped. Otherwise, a stage 6 is performed. During stage 6 the exploration of the process knowledge data base, resulted from the previous stages, is carried out. As a result of knowledge exploration the decision rules are generated. They are a generic description of a relationship between the parameters and variable of the mathematical model and its generalized measures, i.e. values of criteria (see stage 3). After a review and the selection of the decision rules the procedure returns to the stage 3, wherein based on these rules the mathematical model is modified and customised. From this point starts the next iteration of stages 3 to 5 until a satisfactory solution is obtained.

The proposed procedure is experimentally verified and tested on the basis of logistic process. Its nature is to perform a deliveries of components and production parts from a warehouse to the assembly line. The third part logistics service provider is carried out this process and is responsible for deliveries from the picking warehouse to the production plant. The results of a current state are compared with the optimised ones, according to the set of 3 criteria, i.e. process cost, process timeliness and resource utilisation.

★ TH-2- κ -HS4

◆ AHP/ANP

Thursday, 10:30–12:10 – Room HS 4

Session: IS-AHP-TA: Theory and Applications of the AHP/ANP 1

Chair: Metin Dağdeviren

1 - Site Selection for Wind Energy Plant by Using Analytic Network Process

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In today's world, energy has a great importance in government policies and economical and social development of countries. Some events, such as increase in energy prices and changes in supply demand of energy, cause some problems which can be called as a crisis. Because of the rapid depletion of fossil fuel reserves and the environmental effects of fossil fuels, many countries have begun to prefer renewable energy sources to fossil fuels. As a result of this transition in the world, usage of renewable energy in Turkey is started to be a popular way to generate energy. The great

potential of renewable energy in Turkey and requirement of encouragement on the investments on renewable energy resources have been emphasized in the 2015–2019 Strategic Plan of Ministry of Energy and Natural Resources. To generate energy from renewable resources in Turkey, wind energy has the second big potential after hydro energy. So, Turkey must benefit from potential of wind energy sources and plants must be located on the most appropriate places in Turkey. The main aim of this study is to develop an analytic model to support wind energy plant site selection decisions in Turkey. Due to this aim, a literature review is made in order to investigate the wind energy plant site selection criteria. An expert group of five people, which contains two academicians working on renewable energy systems and two professionals who are working at a company in wind energy sector and an administrative staff of Ministry of Energy and Natural Sources, have made an assessment of existing criteria. Then, three main criteria and seven subcriteria which are used in this paper are determined. The main criteria are economic and technical aspects, environmental aspects and social aspects. Economic and technical aspects are cost efficiency, reliability and wind density. Environmental aspects are forest lost and distance to migration of birds. Social aspects are job creation for people and social acceptability. Due to the interdependencies between given selection criteria, site selection for wind power plants is made by using Analytic Network Process. An application of site selection is made in Turkey for five alternative sites by using the proposed decision model to demonstrate that the model is suitable for the wind energy plant site selection.

2 - A compatibility study of priorities vectors for reverse logistics indicators: a footwear industry case developed in Brazil

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Reverse logistics (RL) is important to cover environmental, social, and economic aspects, known as triple bottom line (TBL) dimensions of organizational sustainability. The assessment of RL practices involves multiple aspects interrelated. The Analytic Network Process (ANP) is a significant tool to evaluate RL features because it considers interdependence relations. Concerning to compatibility (closeness) study between vectors, three compatibility indices have been proposed: S and G using cardinal vectors, and V using ordinal vectors. This work presents an assessment of the priorities of reverse logistics (RL) indicators in the footwear industry in Brazilian State of Ceara. It used a model that applies ANP,

and seeks achieve a sustainable business performance, analyzing TBL by means of RL practices, measured and evaluated. Subsequently, outcome obtained was compared with respect to ranking of priority found for a sampling for Brazilian companies. Among the nine RL indicators considered in the model, only three changed their orders (from 5th, 6th and 8th, to 8th, 5th and 6th respectively). However, priorities take different values in each case. The resulting compatibility index, $S=1.128$ indicates that vectors are compatible (according to Saaty, 2001), $G = 0.833$ (less than lower limit 0.9) which can be related to a higher n (according to Garuti and Salomon, 2012), and $V=1.038$ indicates that ordinal vectors are close. This may indicate the importance of using the indices S and V together, as is already suggested in the literature.

3 - Pythia: development of an oracle for automated treatment plan selection in radiation therapy

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Background: A novel method for fuzzy multi-criteria decision-making based on preference relations was evaluated for feasibility in automated radiation therapy plan selection. Radiation therapy is one of the treatments for cancer, where malignant tumour cells are irradiated in order to eradicate the tumour. Treatment plan evaluation is the domain of the physician, who weighs the different criteria with the aim to treat the patient and minimise the probability of radiation-induced complications. This decision is made based on 10-25 competing criteria, and due to the complex relations (trade-offs) between the criteria, difficult to pour in solid hierarchy based decision-making.

Automated plan selection is required in several aspects of treatment plan generation. One important aspect is the selection of beam directions from which the patient should be irradiated. This is a combinatorial problem, as only a handful (5-25) directions are allowed, while it is possible to choose from a continuous 360 degrees circle, or a sphere. This non-convex combinatorial problem can only be solved using heuristics or pattern-search methods. Such approaches require frequent polling to assess the quality of a certain plan compared to its alternatives.

The decision-making can be modelled as a hierarchical analytic network process: for most of the criteria there is a clear preference relation, for others the position in the hierarchy is less well-defined, or they are simply equally important. The relations are also fuzzy: a limited deteriora-

tion of a highly prioritised criterion is acceptable if lower ones are significantly improved.

Quantifying the amount of fuzziness and magnitude of relative importance is a tuning process, as well as the settings of other parameters.

Methods: This research investigated the fuzzy preference relations based decision-making framework of Yu, Xu & Liu (Comput Ind Eng 2013). This method is interesting for application in radiation therapy: 1) criteria are partitioned in hierarchies, 2) each criterion can be evaluated differently in each hierarchy, and 3) lower hierarchies become more influential if there is insufficient variation in the set of alternatives for the higher hierarchies.

Point 1 is a direct result of the natural relations in plan evaluation (e.g. sufficient salivary production is more important than difficulties with swallowing). Point 2 is required for a balanced decision between different criteria: the highest goal is to aim for a minimum deterioration of salivary production, second goal is to aim for a minimum loss in swallowing functionality. Third goal is again salivary production, but now aiming for a more moderate salivary production. Point 3 is to ensure that lower prioritised hierarchies are taken into account even if higher prioritised hierarchies have unacceptable measures. This is especially important as not all criteria are available in each patient case, and can be ignored while using the same parameter set.

The study contained 8 anonymised patients with a tumour in the head-and-neck area. In order to tune the parameters of the decision model, 23 equi-angular distributed beam directions were fixed, so the optimisation problem is continuous and convex. A Pareto-front was generated for 9-15 criteria, resulting in 8583-11644 plans per patient. Because some criteria are evaluated at different levels (see Point 2 above), 23 different criteria evaluation functions were formed and divided in 13 hierarchies (e.g. respective left and right salivary glands were considered equally important and thus grouped in a single hierarchy). For each patient, a reference plan was selected for tuning. The selection was based on the clinical protocol, used for our in-house developed automated treatment planning approach. Although the preference relations to guide the optimisation were similar to that of the decision-making, they cannot be used directly: for planning rigid, stepwise decisions are made which do not allow fuzzy decision-making.

In an exhaustive search, 28 parameters required to shape the transformation functions for the criteria were tuned. The goal was to find a single set of parameters that results in an acceptable ranking for all patients. In practice, the position of the reference plan was scored for each patient, and the parameter set that had the highest average placement of this plan was taken.

Results: It was possible to find a set of parameters that resulted in acceptable ranking for all patients. For 7 out of 8 patients, the reference

plan had the highest score. For 1 patient, the reference plan was ranked as 3th, however the alternatives all showed an acceptable alternative trade-off. For all patients, the ranking of the top best plans was intuitive. Patients with fewer criteria were successfully ranked using the same set of parameters.

Conclusion and outlook: Automated plan selection in radiation therapy is feasible based on fuzzy preference relations, and it is possible to tune towards a preferred solution.

Future work will involve physicians to select plans based on clinical experience, and assess the quality of the ordering in order to clinically validate the method.

4 - A New Decision Making Model for Bank Branch Location Selection

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In today's competitive world, you have to do your job without or with few mistakes for being successful. The way to be successful pass through having a good decision-making and planning processes. One of the most important factors providing the success to the company is its location. The right selection of branches for the companies like banks plays a major role in their success. Branches have also strategic importance on the performance and competitiveness. According to the improving technology and increase in distribution channels, location selection of a branch becomes a very important decision making process. The procedure of decision making process consists of deciding on the criterion that will be used; finding the importance of criterion; determining location alternatives and selecting one of the alternatives. The process includes several criteria (can be differ for each bank) which are based on the strategy, performance and the mission of the bank. The aim of this study is to provide a decision making model for branch location selection problem for a bank. To select the appropriate location, the criterion in locating the branches was selected with the help of experts and the literature review. The expert group consists of four people who are two academicians and two professionals working at the bank. The decision consists of four main criteria as; Demographic, Socio-Economic, Banking and Trade. The sub criterion for demographic: total population, population growth rate, population density; for socio-economic: employee rate, citizens living abroad; for banking: number of banks, number of branches, number of population per branches; for trade: number of

firms, number of organized industrial zone. AHP method and Voting Theory used as hybrid to find the appropriate branch location selection. AHP method used for to get the preference of the cities. Voting theory used for to find the appropriate branch location through cities.

★ TH-2- σ -HS5

◆ Multi Objective Optimization

Thursday, 10:30–12:10 – Room HS 5

Session: Advances in Multi Objective Theory 1

Chair: Matthias Ehrgott

1 - Optimality Conditions in Non-smooth Convex Multi-objective Programming Using Convexificators

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Studying optimality conditions for a mathematical programming problem is a very important issue in optimization. Such conditions are crucial in characterizing the solution set, sketching numerical procedures, and obtaining the duality results. Karush-Kuhn-Tucker (KKT) conditions are most popular and widely-used optimality conditions discussed in the literature. These conditions have been studied in many publications for smooth and nonsmooth convex programming problems in which the objective function(s) and constraint functions are convex. In many optimization problems, the feasible set is described by inequality constraints whose corresponding functions are not necessarily convex or even quasiconvex while the feasible set is convex. In recent years, KKT conditions for such problems, in the single-objective case, have been addressed by some authors in the presence of differentiable or locally Lipschitz constraint functions. In this paper, we consider a multi-objective programming problem whose objective functions are convex and its feasible set is a convex set described by some functions. The constraint functions are neither convex nor differentiable nor locally Lipschitz. Utilizing upper regular convexificators, we characterize the normal cone of the feasible set and then some necessary and sufficient optimality conditions are derived. Some applications of the obtained KKT conditions are highlighted as well.

2 - Two Methods for Finding Representations of the Nondominated Set in Multiobjective Optimization

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Generating all nondominated solutions for multiple objective optimization (MOO) problems may not always be desirable. For multiple objective discrete optimization (MODO) problems, the size of the nondominated set may be too large to be presented to a Decision Maker (DM). For the general case, the nondominated set can be a continuous set and presenting it directly to a DM may not be possible unless some interface is built to help the DM navigate in this set. Perhaps excluding some special cases, it is also computationally expensive to obtain the entire nondominated set. Therefore it makes sense to generate a finite subset of all nondominated solutions so as to be presented to the DM. Such subsets are called representations. Representations must possess some properties to ensure that they can be trusted as replacements of the nondominated set. In an effort to formalize attributes of quality, one of the measures proposed in Sayin (2000) is the coverage error which assumes that any nondominated solution is represented by an element of the representation that is closest to it according to some metric, and the overall error of the representation is determined by the worst-represented nondominated solution. Ideally, one should obtain representations that are guaranteed to meet quality specifications; however, this is not a straight-forward task because the nondominated set remains unknown throughout the process. Successful implementations of the idea are given by Sayin and Kouvelis (2005), Hamacher et al. (2007), Eusebio and Figueira (2014) for bicriteria problems. Generalizations to the p-objective case have remained elusive to date. In this work, we will describe two such attempts. The first is a method that generates representations with specified coverage errors for MODO problems with any number of objectives. We present a modification of the exact algorithm of Kirlık and Sayin (2014) to search the outcome space with p-dimensional rectangles. We solve two-stage optimization problems based on the epsilon-constraint scalarization to find nondominated solutions. During the search, any rectangle that satisfies the desired coverage error level is removed from the search list. Since the expensive computation of the exact coverage error constitutes a shortcoming of our approach, we propose an upper bound that is easier to compute. In our computational experiments, we observe benefits when compared to finding all nondominated solutions. The improvement is more pronounced when subproblems are difficult to solve. While partitioning the search space into non-overlapping rectangles, our epsilon-constraint based subproblem is not able to deliver nondominated solutions exactly within

a particular rectangle due to its nature. This might lead to redundancies in computation. Motivated by this observation, we propose an alternative method that applies to general p-objective MOO problems. The method relies on a subproblem that is based on bilevel programming and is able to deliver a representative element from a chosen rectangle provided that such a solution exists. Our preliminary experimental results are promising for problems of reasonable size. The subproblems become more difficult to solve for larger problems. We believe further improvements may be possible by focusing on efficient solution of the subproblem.

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3 - Optimization over the Weakly Efficient Set of a Multiple Objective Linear Programming Problem with Reverse Convex Constraint

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In this talk, we consider a problem (OES) to minimize a linear function over the efficient set of a multiple objective linear programming problem (MOLP), where one constraint is defined by a strictly convex quadratic function and the other constraint functions are convex. An example of (OES) is furnished by the portfolio optimization problem in capital markets. A fund manager may look for a portfolio which minimizes the transaction cost on the efficient set. It is known that the feasible set of (MOLP) is formulated as a dc set. Hence, it is not always true that the efficient set of (MOLP) is connected. One of the reasons of the difficulty to solve (OES) is

that confirmation of the weak efficiency of feasible solutions for (MOLP) is hard. Hence, we formulate a quadratic programming problem (QP) for checking the weak efficiency of a given feasible solution. Moreover, it is shown that (QP) can be solved by listing Karush-Kuhn-Tucker points. Furthermore, we propose a global optimization algorithm for (OES) by combining a branch-and-bound procedure and a method listing all KKT points of (QP). In order to verify the effectiveness of the proposed algorithm, we show the computational experiments.

4 - Problem decomposition integrated with the bi-objective simplex method

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We propose a novel approach that ultimately enables solving large-scale bi-objective linear optimisation problems in particular those with a prohibitively large number of variables.

Bi-objective linear programmes can be solved using a bi-objective version of the simplex method, known as parametric simplex algorithm. First one of the lexicographic solutions of the problem is obtained. The bi-objective simplex method then iteratively moves from one efficient basic feasible solution to the next by choosing entering variables that correspond to a maximum ratio of improvement of one objective function and deterioration of the other (as represented by reduced costs of variables).

Problem decomposition approaches are used to deal with single objective optimisation problems that have a prohibitively large number of decision variables. A decomposition approach for solving such a large-scale problem starts by solving the problem (also known as master problem) to optimality while considering only a subset of decision variables. New variables are then generated and added to the formulation on-the-fly, as the solution process progresses. This works by solving carefully chosen sub-problems the optimal solutions of which correspond to new variables that are candidates to enter the basis of the current optimal solution of the master problem and improve it. This is achieved by defining sub-problems according to reduced cost information associated with the current solution of the master problem. Solution optimality can be guaranteed once there are no more entering variables, even if not all variables have been enumerated in the process. This allows tackling large optimisation problems as only a subset of variables have to be considered in the process.

We show how to integrate such decomposition (or column / variable generation) techniques with the bi-objective simplex method. Again, only a subset of variables is considered initially and a standard single objective decomposition approach is used to identify a first solution which is optimal for the first objective. In the bi-objective case sub-problems must be adjusted to the variable entering criterion of the bi-objective simplex method and hence become fractional linear programmes. We explore different formulations for the arising sub-problems. Firstly, the fractional linear programme can be converted into a linear programme by applying the Charnes-Cooper transformation. Secondly, we observe that solving this fractional linear programme can also be achieved by identifying a specific extreme efficient solution of a related bi-objective linear programme. More specialised sub-problem formulations can be derived when dealing with a problem of a specific structure. An example of this is the bi-objective multi-commodity network flow problem which can be solved using a bi-objective decomposition technique where, in each iteration, one sub-problem is solved for each commodity. This bi-objective linear programme representing the sub-problem can then be solved by solving path problems.

★ TH-2- χ -HS6

◆ Environment, Infrastructure & Emerging Applications

Thursday, 10:30–12:10 – Room HS 6

Session: IS-INFRA: MCDA for Infrastructure Planning and Environmental Management

Chair: Valentin Bertsch

1 - Eliciting probabilistic long-term forecasts for the drivers of greenhouse gas emissions in South Africa

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Multi-criteria decisions often require an assessment of how attribute evaluations are expected to evolve in the future. Where the mechanisms underlying the attributes are poorly understood, or subject to large uncertainty, or projections are made far into the future, the assessment process can quickly become extremely difficult. We report a project deriving baseline forecasts of carbon dioxide and other greenhouse gas (GHG) emissions for South Africa to 2050. We focus on the elicitation of a small numbers of key drivers of GHG emissions, for which we used a mixed methodology combining expert elicitation, reviews of available local and international liter-

ature, and probabilistic modelling. The results are probabilistic time series that is, they are trajectories rather than point-in-time estimates, and they include assessments of statistical uncertainty around the modal or most-likely trajectory. We contrast the approach with scenario planning and other tools for long-term planning.

2 - Integrating stakeholders in an MCDA-process for sustainable water infrastructure planning

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Infrastructures of the water supply and wastewater system, including water pipes and sewers, treatment plants, and other structures, are of vital importance to our society. They deliver clean water, ensure the environmentally friendly and hygienically safe disposal of wastewater, and they provide flood protection. However, these infrastructures are long-lived, aging, and expensive. It is estimated that in Switzerland, the public water infrastructures need investments of 81109 CHF in the next 40 years. Due to their longevity, the planning of infrastructures is a demanding task, which is strongly influenced by uncertainty such as climate change effects (e.g. heavy rainfalls), and socioeconomic developments. As in other countries, current infrastructure planning procedures do not systematically integrate future uncertainty, past experiences, and the opinions of different stakeholders. The SWIP-project (“Sustainable Water Infrastructure Planning”: www.eawag.ch/swip) was set up to address these deficiencies. Main goal of SWIP was to provide an improved planning procedure that balances economic, ecological, and social aspects.

SWIP developed a Multi-Criteria Decision Analysis (MCDA) framework that allowed to integrate engineering modelling with societal data. It was developed in a case study near Zurich that consists of several smaller municipalities. In this talk, we focus on stakeholder participation through different stages of the MCDA project, including the problem structuring phase, and the later elicitation of the stakeholders preferences to be included in MAUT-models.

To select main stakeholders and identify their interests, concerns, and interactions with each other, we combined a stakeholder with a social network analysis, based on 27 face-to-face interviews. The combination of these two methods

provided very useful insights into the decision problem that could not have been gained with one method alone. Based on this analysis, a study of the literature, and existing engineering requirements, a preliminary objectives hierarchy was set up, which was strongly discussed and adapted in a stakeholder workshop.

To capture future uncertainty about socioeconomic developments we combined scenario planning with MCDA. The scenarios were adapted to the case study in a very refreshing workshop with the local stakeholders. The stakeholders also used these scenarios as stimulating background to develop decision alternatives. This creativity technique was combined with a rather rigorous approach, namely strategy generation table, to ensure that important elements were covered by the decision alternatives. The 14 alternatives consisted of different technical configurations (e.g. central vs. decentralized water supply and wastewater treatment), different rehabilitation strategies (e.g. continuous vs. no rehabilitation), or different management approaches (e.g. public vs. private utilities).

In a later stage, the preferences of ten stakeholders of the water supply and ten of the wastewater system, respectively, were elicited using a combination of online questionnaires with face-to-face interviews. Hereby, a shortened (but still laborious) procedure to elicit the preference data required for MAUT was developed; i.e. concerning the shape of the marginal value functions, the weights, the aggregation model, and the stakeholders risk attitude. We also carried out an online survey (N=314) to elicit the preferences about the main objectives from the public. Interestingly, there were some consistent patterns: “good water supply”, “safe wastewater disposal”, and “protection of water and other resources”, were perceived as more important than “low costs” or the objectives assigned to “high social acceptance”. “Intergenerational equity” was perceived as fairly important by many stakeholders, but others regarded this as rather unimportant.

In this talk, we will present the main results of the MCDA concerning the stakeholder preferences, but not any MCDA-technical details. We found that it was possible to identify compromise solutions that were robust despite large uncertainties of the data, the predictions, the stakeholders preferences, and of the future. Of the scenarios, especially the Boom scenario that assumed strong economic and demographic growth heavily affected the results. For all stakeholders, the current centralized system for water supply and wastewater disposal performed relatively well; however, especially if it included better maintenance of the water supply and sewer pipes, i.e. a proactive rehabilitation strategy, improved collaboration between municipalities and sectors, and better wastewater treatment to remove pharmaceuticals. Interestingly for the wastewater system, a very unconventional alter-

native that assumes a fully decentralized system (without sewers) performed even better. This alternative assumes high-tech treatment of the wastewater and additionally urine source separation, which allows to recycle phosphate as fertilizer. For water supply, the existing central water distribution system could be improved if it were combined with decentral water tanks for firefighting.

The results were shared with the participants in our study, and discussed in a larger workshop with 100 practitioners from the Swiss water sector. In the talk, we will present the mentioned main aspects in more detail. We will focus on the pros and cons of the different elements of stakeholder participation used in the SWIP-project, on lessons learnt, and recommendations for future projects. The decision support procedure is modular; the framework and MCDA-elements were set up in such a way that they are applicable to other water infrastructure decision situations and settings.

3 - Tackling uncertainties in multi-criteria decision analysis applied to water infrastructure planning decision support

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A new approach for tackling uncertainties in preference elicitation and predictive modeling of complex MCDA/MAUT problems and its application to water infrastructure planning in Switzerland will be presented. To this end, a two-step procedure for preference elicitation is combined with uncertainty and global sensitivity analyses (UA, GSA). This covers uncertainty of the preference components (marginal value and utility functions, hierarchical aggregation functions, aggregation parameters) and the attribute predictions. Context uncertainties about future socio-economic developments are captured by combining MAUT with scenario planning.

We perform a global sensitivity analysis (GSA) to assess the contribution of single uncertain preference parameters to the uncertainty of the ranking of alternatives. This is done taking into account the implications of five different GSA designs regarding the choice of the feasible sam-

ple space. We will show the usefulness of UA and GSA to explore the importance and contribution of often ignored uncertainties and to focus on those crucial for discriminating alternatives. Based on these results, we will furthermore demonstrate that a priori assumptions such as linear value functions or additive aggregation can result in misleading recommendations, unless thoroughly checked during preference elicitation and modeling.

This work has been recently published (Scholten et al. 2015). We now strive to adapt this work such that GSA can be used to inform the decision analysis process about the most sensitive parameters before detailed preference assessment and attribute prediction is undertaken. We will present an outlook on work in progress and some challenges faced in further developing the framework. This framework will be beneficial for water infrastructure planning and other complex planning situations, as it allows to identify which components of the overall MCDA it is worth to focus efforts on, and under which conditions.

Reference: Scholten, L., Reichert, P., Schuwirth, N., Lienert, J., 2015. Tackling uncertainty in multi-criteria decision analysis- An application to water supply infrastructure planning. *European Journal of Operational Research* 242(1) 243-260.

4 - Optimal load shedding in power distribution grids based on multi-attribute utility functions for demand side flexibility

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Power generation in Europe continues to shift from centralised thermal power plants to decentralised, renewable energy sources. Among others, an expansion of smart grid technologies in distribution grids shall foster demand side flexibility and help to cope with the rising challenges of grid operation. At the same time, the ongoing electrification leads to a rising importance of power supply security for basically all critical infrastructure (CI) sectors and the society as a whole. As a result, the interdependencies between information and communication technology ICT, power supply and other CI sectors increase constantly and the consequences of potential power shortages continue to become more far-reaching regardless of their origin. Our long-term target is therefore the provision of decision support for designing resilient CIs. Focussing on the CI sectors power supply and health care, we developed an approach for analysing the con-

sequences of CI disturbances (power shortages) and of measures for maintaining the grids operability under such disturbances as a major input to reach our long-term target.

Here, load shedding strategies constitute an important group of measures to be considered and it should be noted that the increasing diffusion of ICT will provide new technological possibilities in this regard. Most existing optimal load shedding approaches, however, are either based on a mere prioritisation or on cost functions. Our approach uses multi-attribute utility functions describing the loss in utility induced by a non-delivery of power for a certain consumer. For critical infrastructure elements connected to the power grid (e.g., health care facilities), the utility function incorporates information on their load profiles and coping capacities (e.g., auxiliary power units), an essential time-dependent component to be considered. For residential consumers, the utility function incorporates information on their load profiles and appliance utilisation preferences elicited within a nationally representative survey for Germany. Our approach is formulated as a nonlinear optimisation problem and solved by an interior-point method. We demonstrate our approach using a 33 bus reference grid. Our results reveal that the loss in utility can be minimised in comparison to traditional approaches by reallocating the non-delivery of power between critical infrastructure and residential nodes.

Thursday, 13:30–15:10

★ TH-3-β-HS1

◆ Decision Aiding

Thursday, 13:30–15:10 – Room HS 1

Session: Decision Aiding: Emerging Applications 2

Chair: Klaus-Peter Scherer

1 - Decision Support To Air Rescue Unit Allocation In Disaster Management Operations – A MCDM Application

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Many countries experiences every year several natural disasters or human catastrophes which takes thousands of millions souls. Many predictive mechanisms for different types of natural disasters have been developed in order to try to minimize the amount of victims, which has

reached such a successful level. However, even with all these predictive systems, natural disasters still happens and will continues to occurs. After a disaster break up, the response phase is the mainly way to save affected people. Rescue helicopters have a valuable role in this phase, reaching and finding unreachable sites where a fast victims rescue action is needed. The allocation of these air rescue units, however, requires a high knowledge's level about certain conditions to avoid accidents and consequently more deaths. These conditions are most of times uncertain and its analysis and trade-offs must be thoroughly done to a successfully mission accomplishment. This paper aims to suggest a methodology to support the air rescue unit allocation decision in a natural disaster response phase context.

2 - An integrated model of service improvement for hot spring tourism based on SIA-NRM approach

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Taiwan is rich in hot springs and however the promotion and utilization of hot spring for tourism is still imperfect. Consumers could only have limited choice for hot spring tour under asymmetric information. Therefore the crowd surge in specific hot spring areas on holidays. It not only lowers the quality of services of facility, but also increases the price of accommodation there. The distribution of hot spring is dispersed discretely and widely in Taiwan and not all the hot springs could be developed and utilized effectively. This research considers that integrated tourism resources and multiple information services of hot springs could serve different customers for various demands. This research would like to find out the decision-making behavior of hot spring tourists by their own preference. This research extracts the influence relationship between the actuation factors of traveling hot spring (experiences of service, facilities of service, price of service, images of service and planning of routes) and traveling decision-making (traveling behavior, degrees of satisfaction and behavior of revisit). It could be analyzed that how the routes of hot spring influence the satisfaction degree of the tourist, and the key factors influence the behavior of traveling and revisiting of the tourists. Through the combined analysis of SIA (Satisfaction importance analysis) and NRM (Network Relation Map), the results offer service providers to select service strategies influencing the traveling decision-making of the tourists. Meanwhile, the high quality service and experiences of service for the tourists could be provided by the improvement of the driving inducements of tourism service.

3 - A context-aware approach of multi-criteria decision making for social network analysis

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The context-awareness is the knowledge background that the agents take into account in doing their decisions. It allows to consider the multidimensionality of the interaction space where decisions and criteria evolve. The idea is to redesign the concept of space making it smart and allowing the single agents to communicate and interact through the global social environment. In a social network, the interaction among nodes, or agents, is able to carry on a strong cognitive value. This process has a strong impact on the context, in which every agent operates. A network node becomes an aware agent capable of interacting within a community or among different communities, sharing its own knowledge, perception and awareness. Through social interaction, the network structure, promoting transmission of social objects, enclosing opinions, data, influences, decisions, enhances the collective knowledge and individual awareness. The space becomes a powerful environment, where each phenomenon has its own dynamic and moves as a flow across bubbles. The intensity of the flow depends on how each agent has a cognition of its neighborhood, of the environment in which it operates and, therefore, of the entire space in which it can act. This bio-inspired and social-based process rules the situated cognition of each agent inside a network smart space.

In this perspective Multiple Criteria Decision Making (MCDM) has to take into consideration the evolution of the preferences due to interaction with other agents within a smart space.

This approach constitutes a change of paradigm for MCDM and requires a re-conceptualization of the main aspects in the discipline. Each agent takes decisions considering not only its current individual preferences, but also the preferences arising from the smart space, for example preferences of agents with which there is an interaction. This increases the complexity of MCDM models that have to handle also the greater uncertainty of the considered environment. We discuss some implications of considering a smart space within current MCDM models.

4 - Decision Support for Ophthalmic Applications

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Problem and medical background In the biomechanical system of the human eye, the natural intraocular lens system is the most important organ for the refraction process to focus the external incoming rays to the retina. Parallel to the human aging process there exist no possibility to prevent a fix, dark cloudy lens with medical treatment. A so called cataract (dark lens) must be removed and it is replaced by a new artificial clear lens. The goal of this proposal is the development of an intelligent information system, which supports the decision making process of the ophthalmologists for complex surgical interventions (especially in cataract surgery) by logical reasoning. The aim is to enhance the human decision quality by a formal description of the knowledge and the relations between the knowledge. In this way, a consistent knowledge base is responsible for an adequate decision making support and guarantees a high quality operation process.

Methods The domain of the ophthalmic expert knowledge including deep reasoning correlation is represented by knowledge based methods and ontologies. A semantic network is developed, which uses frame based concepts of the partial knowledge domains. Concerning preoperative conditions, patient situation, surgical methods and postoperative actions different attributes with numerical as well linguistic values influence the decision. The representation of the dependencies between these concepts is given by complex constraints. For that, a special semantic Wiki based system is developed to represent the descriptive information to the surgeons. Additionally to this semantic network, different visualization models are used to show the refine-

ment of the concepts and the relations between them as basics for an intelligent human decision process. In this way a semantic network is established, which enables a semantic navigation within the decision support system.

Results A computer based assistance and decision support system is developed, which supports the clinical experts for operational planning before the real intervention at the patients as well as for postoperative actions. Ophthalmic knowledge is represented in semantic networks and ontologies. The information for the medical experts concerns not only the diagnostics and patient specific data, but also the related postoperative effects. From the clinical view, the optimization based on the dependencies of the parameters is very complex and it could be increased by a computer based support. The knowledge can also be included in the operation planning acts. With a useful visualization the knowledge and the structured correlations are represented to the user (ophthalmologist) in a very convenient way.

Conclusions In the instantaneous state the ontologies of the assistant support system are responsible for giving information about patient data, measured data, diagnostics, surgical methods and intraocular lens types. Furthermore the attribute related reasoning process between them is a very important criterion for the decision making. Based on different visualization models and on the semantic network there exist a useful comfortable access for the proposed decision in the cataract surgery. The target is to enhance the competence of the system by regarding special constraints and to integrate self learning mechanisms based on structured patient data. So the knowledge base can enhance in a consistent manner. In a first step, the existing knowledge base should be evaluated by new acquired process data before generating in a next step new concepts and correlations related on the case based patient attributes.

The project is a cooperation of the Karlsruhe Institute of Technology, Germany (KIT) and the denkbare GmbH. It is funded as a ZIM-KOOP project by the German Federal Ministry of Economics and Technology (BMWi).

★ TH-3-γ-HS2

◆ Model Building

Thursday, 13:30–15:10 – Room HS 2

Session: Data Envelopment Analysis

Chair: Marcus Brandenburg

1 - Efficiency Measures in Fuzzy Data Envelopment Analysis with Common Weights

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This work considers providing a common base for measuring the relative efficiency for all the decision-making units with multiple fuzzy inputs and outputs under the fuzzy data envelopment analysis (DEA) framework. It is shown that the multi-objective fuzzy DEA model can be reduced into an auxiliary bi-objective fuzzy optimization problem by considering the most and the least favorable conditions simultaneously. An algorithm with the implementation issue for finding the compromise solution of the fuzzy DEA program is developed. A numerical example is included for illustration and comparison purpose. Our results show that the proposed approach is able to generate a common set of weights, which not only differentiates efficient decision-making units with fuzzy inputs and outputs but also detects abnormal efficiency scores on a common base.

2 - An Overall Efficiency-Based Resource Allocation Problem in Data Envelopment Analysis

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Resource Allocation (RA) problem is an important issue in Data Envelopment Analysis (DEA). It deals with assigning a given amount of inputs among different Decision Making Units (DMUs). In this study, we consider an overall efficiency approach for Resource Allocation (RA) problem in Data Envelopment Analysis (DEA). Our aim is to allocate extra available inputs among Decision Making Units (DMUs) in a way that their overall efficiency are improved or stay unchanged after RA. We formulate a Multi-Objective Linear Programming problem model. This research is important in different aspects. Firstly, overall efficiency improvement is considered for the first time in RA instead of technical efficiency. Secondly, we formulate RA problem via a multi-objective linear programming problem and instead of applying scalarization methods, we use Pareto Race to directly search the efficient frontier for finding the best resource allocation.

3 - Modelling the Moderating Factors

and Drivers of New Product Portfolio Management

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New Product Portfolio Management (NPPM) deals with the coordination and control of multiple projects pursuing the same strategic goals and competing for the same resources, whereby managers prioritize among projects to achieve strategic and benefits, optimize resource allocation and improve profitability. In such a scenario, identification of drivers and moderating factors that impact the decision making process and formulation of portfolio is significantly important for an efficient management of New Product Portfolio (NPP). In literature, major focus was given to Identification of Criteria to evaluate projects, Project Evaluation and Selection (PES) Models, MCDM Models and DSS for Portfolio Formulation. These models, though received major attention from academicians implementation of these models is found to be minimal by practitioners. To extend our scope beyond literature we employed qualitative research methodology of case let, to study NPPM in industries and identify drawbacks of the existing models. As it is considered to be appropriate methodology to be used when knowledge on perspective of the objectives are not addressed in literature and existence of uncertainty is observed. Consideration of moderating factors and drivers impact while developing these models didnt receive much research focus and this gap observed in literature turned out be major reason why the developed models are not being implemented in major scale.

In this paper, we make such an attempt to identify various drivers and moderating factors that affect NPPM. So, 4 case-lets for each three sectors (Machine Tools, Automobile Components and Electronic Components) of manufacturing industries are conducted to study decision making process of NPPM. Case-let analysis implies the following:

- (1) industries are in a need of a decision making tools and metrics for efficient management of product portfolio
- (2) the efficiency of NPPM depends upon different moderating factors and these moderating factors varies with respect to different drivers
- (3) industries expressed need for a knowledge base system to implement different metrics/ models for portfolio formulation.

In this paper, we present methodology for modelling case-let implications and incorporating moderating factors and drivers into proposed Decision Support System (DSS). The DSS is based on concepts of weighted Data Envelopment Analysis (DEA) and improvised Balanced

Scorecard (BSC) approach. BSC provides an integrated view of overall organisational performance and strategic objectives. It has proven to be a powerful tool for strategic planning and communicating strategy that assists in strategy implementation. The weighted DEA, quantifies some of the qualitative concepts of BSC approach. Further, DEA is considered to be efficient methodology for multi objective decision making where qualitative and quantitative criteria are involved. The proposed methodology is implemented in MATLAB and workability is demonstrated by developing suitable numerical example. Further, the DSS is proposed to be validated on real life data, which would be the immediate future work of our research.

4 - A data envelopment analysis of financial performance evolutions in automotive supply chains

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Supply chain management (SCM) has become an advantage in the competition between single firms as well as between different supply chains. Conceptual frameworks explain that SCM helps enterprises to achieve and maintain a good financial performance. However, linking SCM to profitability and value creation in a quantitative way remains problematic. As a consequence, empirical studies or formal models that quantify these links across several supply chain echelons are scant. Traditionally, linear regression models and event studies are employed to empirically evaluate the coherence of SCM and financial success, but such analyses do not cover several supply chain echelons or take into account the different supply chain positions of the evaluated firms. The proposed paper picks up this research gap and assesses financial performance evolutions in the automotive supply chain. A sample of 33 decision-making units (DMUs), 17 globally operating automotive manufacturers and 16 suppliers, is in focus of a data envelopment analysis (DEA) in which cost levels and capital requirements are put into relation to sales volume and profitability. Cost of goods sold, working capital and fixed assets represent the financial input of a company while sales and earnings before interest and taxes (EBIT) reflect the its financial output. The financial performance of a firm is indicated by its efficiency, calculated by a constant returns to scale model as well as by a variable returns to scale model.

In order to reveal performance evolutions and changes in performance leaders and followers over time, a longitudinal DEA approach is chosen that covers a time horizon of five years (2008-2012). Furthermore, the study elaborates on

geographical and structural specifics of different DMU groups, such as performance differences between European, Asian and US companies or between original equipment manufacturers (OEMs) and suppliers. Additionally, the number of the links between peer DMUs and follower DMUs is detected as well as and the strength of each link. Due to the fact that the DEA is executed for several years, the stability of these relationships over time is assessed.

★ TH-3-δ-HS3

◆ Industry and Business Applications

Thursday, 13:30–15:10 – Room HS 3

Session: Transportation and Inventory Optimization

Chair: Sandra Huber

1 - Multi-Objective Transportation Problem for Green Logistics in the Pyrenees by Mixed Integer Programming

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This contribution presents a multi-objective transportation problem formulated by mixed integer programming. The problem deals with green logistics for routes crossing the Pyrenees in Navarre, Spain. The objectives are the minimization of the travelled distance by the running vehicles, the minimization of the environmental impact caused by fuel emission and the maximization of the service level provided by the company responsible for the distribution. Constraints ensure that all vehicles begin and end their routes at the depot and that subtours solutions are going to be avoided. Analyses of obtained results could help logistics managers to lead the initiative in area of green logistics by saving fuel, maximizing service level and implementing backhauling for reduction of the amount of empty-running in delivery activities.

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2 - Multicriteria Optimization of Inventory Routing Considering Stock-out Risk, Distance Cost, and Inventory Cost

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The Inventory Routing Problem (IRP) [1] is a recently discussed combinatorial optimization problem that combines aspects of the vehicle routing and the resource allocation problem. The goal is to schedule vehicles for periodically repeating delivery tasks in a way that the covered distance is minimized and the inventory costs of the clients are minimized. Moreover capacity constraints, both for the vehicles and the inventory storage, need to be taken into account. The IRP problem complexity is NP hard, because it is required to solve NP hard vehicle routing problems. This can be done in a bi-level algorithm [1]. The IRP is solved using metaheuristics and for the bi-criteria case (distance, inventory cost) Pareto front approximation algorithms have recently been made available.

Extending the work on a bi-criteria problem formulation[1], we will present first results on a tri-criteria formulation of this problem that accommodates also stock-out risk as a third objective function. We discuss a cooperative swarm based bilevel optimization algorithm for approximating the 3-D Pareto front. It will be discussed how algorithm performance relates to parameter settings and an interpretation of the obtained 3-D Pareto front is provided.

The objective function stock-out risk is modeled by minimizing the amount of stock-out in the worst case, when the customer demand is given by an interval instead of a fixed value, as it was done in previous studies.

Finally, we will discuss possible alternative problem formulations and what data is required for making these test cases more realistic. In particular we discuss what data and changes to the algorithm would be required to extend the current possibilistic to a more accurate probabilistic model.

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3 - Inventory Management of Perishable Products With Multi-objective Framework

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Perishable products inventory management requires different treatments than the traditional inventory management due to the limited shelf lives. So far the literature mainly focused on optimal policies only include cost concern of decision makers. This study suggests different inventory policies for perishable products that take into account age of the products with multiple objectives. Since customers choice is influenced by the freshness of products, we explicitly consider freshness level, availability of products besides cost objective in multi-objective setting. We propose and optimize different heuristics inventory policies to overcome complexities of inventory management of perishable products due to requirement of tracking the age of the products.

4 - Dealing with Scarce Optimization Time in Complex Logistics Optimization: A Study on the Biobjective Swap-Body Inventory Routing Problem

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We investigate a biobjective Swap Body Inventory Routing Problem (SB-IRP). This is a combination of the Swap Body Vehicle Routing Problem (SB-VRP), which minimizes fixed and variable routing costs, and the Inventory Routing Problem (IRP). Our problem is based on the context of the VeRoLog Solver Challenge 2014, where our proposed VeRoLog Solver was ranked third, and our previous work on the IRP. Since we are investigating a multi-period problem, an additional objective function is formulated which includes inventory levels at the customers. Dealing with the allocation of scarce optimization time to the VeRoLog Solver is an essential topic, since an alternating approach of the determination of a replenishment strategy and the routing is considered. We propose an Iterative Variable Neighborhood Search and analyze the allocation of the computational time by extended VeRoLog test instances.

★ TH-3-κ-HS4

◆ AHP/ANP

Thursday, 13:30-15:10 – Room HS 4

Session: IS-AHP-TA: Theory and Applications of the AHP/ANP 2

Chair: Pekka Korhonen

1 - On efficient weight vectors from pairwise comparisons

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A weight vector is called efficient, if there exists no other weight vector such that the latter approximates all the elements of the pairwise comparison matrix at least as well as the former does, and strictly better in at least on position. For example, the geometric mean, the optimal solution of the logarithmic least squares problem, is efficient.

A pairwise comparison matrix is called simple perturbed if it differs from a consistent pairwise comparison matrix in one element and its reciprocal. It is shown that the right Perron eigenvector of a simple perturbed pairwise comparison matrix is efficient.

In another class of pairwise comparison matrices, the right Perron eigenvector is proved to be inefficient. Finally, linear programs are written to check whether a given weight vector is efficient.

2 - Visualization of Inconsistency of a Pairwise Comparison Table in the AHP

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The analytic hierarchy process (AHP) by Saaty is a decision making method that can utilize our experience and intuition. Pairwise comparisons among items in the same level of a hierarchy play a vital role in this method. These pairwise comparisons usually include inconsistency. That is why human being cannot completely evaluate items with a ratio scale. Besides, there is another problem with the fundamental scale of absolute numbers for pairwise comparisons in the AHP, although that is very helpful for AHP users. In order to overcome the problem of inconsistency of pairwise comparisons we know an index such as C.I. by Saaty. We generally regard a pairwise comparison table, or matrix, as consistent enough if C.I. is less than 0.1. Otherwise, we need to revise some pairwise comparisons. We also know some ways to mechanically revise them by the founder or other researchers. However, those ways often construct black boxes to AHP users. For example, they are given only a revised result and cannot know how much the pairwise comparison table was improved. In this study I propose a new way to visually find out the origins of inconsistency of pairwise comparisons. It is to use the notation of a pairwise comparison table according to new rules. This notation is helpful for AHP users. They can easily cancel inconsistency of pairwise comparisons and visually confirm consistent of them. Moreover, this notation is easy to calculate and to clarify relationships among items in the same level, although it is inconvenient to comprehend relationships

among criteria and alternatives in a whole hierarchy. It is based on how many items each item is more important than. We need some theorems in mathematics in order to define this notation. Then it is also shown that the weights of items in the same level are independent upon the order of items in a pairwise comparison table. As far as I know, this fact has not been discussed in previous literatures. I will show three types of examples. This proposed notation does not satisfy uniqueness in terms of mathematics. Nevertheless, it follows from these examples that it is useful to apply to practical problems.

3 - Axiomatic properties of inconsistency indices for pairwise comparisons

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The technique of pairwise comparisons has been used in many decision making methods, as for example the analytic hierarchy process. A fundamental concept is the idea of consistency of preferences, and many inconsistency indices have been proposed in the literature to estimate the inconsistency of pairwise comparison matrices. Such indices are not only used to estimate inconsistency, but also employed in the determination of the priority vector and in the estimation of missing comparisons, to mention two examples. Formally, inconsistency indices are functions mapping pairwise comparison matrices into the real line with the rule that the higher the number associated to a matrix, the greater its inconsistency. Clearly, not all functions mapping matrices to the real line can be used as inconsistency indices.

With these premises, we present and justify a set of properties necessary to define meaningful inconsistency indices. By proving the independence and the logical consistency of the properties we are able to formulate them in the form of an axiomatic system. Furthermore, we shall check if existing indices satisfy the axioms and find out that, in fact, many do not.

4 - Setting “Condition of Order Preservation” Requirements for the Priority Vector Estimate in AHP is not Justified

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We demonstrate that the Condition of Order Preservation proposed by Bana e Costa and Vansnick (2008) for the priority vector in AHP is based on the very restrictive assumption that only the direct (explicit) pairwise judgments matter in estimating the priority vector. Bana e Costa and Vansnick (2008) criticize the use of the eigenvalue method as an estimation technique

because the derived priority vector at times may not satisfy the Condition of Order Preservation requirement. Their criticism, however, is not justified because the consistency measure of the AHP provides additional implicit information about the preference ratios that has to be taken into account and Saaty's (1977) eigenvalue method does this. In the examples given in this presentation the priority vectors are estimated using both the eigenvalue method and the regression technique. The results are quite similar.

★ TH-3- σ -HS5

◆ Multi Objective Optimization

Thursday, 13:30–15:10 – Room HS 5

Session: Advances in Multi Objective Theory 2

Chair: Alexander Engau

1 - Approximate proper efficiency in vector optimization with variable ordering structure

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A very important solution concept in vector optimization, which plays a crucial role from both theoretical and practical points of view, is proper efficiency notion. Properly minimal solutions have been introduced at first to eliminate the minimal points with unbounded trade offs. This concept has been defined in the literature in different senses and such solutions have been characterized utilizing different tools. On the other hand, vector optimization problems with variable ordering structures have been investigated by various scholars in the recent years. These problems, in which the ordering cone depends on the image point under consideration, are more general than classical ones. In the recent decades, there has been a lot of attention to approximate solutions of optimization problems due to two facts. Firstly, numerical algorithms may generate only approximate solutions to optimization problems, and secondly the set of exact solutions may be empty in some practical problems whereas approximate solutions exist.

In this paper, we study approximate proper efficient (nondominated and minimal) solutions of vector optimization problems with variable ordering structures. Approximate proper efficient/nondominated/ minimal solutions are defined in different senses (Henig, Benson and Borwein) for problems with variable ordering structure from new standpoints. The relationships between the introduced notions are studied, and furthermore, some scalarization approaches are developed to characterize these solutions. More-

over, some existence results are addressed. Notice that, here, efficient, nondominated, and minimal solutions are different solution concepts, due to the variable ordering structure.

2 - Multiobjective Programming Applied to Econometric Models. A Theoretical Framework.

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In this paper, we propose a theoretical framework which combines econometric and multiobjective programming methodologies to help researchers and/or decision makers to achieve optimal solutions to socio-economic problems. Broadly speaking, econometrics is aimed at giving empirical content to economic model, in order to forecast how some variables will be affected in the future conditional on the changes in some others. Regression analysis is the most extended methodology used to study the relationship existing between the (endogenous) response variables and the explanatory variables (exogenous) considered. By studying the regression model, interesting relations and dependencies between the explanatory and response variables can be extracted, which in turn provide some interesting conclusions about the phenomenon studied itself. However, certain degree of conflict may be observed among the set of outcome variables under scrutiny in the problem. In such situations, based on these results, a multiobjective optimization problem can be formulated from the coefficients estimated in the econometric model. Afterwards, the application of multiobjective optimization techniques can enable us to find optimal solutions to the problem which the classical econometric techniques are not able to provide. This is the main contribution of the combined methodology proposed. Furthermore, the present work tries to fulfil the existing gap among econometrics and multiobjective optimization, to the extent that previous literature on this is almost non-existent and consists of just few articles focused on certain practical examples.

3 - Proper efficiency and tradeoffs in multiple criteria and stochastic expected-value optimization

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The mathematical equivalence between linear scalarizations in multiobjective programming and expected-value functions in stochastic optimization suggests to investigate and establish further conceptual analogies between these two areas. In this talk, we will focus on the notion of proper efficiency that allows us to provide a first comprehensive analysis of solution and scenario tradeoffs in stochastic optimization. In generalization of two standard characterizations of properly efficient solutions using weighted sums and augmented weighted Tchebycheff norms for finitely many criteria, we first show that these results are generally false for infinitely many criteria. Second, we are also able to prove that expected-value optimization over continuous random variables still yields bounded tradeoffs almost everywhere. Further consequences and practical implications of these results for decision-making under uncertainty and related theories and methodologies of multiple criteria, stochastic and robust optimization are discussed.

★ TH-3- χ -HS6

◆ Environment, Infrastructure & Emerging Applications

Thursday, 13:30–15:10 – Room HS 6

Session: Infrastructure and Location Analysis

Chair: Götz Vollmann

1 - Plant location selection under uncertainty A case study of an American family owned manufacturing company in Asia

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This paper presents an application of the evidential reasoning (ER) approach along with the support of the Intelligent Decision System (IDS) to aid decision makers for plant location selection under uncertainty in an American family manufacturing company in Asia (the company). The decision criteria of plant location are firstly established through literature review and interview with the owners and management team of the company. The process of model building, data collection and aggregation, and the graphical presentation of outcomes are described. The outcomes of two approaches are discussed, which demonstrates advantages of the developed ER methodology in aiding the decision analysis for plant location selection under uncertainty.

2 - Application of Interpretative Struc-

tural Modeling in Determining Dominant Criteria of Information System Success Model at Handcraft Small Medium Enterprise in Yogyakarta Indonesia

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Business in small medium enterprises (SME) is a part of industrial development in Indonesia. There are many handcraft SMEs in Yogyakarta. The handcraft SMEs has strategic role as catalyst of local economic growth and community participation. They have limited utilization of technology, especially utilization of information system (IS). In the preliminary research, researchers identified that most of all handcraft SMEs are still in manual administration. The purpose of this research is to determine the dominant criteria of IS success. Researcher used interpretative structural modeling (ISM) to determine the dominant criteria. For the success model, researchers used Gable IS Impact Model, with 4 dimensions (system quality, information quality, individual impact, organizational impact) and 37 criteria. Sixteen handcraft SMEs (divided in 4 types of SME namely pottery, leather, wood, metal) were involved as research objects in this research. After the group discussion forum conducted separately, researcher found 3 IS criteria cluster of handcraft SMEs. It is observed that three criteria, namely 'data accuracy', 'easy of use', and 'easy of learning' are the most influential criteria. 'Improve outcome' is criteria on that is most affected.

3 - Risk-informed evaluation of infrastructure project portfolios subject to variable uncertainties

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The U.S. Army Corps of Engineers (USACE) is responsible for developing and maintaining much of the U.S. public water resources. In 2005, Hurricane Katrina resulted in catastrophic levee fail-

ures, encouraging the USACE to move towards a risk-centric approach to resource management. The agency specifically seeks to balance the risks to economic, environmental, and social objectives. In order to meet these objectives a holistic approach for allocating scarce resources in a way that aligns with multiple missions, mitigates risk, and provides the most overall value, is required. Multicriteria decision making, incorporated with value-focused thinking and project portfolio management has been used as the basis for developing a portfolio analytic tool for the agency, known as Asset Management Portfolio Analytics (AMPA). AMPA aims to aid decision makers by providing a rational and transparent evaluation of investment alternatives. With an enterprise purview, AMPA can be applied agency-wide, standardizing risk-mitigating analytical methods.

AMPA employs a multiattribute value model, including rank-order-derived weights, to provide decision-support for allocating funds for USACE work packages. Stakeholder elicitation was used to identify attributes as they relate to the agency's mission and specific business line objectives. A case study is performed with a focus on three business lines: Hydropower, Navigation and Flood Risk Management. Considering the attributes as categories of consequences, the value function quantifies consequence of the failure. The consequence of failure, as well as the probability of failure, is evaluated separately depending on whether a proposed work package receives funding, thus enabling comparison and ensuring that funded work packages reduce adverse consequences. After filtering out infeasible alternatives, work packages are ranked in order of productivity to provide the most value at a given budget level.

In a process heavily dependent on stakeholder elicitation and assessment, various types of uncertainty can be introduced. These sources are identified and appropriate mitigation measures recommended. Among uncertainties explored are assumptions about linearity of utility functions, independence of work packages and parameter estimation. Although AMPA aims to provide a basis for comparison across the agency, individual business lines have significant influence on key input and the results must be interpreted with that in mind. Lessons learned from the effort include how water resource management can benefit from risk-informed decision making to meet multiple diverse objectives subject to evolution over time. The method can be extended to other types of infrastructure assets exposed to variable uncertainties, such as in transportation, electrical systems, and telecommunication.

4 - Criticality assessment of Germanys road tunnel infrastructure using MCDM from the theoretical approach and the adoption of the model to the

practical application

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Tunnels are key elements in modern traffic networks, often crossing rivers and city regions with a high traffic density and with important, highly frequented buildings and infrastructures in close distance. With this in mind it is more than obvious that economical and societal consequences of large scale accidents and malicious threats such as fires, explosions, etc. are potentially very high and thereby threatening to our societal wealth. This is the reason why the German Federal Ministry for Education and Research launched two huge research projects (SKRIBT and SKRIBT-Plus) with the purpose of tackling all issues for infrastructural tunnels resulting from such accidents as well as man-made hazards like criminal acts and terroristic attacks. One of main the purposes of these projects was to develop a method to assess the criticality of specific infrastructural buildings within the surrounding network and to get an idea about how additional measures (e.g. structural upgrade or additional technical systems) might reduce the overall impact of such threats. The idea was to become enabled to identify the most critical facilities within our road network and to derive first ideas for a potentially needed amount of upgrade for a safe and secure operation. Within this context the criticality of an infrastructure is defined as a function of structural safety (e.g. structural resilience in case of a fire or an explosion), user safety (the specific risk profile as a product of the probability of occurrence of an incident and the corresponding amount of fatalities, assessed via a quantitative risk analysis (QRA)), possible costs for refurbishing or rehabilitation of the damaged structure, the life-cycle costs of the facility as a whole, availability downtimes and subsequent reactions of the infrastructural network itself (e.g. travel time elongations due to necessary detours) as well as soft criterions such as the symbolic meaning of a building. First results from traditional engineering approaches indicated, that a comparatively small initial damage to a specific structure might lead to a disproportionate effect for the tunnel itself, the whole urban infrastructural system or structures which are founded above or beneath the tunnel. In addition it was obvious that not all buildings need to be upgraded and even more imminent not all facilities could be upgraded due to political constraints such as budget restrictions. Thus, a more precise and holistic approach had to be taken for the overall criticality assessment. In other words: the assessment of one buildings

criticality had to be considered as a multicriterial analysis, combining heterogeneous engineering expertise, different physical parameters and dimensions as well as a meta-complex decision problem. Within the proposed paper the authors will demonstrate how such an approach for the assessment of a criticality ranking of Germanys road tunnel building stock was taken in the course of the mentioned projects. Here, a fuzzy-logic and risk-based AHP-approach was used for the development of a holistic assessment tool. The underlying hierarchy will be explained, specifying the different criteria for the criticality assessment as well as the corresponding indicators of the different engineering analyses. For the purpose of adoption, the AHP algorithm had to be adjusted for specific evaluations and even implemented as a subroutine for the global criticality assessment. For instance, a method was developed to enable a comparative evaluation of QRA-results in the course of the user safety assessment. The final software tool was realized as a Java-based programming, providing all necessary interfaces to the underlying engineering analyses, followed by first exemplarily assessments of a predefined set of buildings. These results will be explained in detail in the course of the proposed publication. The authors will close with an outlook on future applications of the developed tool, such as they are planned together with the German "Bundesanstalt für Straßenwesen" (BASt) for the German road network.

Thursday, 15:40–16:30

★ TH-4- α -HS1

◆ Behavioral Aspects, Group Decision Making, Negotiations, Interactive Methods, Software

Thursday, 15:40–16:30 – Room HS 1

Session: Goal Programming and Utility Functions

Chair: Hocine Mouslim

1 - Utility Function for modeling Group Multicriteria Decision Making Problems as Games

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For group decisions, the strategic analysis of the decision is commonly addressed by Game Theory GT (Osborne & Rubinstein, 1994). Some studies have proposed the use of the GT approach for modeling MCDM problems. Notably, Madani and Lund (2011) proposed modeling Multi-Criteria Decision Making problems as a strategic game, and solving this using non-cooperative Game Theory concepts.

The key item to unify GMCDM and GT is a Utility Function UF which translates into a real

number all the possible combinations of choices (Strategies) in the GMCDM process. Hence, the aim of this research is to propose a UF and demonstrate its application through modeling the classic game “Battle of the sexes” as a GMCDM problem. The advantage of modeling the GMCDM problems as games is that it allows the possibility to consider equilibrium solutions, generally used in GT, rather than use the traditional concept of optimization by preferences aggregation.

Based on the idea that the Euclidean Space allows a comparison between alternatives (Zahir, 1999), a Comparison Function CF, based on their angles and the distance (norm) between them, is proposed as an intermediate step for the proposition of the UF. The use of these relations has been previously reported by other authors to propose MCDM methods (Deng, 2007; Zahir, 1999). The CF proposed has two main components: (i) a relative component, calculated by the projection of one alternative onto another; and (ii) a weighting component, based on the angle between the alternatives.

In mathematical terms, the CF satisfies the following properties: (i) it establishes intermediate values between zero and one for alternatives comparisons; and (ii) is asymmetric, i.e., it establishes different values when it has at the beginning one alternative instead of another. One means of differentiating between the alternatives in a Euclidian Space is the use of an Ideal Alternative IA, which incorporates the best scores for all criteria (Hwang and Yoon, 1981). Subsequently, the CF is weighted multiplying the value of the comparison between each alternative and the value of their comparison with IA, which is called the Weighted Comparison Function WCF. According to Keeney (2013), it is possible to define a UF for every joint strategy of a set of players combining their UFs values. Here, the combination of the individual WCF values is used to define a numerical value for the joint strategy of the players, which is used to propose the UF for the game.

The use of the UF will generate the Pay-off Tables PoT for the players, which estimates a measure of satisfaction for every possible strategy in the set of actions. The PoT can be used to aid the DM in choosing strategically the preferable alternative considering the choice of the other players.

To illustrate the use of the UF for modeling GMCDM as Games, the classic game “Battle of the sexes” is described as a GMCDM problem. In this sense, let us consider a group of two persons: “Husband” P1, and “Wife” P2, who should decide together which event to attend: “Cinema” A1, or “Football” A2. Let us also consider two criteria to differentiate the alternatives A1 and A2, which are “Adventure” C1, and “Romance” C2. If we suppose that the level for the criteria C1 and C2 of the alternative A1 are zero and ten, respectively, and for the alternative A2, ten

and zero.

Here, both players have the same two actions, which are either to go to the cinema or go to the football match, but they might have different preferences, since men would usually rather go to a football match than to the cinema, while for women it is the opposite. In this sense, let us suppose that the WV for player P1 is $[0.6;0.4]$, meaning that the “Husband” prefers C1 (adventure) to C2 (romance), while the WV for P2 is $[0.4;0.6]$, meaning that the “Wife” prefers C2 (romance) to C1 (adventure). These WV will be used to weight the DM before applying the UF to create the game. Finally, the UF applied onto the two WDMs, creates the PoTs, which are the framework for the game.

The solution for the game can now be found using GT principles rather than optimization, which is frequently applied in the traditional GMCDM approach through WVs aggregation. For the aforementioned example, if the arithmetic mean were used, the set of average weights would be $[0.5;0.5]$, which would not reflect the actual players preferences. Therefore, by establishing an unprecedented UF for modeling GMCDM as Games, the main contribution of the present research is to allow decision-makers to choose the strategies that will give them the highest Pay-off, taking into consideration the preference of the other players involved.

2 - Fuzzy Multi Target Goal Programming with Nonlinear Functions: Piece-wise Linear Approximation

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Multi-Choice Goal Programming (MCGP) is considered as a novel technique in management science and operational research to solve multi-criteria decision making (MCDM) problems. However, in some practical cases, there may exist situations that the manager is interested in establishing multi targets and tolerances for goals that not be expressed in a linear form of their membership functions. In this paper, an efficient methodology is presented, which is considered as a combination between the (MCGP) suggested by Chang in 2011 for standard goal programming (GP), and the fuzzy multi target GP (FMTGP) proposed by Mouslim et al. in 2014, where the concept of multi-target nonlinear functions (MTNFs) is used for modelling the fuzziness of the goals that have many targets of the nonlinear form. The model of Chang is adapted in a very evident manner to introduce the technique of FMTGP for solving this type of problems. In addition, this new formulation can easily be applied to a decision problem with the

S-shaped membership functions compared with the method of Yang et al. presented in 1991, and the model suggested by Li and Yu in 2000. Finally, the developed model will be illustrated through numerical examples.

★ TH-4- γ -HS2

◆ Model Building

Thursday, 15:40–16:30 – Room HS 2

Session: IS-INTEG-AUTOMAT: Integrated and Automated Decision Making

Chair: Y. Ilker Topcu

1 - An Analysis of Logistics Performance and International Trade Interaction

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The interaction between the performances of logistics sector in a country with that of economic growth has long been investigated by different researchers. Since the transport and logistics sector affect production, consumption and trade in a country, it is clear that the performance of logistics sector has positive effect on economic growth (Nguyen and Tongzon 2010). That is, if a country can obtain a competitive advantage in terms of logistics performance, this will increase its international trade, help to open new markets and encourage business (Arvis et al., 2012). Wilson et al. (2003) also states that substantial growth in trade can benefit from the quality of logistics sector. This study aims to investigate this relation and tries to find an answer to the question of which logistics indicators especially affect the country's trade level. For this purpose, initially, the relationship between the international trade and logistics performance index (LPI) indicators are analyzed using artificial neural networks (ANN) where LPI indicators, GDP level and exchange rate are inputs while the export is an output. As the second step, the most important factors that have effect on international trade are determined by a scenario analysis approach. Finally, Turkey is selected as a case study for scenario analysis and policy suggestions. As an important logistics center in Europe due to its high values of trade with regional partners, Turkey has set a goal of realizing 500 billion dollars worth of export for 2023. That is why, it is especially important for Turkey to determine how to reach this ambitious goal by leveraging its performance on logistics sector. The LPI, published by the World Bank Group is composed of six indicators namely cus-

toms, infrastructure, service quality, timeliness, international shipments, and tracking and tracing as the key elements of logistics and compares these logistics profiles among countries and rates them on a scale of 1 (worst) to 5 (best) (Arvis et al., 2012). The relationship between export and LPI are expected to be complicated and highly non-linear. Due to its predictive quality, ANN is one of the appropriate methods to illustrate this property. (Gevrey et al., 2003). ANN techniques have been applied to a variety of problem areas and have, in many instances, provided superior results to conventional methods (Fan et al., 2013). The literature (Hwang and Ang, 2001, Resop, 2006) suggests the potential advantages of ANN vs statistical methods. Since the contribution of each input variable on output variable cannot be easily interpreted in ANNs, they are generally considered as black boxes. That is why, in this study a scenario analysis approach is proposed in order to determine the importance of inputs on the given output by using the predictive capability of the resulting ANN. The ANN defined in this study is a two layer feed-forward network. Levenberg-Marquardt back-propagation method, which is one of the fastest back-propagation algorithm is used for training the ANN. The analysis showed that the best performance values are obtained for 44 hidden neurons (Performances: test = 0.99, validation = 0.98, train = 0.98). This best performing network is used to conduct the detailed scenario analysis. The aim of the scenario analysis is to find the most important factors to determine the export level of a country. In the proposed scenario analysis procedure, initially LPI indicators current values are obtained from the data sources and the target values are determined based on the scores of benchmark countries. Then LPI indicators are increased to their target levels for all different combination of LPI indicators. In this way, 26 -1 (=63) different scenarios are obtained. The scenarios that give the highest export level is selected for different number of improved indicators. The results of the scenario analysis shows that, the most important factor affecting the export of a country is tracking and tracing indicator if only one indicator is improved at a time. Infrastructure and international shipments are the other important indicators that have effect on the level of exports of the country. If two indicators can be improved simultaneously, then infrastructure and international shipments are found to be the most important indicators in order to increase the export level of a country. If three indicators can be improved at the same time, then the scenario in which infrastructure, international shipments and tracking and tracing are improved, gives the highest score for the export level.

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2 - Combination of Machine Learning and Optimization for Automated Decision-Making

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The long-term vision of this work would be the development of a fully automated decision-making system so that only data and desired outputs need to be provided by the user. However in the real-life business contexts the power of multi-objective optimization for making automated decisions is still largely unexploited. One of the main reasons blocking its widespread adoption is that the standard optimization assumes the existence of the functions to be optimized. Yet such functions, notably on big datasets, often are extremely costly and difficult to be created. Here the recent advancements in the field of machine learning and data mining for creating the decision-making models (functions) are discussed. Furthermore the potential of combination of learning from big data and optimization which can be applied to complex and dynamic contexts is described. This combination dramatically increases the automation level and puts more power directly in the hands of decision makers without resorting to intermediate layers of data scientists. Nevertheless reaching the goal of a fully automated decision-making system is

a huge challenge and it will require further research at the boundary between two areas of machine learning and optimization, which have been traditionally separated.

★ TH-4-δ-HS3

◆ Industry and Business Applications

Thursday, 15:40-16:30 – Room HS 3

Session: Industrial Optimization 1

Chair: İrem Uçal Sarı

1 - Bi-objective Single Machine Scheduling Problem with Learning Effect

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In this paper, we present two objectives scheduling problem under position dependent learning effect in the single machine environment. We aim to minimize both makespan and total completion time under position dependent learning effect in the polynomial time. In the scheduling literature, the classical scheduling theory assumes that job processing times are constant. However, in various real life production systems workers undergo a process of learning. The repetition of similar operations induces a process of specialization and workers acquire better skills. We prove results, which is obtained in polynomial time, using numerical example.

2 - Determination of Price Discount Ratios for Vendors Based on Their Expectations

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Due to the fact that the successes of vendors directly affect the sales volume and the market share, vendors have critical roles in supply chains for B2B companies. In the literature it is seen that the previous studies have been focused on the selection problem of the vendors. But there is another issue which is at least important as selection of the vendors, motivating vendors to have the best sales performance. B2B companies imply different discounting strategies to motivate vendors which occurs an increase in the market share and the sales volume of the company. Discounting strategies are based on different criteria such as ordering amount of the vendor, total yearly demand of the vendor, prices of the competitors in the region of the vendor and payment type of the vendor. There are also additional discounts for special cases such as the ability of the vendor being a distributor for the com-

pany. In some regions using a vendor as transshipment point for the company has a critical role. For the vendors who give that opportunity, additional discounting strategies could be applied.

In this paper a methodology is proposed to determine the discount rates for the best discounting strategy for each vendor. At first, a questionnaire is used to determine the discounting expectations of the vendors. By using the vendor expectations the discounting strategies are determined by the experts. After determination of discounting strategies, fuzzy analytical hierarchy method is used to define the weights of the criteria which are considering when determining the discount rates. Criteria which are used to determination of discount ratio are ability of the vendor being a transshipment point for the company, average ordering amount of the vendor in the past year, expected average ordering amount of the vendor, average number of the orders of the vendor during the past year, expected average number of orders of the vendor, total demand of the vendor in the previous year, expected total demand of the vendor and payment method (payment risk) of the vendor. The sales specialists and the sales department managers evaluate each vendor due to the criteria given above. The results of the method give the prioritization of the vendors for the company including the risks of the vendors. The discount ratios are determined by using goal programming which has total profit maximization and total sales volume maximization objectives.

A real case study is performed to validate the proposed model. An international company is analyzed which sales isolation materials for construction sector. The company works with more than 300 vendors which are located in 56 cities. The vendor sales performances in the presence of different discounting strategies are determined by using statistical analysis of the past data. The result of this analysis shows that the change in the discounting strategy have a significant effect on the sales volume of each vendor. Each vendor is affected from the different discounting strategies but the ways of this effect is changes from one to another.

To validate the proposed method a pilot region is selected where 47 vendors are located in. The results of the application are summarized as follows. Questionnaire which is used to determine the discounting strategies is resulted in 4 groups of expectations. In the first group the vendors prefer to get the same discount ratio for all orders given in the same period (e.g. in the same year) independent from the ordering amount and they accept a promise of total ordering amount in that period. In the second group they prefer to get a discount ratio which could be depending on the ordering amount and they do not want to give any promises on the total annual ordering amount. In the third group vendors prefer to get higher discount ratios depending on the to-

tal previous ordering amounts in that year and also they do not want to give any promises for the next orders. In the last group the vendors prefer the same discount ratio for all orders and if the total sales volume exceeds an agreed level they want additional payment which is determined as a percentage of total yearly sales volume. Another result of the questionnaire is that the vendors want to negotiate on the payment method. The vendors want additional discount for the cash payments. Sales managers decided to have four discounting strategies in the model based on the results of the questionnaire. In the first strategy, the discount ratio is determined by the ordering amount and differs from order to order. In the second one the discount ratio is fixed in the beginning of the year for an agreed total yearly sales volume. In the third one discount ratio is determined for each order depending on the total previous ordering amount of the vendor. In the forth one discount ratio is fixed at the beginning of the year and for different levels of total yearly sales volumes additional discounts over the total sales which will be paid as a bonus to the vendor at the end of the year. The first, second, third and forth discounting strategies are applied to 18, 9, 12 and 8 vendors, respectively. The discount rates for the vendors are determined between 15% and 45% based on the list price of the goods by using goal programming. To validate the results another questionnaire is prepared and applied to the vendors. This questionnaire shows that with the proposed method, vendors who have a word on the strategy determination process feel more satisfied with the resulted strategy and the loyalty of the vendors is increased in a significant way.

★ TH-4- κ -HS4

◆ AHP/ANP

Thursday, 15:40–16:30 – Room HS 4

Session: IS-AHP-TA: Theory and Applications of the AHP/ANP 3

Chair: Alev Taskin Gumus

1 - A Fuzzy MCDM Method To Identify Critical Evaluation Factors for Immigrants' Living Regions

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Starting from the day when violence, unemployment and other immigration factors increased in some countries, people who are living there

started to immigrate (or they had to immigrate) in neighboring countries. Nowadays, especially Syrian citizens have immigrated to Turkey because Syria is Turkey southern border neighbor so they usually choose Turkey as target or transit country. The numbers of asylum seekers are growing especially in the southern border, and it has caused living region determination problems for them in Turkey. In this paper, it is aimed to propose a solution to the location selection problem for asylum seekers. As a solution method, interval type-2 fuzzy AHP method will be used according to criteria and sub-criteria which will be also proposed in this paper.

There are limited numbers of studies about asylum seekers in literature to solve the living area selection problem. By this study, first, some key factors are empirically identified, which must be considered for living area evaluation for immigrants, by a literature survey and based on expert opinions. And then, interval type-2 fuzzy AHP method are used in computations.

2 - Big Data, Supply Chain Management, AHP/ANP; State-of-the-art and future research directions

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Recently, businesses and research communities have paid a lot of attention to big data. However, the field of supply chain management (SCM) has been relatively slow in studying big data for research and practice. Multiple Criteria Decision Making (MCDM) community has, to the best knowledge of authors, been even slower studying implementing MCDM into Supply Chain Management where big data is likely have impact.

The key factor to gaining competitive advantage in today's rapidly changing business environment is the ability to extract big data (tweets, videos, click-streams, and other unstructured sources) to gain business insights. Big data have the potential to revolutionize supply chain dynamics. We explore research where supply chain management (SCM) intersects with data science, predictive analytics, and big data, collectively referred to as DPB. We show that these terms are not only becoming popular but are also relevant to supply chain research and education. Research in the area of DPB is needed by researchers with domain knowledge in logistics and SCM.

We will clarify the definition and concepts related to "big data in supply chain management," develop a conceptual framework for the classification of articles dealing with "big data in

supply chain management," use the conceptual framework to classify and summarize all relevant articles, develop future research directions where the deployment and use of "big data" is likely to have significant impacts in supply chain management and we will explore applicability of Multiple Criteria decision-making (MCDM) techniques, especially Analytic Hierarchy Process/Analytic Network Process (AHP/ANP) and combined applications of them in the area of big data when used in supply chain management. After comparing and summarizing the reviewed approaches we identify the primary research opportunities.

★ TH-4- σ -HS5

◆ Multi Objective Optimization

Thursday, 15:40–16:30 – Room HS 5

Session: Optimization in Healthcare 2

Chair: Alexander Scherrer

1 - Column Generation to Generate a Representative Set of Deliverable Radiotherapy Treatment Plans

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We propose a column generation based approach to compute a representative set of non-dominated points of multi-objective linear programmes. The method implements column generation within the revised normal boundary intersection (RNBI) framework, which is based on projecting a set of equidistant reference points onto the non-dominated set to determine a representative set of nondominated points. To find the projected points, one needs to solve an RNBI sub-problem for each of the reference points. In this study, the RNBI sub-problems are solved by column generation. The column generation process adds non-basic variables to the restricted master problem of the RNBI sub-problem, which moves a current objective point towards the nondominated set. Different initialisation approaches for column generation are implemented, including the so-called Farkas pricing, which provides a mechanism to conclude the infeasibility of an RNBI subproblem. A reference point bounding method is proposed to eliminate reference points that lead to infeasible RNBI subproblems. We apply the method to the problem of optimising the fluence map in radiotherapy treatment

design. In this context, the RNBI sub-problem corresponds to finding a fluence map with particular values of radiation dose delivered to tumour, organs at risk, and normal tissue. In contrast to standard planning procedures, the column generation approach has the advantage of generating plans with a small number of apertures for the radiotherapy equipment. This implies that generated plans are deliverable without applying an additional segmentation step, which decomposes a fluence map into deliverable apertures, but deteriorates plan quality. In addition, the generated plans are close to efficiency in the underlying multi-objective optimisation plan. We demonstrate the effectiveness of the reference point bounding procedure to eliminate solving the RNBI sub-problem for reference points that do not project onto the non-dominated set.

2 - Multi-criteria optimization and decision support in focused ultrasound therapy planning

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Focused ultrasound (FUS) allows for minimally invasive cancer therapy. Acoustic waves emitted by a FUS applicator induce a pressure field in the sonicated volume, which heats the tissue causing a coagulation of cells. Recent technological advances on FUS treatment devices provide a significant curative potential in terms of sufficient tumor control and still acceptable side effects. Clinical routine has only a small time slot for creating a FUS plan between a preceding medical imaging and subsequent treatment. FUS therapy planning from a mathematical perspective forms a multi-criteria decision making (MCDM) problem and in clinical terms could clearly benefit from such methods: numerical optimization methods and decision support methods would allow for efficient computation of high quality plans and suitable balancing of planning goals. Current FUS planning tools do not support this approach and clinical routine still features time consuming manual planning and reduced plan quality. This implies the question how to bridge the conceptual gap between the state of the art in FUS therapy planning and advanced MCDM.

This talk presents an innovative approach for multi-criteria FUS therapy planning, which aims for an establishing of MCDM in clinical FUS routine in a smooth way starting from the state of the art. It features the formulation of planning problems with multiple therapy goals and their intuitive balancing, the efficient plan computa-

tion with hybrid numerical optimization and the interactive exploration of treatment options.

The planning criteria rely on the cell-biological impact of temperature in the tissue based on the Arrhenius model and the averaging of impact over a tissue entity. The frequent violation of plan quality requirements observed in clinical routine indicates a significant risk of infeasible FUS plan optimization problems motivating an unconstrained formulation. FUS practitioners are not used to converting medical quality into abstract criteria and model uncertainties give criterion values some imprecision further complicating their interpretation. The balancing of therapy planning criteria thus requires a scalarization like the Tchebycheff approach without any non-interpretable reference values. Clinical FUS routine features limited user experience with planning tools and thus needs a simple software feature for the intuitive balancing of planning criteria and triggering of plan computations. These needs are addressed by a novel triangular planning screen with a single functional element inside, whose position determines the criterion weights.

Simulation of the FUS physics starts with the computation of the pressure field by solving the Helmholtz equation on the sonication volume discretized in about 10^6 elements. The configuration of the FUS applicator for each single of the about 10^2 sonications determines the source terms. Parameters are the applicator alignment, location of sonication points and sonication times, and the phase shifts and energy emissions of the about 10^2 applicator elements. The pressure field yields the source term of the Pennes equation, whose computation for instance with Euler's method yields the temperature field over the volume elements and a discretization of the plan application time frame in about 10^3 steps. FUS physics simulation run requires about 10^0 seconds, however, repeated simulation runs in FUS plan optimization are still time consuming. Speed ups can be achieved by imitating empirical approaches for parameter specification from clinical FUS therapy planning, which motivate the following hybrid optimization algorithm:

First, the applicator is aligned via a nonlinear programming problem relying on geometric approximations for the tissue entities and acoustic wave propagation. Then the sonication points in the tumor entity are placed and ordered with a heuristic on a triangular grid from back to forth and inner to outer. The optimal phase shifts for each sonication point can be directly obtained from the element contributions to the pressure field in the point. Optimization of sonication times and energies as final step requires numerical simulations of pressure and temperatures, which motivates an optimal control approach based on the Pontryagin maximal principle in order to obtain the corresponding objective function derivatives. The memory required

for intermediate saving of simulation output can be reduced by a factor of 10^2 by just doubling simulation runs and saving of temperatures at the sonication starts. The obtained objective function value and partial derivatives serve as input of a generic nonlinear programming method for solving the typically non-convex problem.

A computed FUS plan is depicted in the planning screen with an additional marker representing the used criterion weights. Selection of this marker triggers plan visualization in a novel histogram form, which provides for each tissue entity a volumetric overview of the cell-biological impact. These markers in combination with the histogram display provide the planner with an intuitive overview of the existing planning options. The small time slot for creating FUS plans permits only a few optimization runs with the risk to miss the desired plan located somewhere "in between". This risk is overcome by an additional feature for plan recombination: placement of the functional element between the markers depicting the existing plans and its selection triggers an interpolation of plan parameters with the coefficients determined by the element position. A simulation run for the interpolated parameters in about 10^0 seconds then allows for the interactive exploration of a continuous range of planning options.

★ TH-4- χ -HS6

◆ Environment, Infrastructure & Emerging Applications

Thursday, 15:40–16:30 – Room HS 6

Session: IS-MOO-CIVIL: Metaheuristic Algorithms in Multi-Objective Optimization of Civil Engineering Problems

Chair: Sinan Melih Nigdeli

1 - A Multi-Objective Optimization of Tuned Mass Dampers for Structures Excited by a wide set of Earthquakes

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Tuned mass dampers (TMD) are vibration absorber devices and the properties of these absorbers are tuned according to the frequency behavior of the mechanical systems in order to surpass the vibrations. In the tuning process of TMDs, optimization is needed in order to consider design constraints for the best efficiency. Also, TMDs have been used on civil structures subjected to the random vibrations of winds, earthquakes and other dynamic excitations. Dynamics of structures have coupled equations which can be solved by using numerical analyses. For tuned mass damper (TMD)

implemented structures, TMD has also a dynamic equation which is depended on other degrees of structure. In optimization of TMDs using time domain analyses, a mathematical solution cannot be found. Due to this reason, numerical searching algorithms have been used in optimum design of TMDs for structures excited by non-stationary vibrations like strong winds and earthquakes. In this paper, a multi objective optimization of TMD parameters is proposed. Harmony search (HS) algorithm developed by Geem et al. is employed. Like other metaheuristic methods, HS imitates a process in which a musician tries to find best harmony. The optimum design variables are investigated globally or locally according to the rules of the HS algorithm. The proposed method is proposed for two objectives which are related with the performance and practicability. The first objective is the reduction of maximum first story displacement and this objective is also considered in the previous HS approaches because it is main criterion about the vibration absorbing performance of TMD. The other objective is new in HS based TMD optimization methods. A scaled displacement value of TMD is used in order to consider the stroke capacity of TMD. The multi objective optimization methodology can be divided in two sections for initial calculations and iterative optimization. First structural properties, external excitations and ranges of design variables are defined as optimization constraints. Then, the structure without TMD is analyzed because one of the objective function is depended to it. After that, the initial Harmony Memory (HM) matrix containing Harmony Vectors (HVs) is generated. Each HV contains possible solution for mass, period and damping ratio which are the design variables and these variables are defined with random numbers generated within the range. Also, the optimization objectives are calculated for these set of variables. There are two objective functions. The first one is the reduction of maximum top story displacement of the structure to a user defined value (x_{max}). If the user defined value is not applicable by using the design variable ranges, this value is iteratively increased. The other objective is related with a scaled stroke capacity limit of the TMD (st_{max}). After the initial calculations, the iterative optimization process starts. A new HV is generated and calculations of objective functions are done. If the solution of a new vector is better than existing ones in HM, it is replaced with the worst one. The second objective given is considered in elimination. If this objective function is lower than st_{max} , the first objective function is considered in elimination. This iterative search is done until the criteria given by two objectives are provided. A new harmony vector is generated in two ways according to a possibility called Harmony Memory Considering Rate (HMCr). The new vector can be generated by a smaller range around an existing vector in HM. The ratio of

the small and whole range is defined with Pitch Adjusting Rate (PAR). For global optimum solution, 44 different earthquake records were used in the optimization of the ten story structure. Also, these earthquakes are grouped as a set in FEMA P-695 as far-fault ground motions. A TMD implemented on a ten story structure is optimized as a numerical example. The mass, stiffness coefficient and damping coefficient of a story is 360 t, 6.2 MNs/m and 650 MN/m, respectively. The st_{max} limitation was taken as 1 and x_{max} was taken as zero in order to find a solution with maximum efficiency on reduction of displacement. The optimum TMD is effective to reduce the maximum displacement from 0.41 m to 0.32 m for the critical excitation. The optimum TMD is effective to reduce maximum displacement in addition to obtain a steady state response. According to the results, optimum TMD obtained by using the proposed method is effective to reduce structural vibrations for desired stroke capacity. As a conclusion, the proposed method is feasible because of capability of finding practical and realistic solutions.

2 - Multi-objective optimization of reinforced concrete footings using harmony search

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In the design of reinforced concrete (RC) members, several design variables are assumed by designer and design requirements in codes are checked and the assumed variables are updated if necessary. The chosen design variables may not be optimum ones, because RC is a composite design. The material of RC; concrete and steel are extremely different materials in behavior and price. Generally, big cross-sections are found as optimum results but precise optimum values must be checked. By the increase of the cross-sections, the minimum required reinforcement area is also increased. For that reason, optimization is important in design of RC members including RC footings. In the design of RC footings, three important factors must be handled by design engineers. The factors are related with allowable bearing capacity, design internal forces and total cost of RC footing. In this study, the design variables such as dimensions of footings (in two directions), effective depth of footing, size of steel reinforcements and distance between steel reinforcements are optimized by using a music inspired metaheuristic method called harmony search (HS). Five different objectives are checked in the optimization process. The first objective is checked according to stress on the soil. The maximum compression must be lower than allowable bearing capacity and the minimum stress must not be tensile. The second

objective is related with the flexural security of footing. The design flexural moment is calculated for the sections at column faces and the capacity of RC footing is checked according to reinforcements in two directions. The third and fourth objective are related with design requirements about shear and punching. The last objective is the minimization of the total cost of RC footing. In the proposed method employing HS, initial harmony memory matrix is constructed by the combination of harmony vectors. Harmony vectors contain randomly assigned values of design variables. In design of RC members, discrete variables are used because the concrete dimensions cannot be produced precisely in construction yard and steel reinforced sizes are constant. After the generation of initial harmony memory matrix, the harmony memory is updated with the new harmony vectors and the worst existing one is eliminated. A new harmony vector can be generated around existing ones with a possibility called harmony memory considering rate (HMCR). The range when the generation done from an existing vector can be decreased with a parameter called Pitch Adjusting Rate (PAR). The worst vector is chosen according to the optimization objectives. The control of design objective starts from the first one. If the first objective is suitable for all harmony vectors, the second one is checked. This process is done until the last objective. For the last one, the design with the maximum cost is eliminated. The iterative optimization process is repeated by generating new vectors and updating harmony memory. This iterative process continues for a defined iteration number. The proposed method was examined with a single footing under a RC column. The footing is under the effects of axial loading and flexural moments in two directions. The optimum results ensuring the four objectives has a total cost of 182.74 USD. This price is decreased from 419.49 USD which is the best result for the variables of initial harmony memory matrix containing five harmony vectors. Also, optimum design variables are not found as limits of the defined range. Thus, the proposed approach for optimum design of RC footings is an effective and feasible approach in order to find a global optimum solution.

Friday, 09:00–11:00

★ FR-1

◆ MCDM Award Talks

Monday, 09:00–11:00 – Aula

Session: MCDM Award Talks

Chair: Theo Stewart

Friday, 11:30–13:10

★ FR-2-β-HS1

◆ Decision Aiding

Friday, 11:30–13:10 – Room HS 1

Session: Decision Aiding: Emerging Applications 3

Chair: Kaiquan Cai

1 - Applying a MAMCA approach for sustainable transport decision making

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Decision making within the transport area is often a complex task as multiple criteria and multiple stakeholders are influencing the decisions to be made. Moreover a strong focus on sustainable solutions has emerged during the recent years. This development has not made the decision making task less complex as the assessments now need to be based on criteria stemming from all the three pillars of sustainability consisting of economic, social, and environmental criteria. Within transport decision making there is a strong tradition in Denmark (and many other countries) for conducting socio-economic appraisals using cost-benefit analysis (CBA) for a long range of impacts. However, the CBA is due to pricing difficulties not able to capture all impacts relevant for the decision. For this reason the use of multi-criteria decision analysis (MCDA) is introduced into Danish transport planning. This paper proposes an approach for combining the conventional CBA with a MCDA that makes it possible to include criteria of a sustainable type for the appraisal of transport initiatives. This composite model for assessment (COSIMA) is based on a multi-actor multi-criteria decision analysis (MAMCA) to ensure the involvement of relevant stakeholders along the decision support process. A main principle of the COSIMA model is that examined alternatives are assessed both absolutely and relatively. Thus the CBA provides an absolute, conventional assessment related to the alternatives core performance. The MCDA on the other hand provides a relative, context-dependent assessment related to the alternatives performance set against the other alternatives in the appraisal. Subsequently the scores of the alternatives are transferred into an absolute measure by using a local scale which assigns the value 0 to the worst performing alternative and the value 100 to the best performing alternative. The rest of the alternatives are then rated by relating them to these alternatives. Once the CBA impacts and MCDA criteria are

specified, the ‘anchoring’ part of the COSIMA model formulation takes place. This partly concerns determining the weights for the MCDA criteria, and partly determining the importance of the MCDA criteria set against the CBA impacts, i.e. the overall MCDA/CBA trade-off. The COSIMA model then calculates a total gross value (TV) in monetary units for an alternative A_k obtained by spending the investment cost C_k : $TV(A_k) = CBA(A_k) + MCDA(A_k)$. In a situation where the investment in A_k (equal to the investment cost C_k) is not profitable seen from the conventional CBA point of view, i.e. $CBA(A_k) < C_k$, the investment can still be justified by the wider COSIMA examination if $TV(A_k) > C_k$. If this is examined as a total rate of return (TRR), the latter can be expressed as $TRR(A_k) = TV(A_k)/C_k > 1$. The set-up of the COSIMA model only requires that value function scores can be assigned to the alternatives and weights can be determined for the criteria. Hence, no specific MCDA technique is linked to the methodology, and it is possible to use different techniques as well as combinations of them dependent of the relevance for the decision problem in hand. In this paper a restricted number of MCDA techniques with different characteristics are proposed for use in the approach. These techniques are: the simple multi-attribute rating technique (SMART), SMART exploiting ranks (SMARTER), swing weights, and the multiplicative AHP. Which MCDA technique to use in the decision process - and thereby in the COSIMA model - highly depends on the persons that are to apply it. Two main modes are in this respect relevant: a basic-user mode consisting of non-professionals, and an expert-user mode consisting of professional and experienced users of the techniques. The paper examines which of the techniques mentioned above that are relevant to use in the specific situations and contexts. Transport decision making often involves groups with divergent objectives, and the final decision is likely to involve some form of political negotiation between stakeholders, each of whom may adopt different sets of criteria for evaluating alternatives. The analysis may need to be conducted within a group setting involving representatives of all stakeholders, or may be carried out separately for sub-groups as a form of scoping exercise or impact assessment. For the purpose of handling these issues the use of the COSIMA model is set up as a MAMCA. The use of a MAMCA approach makes it possible for a group of stakeholders and decision-makers representing very different viewpoints to work together in an efficient way so they can create a vision based decision with regard to the common goal. The fundamental objective is to create a synthesis of decision analytical techniques and the positive features and dynamics which are found by decision making in groups. Common understanding of the issues is achieved on the basis of decision techniques and social interaction. Hereby, the

participants obtain a sense of the common objective and obligate themselves to act towards implementation. Thus the MAMCA assists in conducting the assessments according to the preferences of the participants in a comprehensive and transparent way. The approach is presented using a case study dealing with sustainable solutions for resolving a transport infrastructure issue. The case has been worked out within the international research project SUSTAIN 2012-16 that aims at setting up a framework for national sustainable transport planning.

2 - A Multicriteria Method Using Bivariate Evaluation for plant location Selection

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Plant location selection refers to the selection of a particular site for setting a business factory. Selecting the best plant location among many alternatives is a multicriteria selection problem including both tangible and intangible factors. In this contribution we propose a multicriteria method to solve the plant location selection problem using the so-called evaluative space grid to evaluate the intangible factors impacts. For each alternative we derive favorability and unfavorability degrees. Here, favorability and unfavorability are considered antagonistic and completely independent. We concede the point that unfavorability influences decisions making more than favorability. The proposal method makes use of linear programming along with interval order relations to select the best plant location. A numerical example is provided to illustrate the proposed method.

3 - Personnel Selection using DEMATEL and TOPSIS approach

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Human resources management is crucial for an arts organization as every organization. They endeavor to identify effective methods, especially in personnel selection for HRM. There are different processes and criteria of each organization for personnel selection. At the same time each criteria have different importance for organizations.

This may be due to several reasons such as organizations structure, culture or staffing needs of departments. With all these, organization wants to apply the optimum selection process and try to find the best applicant for their job. Fair selection process is of great importance not only for organization, but also for personnel and applicants. For this reason, criteria of applicants have to be evaluated fairly. However, while it is easier to evaluate objective criteria such as education level or work experience, subjective criteria such as communication skills or desire to work are relatively more difficult. Especially, subjective criteria are very important in selection of the artists to work at the arts organization because of the creativity skills. Therefore, in this paper, the Decision Making Trial and Evaluation Laboratory (DEMATEL) method applied to obtain weights of criterion and find interrelations among criteria that arts organization require. Then, qualitative values are changed to quantitative values out of 10 points by the organization in interview process. Finally, Technique for the Order of Prioritization by Similarity to Ideal Solution (TOPSIS) method is applied to determine the ranking of the applicants. This model is applied in an arts organization for selecting an assistant who will work with the artist, keeps the organization.

4 - A Multi-criteria Decision Analysis based Two-stage Approach for Aircraft Conflict Resolution

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Aircraft Conflict Resolution (CR) is one of the key decisions made by air traffic controllers to maintain flight safety in current air traffic control operations. If the distance between each aircraft pair in the flight plans gets smaller than a certain separation minimum, the controllers should issue the resolution maneuvers by precisely modifying the flight path or the corresponding velocities to guide the pilots to resolve the conflict. The CR decision-making process aims to minimize the overall cost of involved aircraft from controllers' perspective. However, during the real flight phases, the trajectory is affected by some stochastic disturbances (e.g. winds) and it is of-

ten different from the adhered plan. To handle the uncertain trajectory, pilots should be authorized a certain degree of flexibility while relaxing some requirements of controllers. Therefore, it is necessary to develop a novel CR decision-making framework balancing the benefits of controllers and pilots.

In this paper, we introduce two criteria of CR maneuvers to represent the benefits of controller and pilots separately. The first criterion “overall cost” refers to the sum of the deviations of travel distances between the redesigned paths (represented by the positions of way-points) and planned paths for all involved aircraft. Clearly, the minimum cost leads to the benefit of all aircraft involved. The second criterion “individual flexibility” is defined as the number of conflict-free trajectories realized from the specific aircraft flying along some fixed path but with admissible velocities. The goal of CR decision-making is to minimize the overall cost and maximize the individual flexibility.

Taking into account these two criteria, we then propose a multi-criteria decision analysis based two-stage approach for CR. At the first stage, several candidate CR maneuvers are generated by formulating the CR problem into a standard Second Order Cone Program (SOCP), where the way-points of conflict-related aircraft are modified to minimize the overall cost. Note that, based on the obtained way-points, the optimal velocities can be derived according to the Required Time of Arrival (RTA) to these way-points.

At the second stage, the individual flexibility of each candidate CR maneuver is assessed by adding some tolerance to the RTA for each path. Then, a multi-criteria decision analysis method is applied to select the best compromised maneuver, while satisfying all the criteria simultaneously. Specifically, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is applied to compute the Euclidean distances of each maneuver to the positive ideal point and the negative ideal point. The best maneuver is selected from the Pareto frontier.

Some numerical examples are used to verify the efficacy of the proposed CR framework. The results are discussed in both deterministic CR case and uncertain CR case, where the uncertain trajectory model developed in our preliminary work is used.

★ FR-2-γ-HS2

◆ Model Building

Friday, 11:30–13:10 – Room HS 2

Session: IS-MIPA: Methodological Issues for Practical Applications of MCDA Models

Chair: Danielle Costa Morais

1 - Multicriteria Evaluation of Sustain-

able Solutions for Small Dairies: a case study

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In Northeast Brazil there are many dairies that are small family businesses, without an adequate technology level and, in general, a minimal organizational management. Realizing this fact, a Local Productive Arrangement (LPA) was created in order to develop and share solutions that contribute to the sustainability of these companies. From a study for the strategic structuring of this problem using the Value Focused Thinking (VFT) methodology a number of alternative actions that contribute to the main objective and some criteria to assess the contribution of these actions to the goal of sustainability were obtained. Thus, this work aims to solve the multicriteria ranking problem generated from these data applying the additive-veto model proposed by Almeida (2013). An analysis of the implications of the results is also provided.

2 - A multi-criteria approach for evaluating conflicts within Dempster-Shafer Theory

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The Dempster-Shafer Theory (DST) is seen as one of main tools to deal with some kinds of uncertainty in which it is difficult to model with classical probabilities. Ignorance and vagueness can be considered two examples of uncertainties. One of the main uses of DST is to consider Dempsters combination rule, which allows two independent Bodies of Evidence (BOE) to be combined. In spite of its extensive use, the application of Dempsters combination rule may generate counter-intuitive outcomes when the sources of information to be combined show high conflict. In this sense, two different approaches have been applied to overcome the problem caused by two BOE in high conflict: one focuses on modifying Dempsters rule, and the other takes into account managing the conflict without necessarily changing the combination rule. In this work is presented the conflict classification problem in DST as a multi-criteria classification problem.

3 - Is Insurance Enterprise Risk Management Reliable?

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Enterprise Risk Management (ERM) is a framework to help an insurer determine its acceptable range and appetite for the consequences of risk-based decisions. Furthermore, it fosters a holistic and more informative means of identification, measurement and understanding of risks that transcend an organisation. Risk models are often used in this process. The results support optimal risk-based decisions surrounding the management and allocation of limited capital resources, and other facets of an insurers balance sheet. This study will review certain evidence to see if the end result of decisions by insurance company managers that apparently practice superior ERM are indeed reliable, and have subsequently translated into higher financial performance relative to those that have weaker ERM frameworks and models. Metrics for the evidence will include valuation (e.g., stock or earnings multiples), efficiency (e.g., return on assets, return on revenue, return on risk-adjusted capital), and risk perception (e.g., credit default swaps, regulatory risk-based capital figures, Value-at-Risk statistics). Although the evaluation will focus on the insurance sector, and given that ERM is not unique to insurance, it is expected that other industries and governments could benefit from the findings of this research.

4 - Multicriteria Group Decision Making To Support the Water Distribution Network Segmentation Problem

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Water is a scarce resource being necessary water management measures in order to improve its availability and use. It is common in Water Distribution Networks (WDN), especially in developing countries, large percentages of water loss due to depreciated infrastructure and problems in the maintenance management of these networks. To perform proper maintenance activities in WDN, the pipes need to be isolated. Isolating valves are allocated, usually, near the ends of pipes, blocking the flow of water; at most two valves must be allocated to each pipe. Thus, the WDN is partitioned. We call this Network Sectorization or Segmentation (NS). However, in general, it is not a viable option put two valves in each tube, not only due to budget constraints, but also because of operational aspects. Thus, to isolate a pipe is necessary to closed more than two valves and, thus, the isolation of more than one pipe. In this case, other users in addition to those connected to the broken pipe will remain without service during maintenance. Thus, the problem is to define an alternative of NS (this alternative relates to the number of valves and its location in the network) which shows a good

compromise in different criteria. Moreover, in addition to technical and financial aspects, the characteristic of the consumers must also be considered in determining the size (dimension) of each network segment, such as the amount of water consumed and the types of consumers (hospital or residence, for example). Furthermore, this type of decision usually is made by more than one decision maker. These decision makers may be responsible for different areas or departments of the Water Company, such as financial, technical, etc., and it should be considered their different points of view. Therefore, we propose a multicriteria group decision model to support the decision makers to evaluate the segmentation of WDN, i. e., in the definition of a good alternative of NS.

★ FR-2-δ-HS3

◆ Industry and Business Applications

Friday, 11:30–13:10 – Room HS 3

Session: Industrial Optimization 2

Chair: Anatoly Levchenkov

1 - Multi-criteria pricing policy for perishable products in supermarkets

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A perishable department is an important part in many supermarkets as fresh commodity sales typically comprise around 30% of the total stores turnover. This research aims to generate theoretical results and methods to help supermarkets to make decisions on pricing and inventory control for perishable products. The existing literature, generally considers two types of perishable problems: one investigates ordering policies, which is based on the cost structure; while the other discusses pricing policies, which is based on the profit structure. Few studies discuss the optimal ordering policies for perishable commodities, in which the utility decreases continuously over time, and the commodities will be obsolete after their lifetime if not sold. This research will investigate pricing problems for perishable commodity in supermarkets. The supermarket has its opening time, during which new items are produced and sold; any unsold items will be thrown away at the end of day. The inventory is building up over the time to satisfy demand. If the demand is not satisfied, the supermarket incurs a penalty cost for losing business opportunity. On the other hand, if the inventory exceeds a certain level, a discount price will be in place to attract extra demand from customers. When the items are selling at the discounted price, no new items will be produced until the store closes. The supermarket needs

to decide inventory levels and pricing strategies over times. There are several objectives that supermarket would like to consider: 1) to maximize the profit from selling bakery products; 2) to maintain the service level; 3) to minimize the waste at the end of day. This research focuses on a single fresh bakery product in supermarkets. We develop a goal programming model and design a genetic algorithm to solve the model. The research outcomes could help store managers to make pricing strategies, such as original selling price, discounted price, promotion time, and inventory levels over times. Several observations have been made to help store managers to decide different pricing strategies. We analyse the impact of the genetic algorithms parameters on the performance of the model and derive the optimal parameter settings for the problem. The model and algorithm provided in this study could be taken as the first step toward understanding the more complicated situation. For example, customer demand can be affected by other factors except selling prices, such as the quality of the products, the inventory levels, which could be considered in the future work. Another extension would be the ability to coordinate pricing plans across multiple products in multiple periods.

2 - A Greedy Random Adaptive Search Algorithm for the Bi-Criteria, Multi-Level Facility Location Problem

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In this work, we consider the multi-level facility location problem in the context of distribution system design. A new approach for enforcing service level restrictions in a bi-criteria, multi-level facility location problem is given. Additionally, a multi-objective greedy random adaptive search (MOG) metaheuristic is applied to solve a series of bi-criteria, multi-level distribution system design problems.

3 - A multi-objective approach for distribution planning in supply chain with lateral supply

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This study deals with distribution planning of a two level supply chain that consist of a manufacturer and multiple retailers who faces stationary stochastic demand. The retailers may replenish their stocks from manufacturer and allowed to pool inventories. Here we assume unsatisfied demand at one point could be satisfied from stocks of other retailers using lateral shipments.

This type of additional flexibility of supply is of paramount important to the supply chains where stock outs are critical. We developed a multi-objective optimization approach that includes both cost and customer service levels concerns of decision makers. Therefore a more comprehensive performance measure is included to analyze the performance of supply chain. We examine different inventory policies and compare their performance.

4 - Algorithm for Multiple Criteria Decision Making in Clash Prevention at Railway Stations

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The paper proposes the algorithm for solutions of railway safety task by multiple-criteria decision making. The goal of the algorithm is to prevent clashes and collision of trains at railway stations by reducing the human factor and using of genetic algorithm for multi-objective optimization of the interaction between various moving railway vehicles. The main challenge of this research is a real-time optimization using embedded devices taking in account dynamics and stochastics of the real railway transport system.

The main reason of this research is various train accidents that happed mainly at railway stations, when two or more trains have moved on parallel tracks and collided at the switches. Some of the causes are delay of trains and infringements of the planned schedule. Current railway traffic control systems do not allow forecasting the probability of collision and preventing it.

Therefore, the main goal of the research is to investigate and develop the algorithms of MCDM for real-time railway transport scheduling and control. The combination of two solutions is proposed. On one side, it is possible to stop the train just before the fact of collision. On the other side, it is more effective to foreseen the probability of collision by real time control of the actual situation and then just minor reduction of the speed of change of the schedule may prevent the crash.

The research includes the analysis of existing railway transport system, the development of the mathematical models and multiple criteria schedule and speed fitness function of the genetic algorithm for train anti-collision task.

The computer model of the train movement including stochastic parameters, such as traffic, technical condition, delays, and weather conditions is created. In addition, prototypes of embedded intelligent devices are developed to test the algorithm in real conditions.

During the optimization process the information

about all trains approaching the station are collected and the control system is self-trained to minimize the risk of the collision. The real system is based on microprocessors and using RF wireless communication. The system is able to evaluate the situation and to propose to change the speed of the trains to avoid the dangerous situation.

Set of more than thousands experiments have been performed to get statistics for analysis. The developed models and algorithms may improve the safety level of transport system control. The schedules developed by the algorithm provide better results than the original schedule by all target function criteria. Smart networks of the embedded devices for railway transport may be used to prevent collisions, and can be integrated in existing working infrastructure.

The research leading to these results has received funding from the ARTEMIS/ECSEL Joint Undertaking and from State Education Development Agency and Ministry of Education and Science under grant agreement no 621429.

★ FR-2-κ-HS4

◆ AHP/ANP

Friday, 11:30–13:10 – Room HS 4

Session: AHP/ANP for Sustainability

Chair: Yannick Cornet

1 - Fair centralized allocation of resource limitations among processes

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Introduction

Due to an increasingly competitive business environment, companies are forced to strive for advanced planning mechanisms to allocate their resources as optimally as possible. This allocation is usually decided centrally, and is ideally based on a performance analysis such as the Data Envelopment Analysis (DEA), which has received increasing attention since the publication of three groundbreaking papers in 2004 (Korhonen & Syrjnen, 2004; Lozano & Villa, 2004; Lozano et al., 2004). However, some circumstances limit the usability of existing approaches. First, if it is intended that the total resource level

that should be allocated among the processes is defined ex-ante, as is regularly the case within strategic planning processes, a further decision-making problem that goes beyond DEA analysis occurs. Second, the common assumption that external benchmarking figures are available to perform a DEA analysis is often not fulfilled in business practice. To address these challenges, we developed a decision-support method allowing the allocation of an ex-ante defined resource level across the various processes of a single organization to ensure the achievement of overall organizational targets, without the requirement of collecting external benchmarking figures. We propose an allocation model formulated as a mixed-integer/linear program (MILP) that incorporates a social welfare function, allowing decision makers to consider fairness aspects. Within the DEA analysis, allowing for heterogeneity, the processes of an organization are defined as operating units. The practicability of the method was demonstrated in a real case setting, by applying it to the indirect processes of a first-tier automotive supplier plant. Within the case study, an Analytic Network Process (ANP) was applied to determine the required process data. The usability of the method is further underlined by comparing the real case results to alternative allocation strategies, as well as to the allocation strategy applied by the case organization.

Methodology

The allocation method consists of two main steps.

First, the processes of a single organization are analyzed with regard to efficiency via a DEA analysis. Within the DEA analysis, based on the further development of a recently published approach by Lozano (2014) that allows for heterogeneity, the processes are defined as operating units, their costs as inputs, and their value contribution to the overall organizational goals as outputs. The second step is to define which and how much each inefficient process needed to improve, given a reduction goal defined by the centralized decision maker. By improvement, we mean the reduction of costs while still producing the same value. This effort is not linear, and is different for each process. Therefore, further allocation objectives are required to ensure a specific and precise allocation proceeding. Based on the work of Hooker and Williams (2012), we rely on the objective to enable the centralized decision maker to obey a tradeoff between efficiency and fairness respectively equity and utilization, considering the strain of each process to reach improvements within the allocation processes. To achieve this aim, a social welfare function is used as a basis, and is maximized by MILP. The model integrates two approaches: a maximin principle (maximizing the welfare of the worst off) and, in extreme situations, a utilitarian objective (if it takes too many resources from others). determines, defined by the deci-

sion maker during the allocation process, when the switch happens. For a given α , it ensures that the same policy is applied in any allocation situation by maximizing the social welfare function. In other words, α determines how many of the inefficient processes have to contribute in order to reach the overall resource level, and to what extent.

Case study

We considered an organization that was confronted by demanding cost pressure. Top management asserted that cost reductions across their indirect processes were crucial in order to stay competitive. In addition to the definition of the processes and the determination of their costs and values, an important step was to determine their utility functions. We did this by expert evaluations and piece-wise linearization based on a certainty equivalence approach, as described by Goodwin and Wright (2004). An ANP was applied to determine the values of the processes. Different allocation scenarios for different α and reduction goals were analyzed.

Conclusion

The developed method allows decision makers to decide whether to allocate required resource reductions, for example to ensure market competitiveness, among more or fewer processes in an organization, based on fairness and efficiency factors. The usability of the developed approach became obvious when applied in a real case setting, and when compared with alternative allocation proceedings: It allows for the allocation of resource reductions among significantly fewer processes, while still generating higher utility values and ensuring fairness.

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2 - Success factors for integration of sustainable practices at high performance building processes through AHP-based MCDM

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Much of the efforts towards low carbon built environment focus on the building energy performance and the relationship between occupant behavior and efficient supply facilities, arguing that impacts are higher during operational stage. However little progression has been - The ongoing study aims to provide a simplified method to decide upon constructive systems for structural slabs based on hierarchical multicriteria weights applied to a set of criteria through a value function: durability, resource depletion, climate impact, investment cost, user comfort and functional desing. The main function of slabs as load distribution layers of the structural frame used to be the solely priority of design practice. Other functions of the building as a dynamic system interact within the environment and occupants along time. Currently dealing with sustainable materials and life cycle inventories we aim to provide with a reproducible method for early election of the type of slab by embedding environmental (resource efficiency) and social (durability and performance) criteria among the design criteria. First, we seek for a way to hierarchically distribute the criteria and sub-criteria among the goals against resource depletion and the diverse alternatives. AHP-based MCDM is chosen to build a multi-level hierarchical structure of objectives, criteria, subcriteria, and alternatives. The analysis outlines the expert preferences for factors of buildability and cost premium of implementation of high environmental value of project design. Further analysis will focus on interrelation among factors.

3 - High speed rail: a mandate from future generations? Applying strong sustainability theory to the UK's HS2 assessment using a multiplicative AHP decision support model

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The EU White Paper sees high-speed rail (HSR) as one essential component in shifting passenger transport to rail. Currently France and Spain lead in terms of share of HSR in total passenger-kilometres, whereas the UK can be considered a new entrant.

Due to cost-benefit analysis (CBA) methods used in standard transport assessments, speed and expected travel time reductions have come to the forefront as the main benefit component justifying the heavy upfront investments required by HSR. However these results are often contested, largely because of the difficulty to

model and monetize adequately the overall network impacts of HSR as part of a wider multi-modal transport system.

The renewed interest in high speed rail in the UK has brought into question the assessment methodologies for these types of large infrastructure projects. It remains unclear to what extent and how critical various aspects of sustainability should be considered, and for this reason environmental impacts have been relegated to a subsidiary role. Furthermore, the interplay of economic, technical, and environmental factors in the longer term have challenged the suitability and credibility of traditional cost-benefit analysis and accompanying benefit cost ratios (BCR) in guiding decision-making. As a consequence, new value-based narratives have emerged to justify investment in HS2, such as the reduction of wealth inequalities between regions (regional integration).

There is thus a need to reconcile the science with the practice, particularly concerning the appraisal of transport projects and long term visions of environmental sustainability. In this context, the paper examines how a more finely grained assessment of sustainable transport principles together with MCA/AHP methods can provide a framework for future action and inform the selection and prioritisation of indicators for the appraisal of the impacts of HSR.

The methodology applied here was originally developed as part of the SUSTAIN project on an infrastructure assessment case in Denmark. The purpose of this paper is to test and improve this sustainability assessment methodology on a complex transport infrastructure project of national scale.

The complete approach consists of mixed methods, including surveying key actors representing different viewpoints and consolidating the input using Multi-Criteria Analysis (MCA) as a way to assess direct and indirect effects that are not easily monetizable or quantifiable. A review and discourse analysis of the existing assessment literature of HS2 allows the definition of a set of contextually relevant criteria which can be ascribed to one of the three common dimensions of sustainability (economic, social or environmental). A shortlist is then kept as the basis for the assessment, for e.g. capacity improvements, regional integration, or protection of biodiversity respectively.

A list of alternatives are defined, including for e.g. building HS2 as defined in the current proposed Bill, investing in the electrification of the existing rail network, investing in other modes of transport, or not investing in any project. Each of the alternatives is first assessed against each of the criteria by eliciting preferences from a group of transportation experts using a multiplicative version of the Analytic Hierarchy Process (AHP) by Saaty (also known as the REMBRANDT technique) which has been proven well suited for group decision making.

The purpose of the MCA approach here is not to provide a truth as to which option is deemed most sustainable, but rather to assist the decision-maker by providing different viewpoints which help put the project in perspective, providing a type of sustainability benchmark to compare with. For this purpose, three stakeholders are created: 1) key actors position 2) sustainability expert forum 3) strong sustainability theoretical position.

The first “key actors position” is intended to represent the outcome of the official appraisal; it represents the UK government position. The other two positions are both intended to provide a new perspective representing the interest of future generations. The “sustainability expert forum” elicits criteria preferences from the perspective of a group of sustainability experts. This position thus forms a type of sustainability advocate. The third position is similar to the second, except that it does not rely on stakeholder involvement, but rather attempts to represent a “theoretical position” by applying concepts of strong sustainability proposed by the ecological economics literature.

The three positions are then compared and analysed for the strength of their support to each of the given alternatives. The robustness of each criterion is evaluated to test to what extent each of the position can be reconciled with one another.

The approach is finally analysed in terms of its strengths and weaknesses. It is found that the methodology is useful in providing a stronger sustainability perspective to compare with the key actors position in the HS2 case. The results provide a basis for decision-makers to compare with the outcome of more traditional decision-making processes such as CBA. More importantly, the approach provides clarity and explicitness of the actual criteria considered in the decision process, and thus allows challenging and testing for various options if the preference of a single criterion is increased or decreased.

The research also brings forth a few conceptual and operational challenges for further study which the authors are keen to discuss in an appropriate forum. The authors have a preference for the IS-SUST track at MCDM 2015.

The authors are grateful to the SUSTAIN research project and to the SINTROPHER study.

★ FR-2-σ-HS5

◆ Multi Objective Optimization

Friday, 11:30–13:10 – Room HS 5

Session: Robust and Combinatorial Optimization

Chair: Kathrin Klamroth

1 - A cut and branch approach for a class of bi-objective combinatorial op-

timization problems

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In this talk we discuss a cut and branch approach for bi-objective optimization problems with integer outcome vectors. The approach improves the LP-relaxation by adding cuts at each extreme point of the efficient frontier of the LP-relaxation. After improving the LP-relaxation, we propose a branch and bound algorithm which alternately branches in objective space and in decision space. Experimental results for the single source capacitated facility location problem is reported.

2 - A Multiple Objective View on Outlier Handling at the Example of Center Location Problems

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

We model the exclusion of very distant facilities in a center location problem by using k max functions: Not the maximal, but the k -th largest distance should be minimized, where k is at least 1. It turns out that k max-center location problems on networks can be solved efficiently by enumerating candidate solutions from a finite dominating set that is independent from the particular value of k . As a consequence, k max-centers can be found for all reasonable values of k at little extra cost as compared to a single solver call, for one fixed value of k . We discuss the problem of selecting a suitable value for k in the light of the trade-off between k , i.e. the number of customers excluded from service, and the transportation cost when ignoring these customers. We show that the complete nondominated set of this biobjective optimization problem (number of outliers versus original objective function value) can be determined in polynomial time.

3 - Robustness concepts in multi-objective optimization

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The best solution is often not helpful in practical applications if changes of the input data or disturbances occur. This makes robust optimization an important field of research. Uncertainties do not only apply in single-objective optimization problems, but also in multi-objective optimization. It is hence a challenging question to define what a “robust Pareto solution” is and to provide algorithms for its computation. This is not an easy task, even in single-objective optimization different definition when a solution x is called robust are published and it depends on the respective application which of them is appropriate.

In this talk we develop, discuss and compare different ideas to define robust Pareto-solutions. We present the concepts of highly robust efficiency and flimsily robust efficiency and collect different generalizations of the concepts of minmax robustness. We furthermore show how the concept of light robustness can be extended from the single-objective to the multi-objective case. From the literature we also collect the concept of properly robust efficiency (Kuroiwa and Lee, 2012) concepts of local efficiency (Georgiev et al, 2013) and of some kind of reliability (Gunawan and Azarm, 2005).

We analyze the properties of the resulting robust Pareto solutions, show dependencies between these concepts and give some first algorithmic ideas on how they may be solved. All our findings are illustrated in examples.

To be more formally, let a multi-objective optimization problem $\min f(u,x)$ be given, where f is a vector-valued objective function whose value does not only depend on our solution x but also on some parameters u which are not known in advance. As common in robust optimization we assume that u only takes values from a given uncertainty set (which may be finite or infinite) which contains all possible scenarios which can occur for u .

We start with two intuitive concepts: A solution x is called highly robust efficient if it is a Pareto solution for all scenarios u , and it is called flimsily robust efficient if it is a Pareto solution for at least one scenario u in U . Not surprisingly, we will usually find too many flimsily robust efficient solutions while highly robust efficient solutions need not exist at all. We will also demonstrate that a highly robust efficient solution need not always be what a practitioner expects.

We then turn to three possible variations of the concept of minmax robustness for multi-objective problems. The idea of minmax ro-

bustness is to hedge against the worst case. In single-objective optimization, the worst case over all scenarios can for a fixed solution x be determined by solving a single-objective optimization problem. This is no longer true for the multi-objective case, since even the determination of a worst-case scenario for a given solution results again in a multi-objective optimization problem. More precisely, instead of looking at one value $f(x)$ for a given solution x we are now left with a set $F(x, U)$ of values, namely $f(x, u)$ for every u in U . In order to decide if a solution x dominates another solution y we hence have to compare the resulting sets $F(x, U)$ and $F(y, U)$. Depending on the order relation between sets to be used we obtain e.g. the set-based approach described in (Ide, Ehrgott and Schbel, 2014). We show that strictly robust efficient solutions need neither be flimsily nor highly robust efficient, and that also the converse does not hold in general. However, they have more appropriate properties than flimsily and highly robust solutions.

If dominance between the sets $F(x, U)$ and $F(y, U)$ lead to other concepts. An example is the concept of point-based strictly robust efficiency (Kuroiwa and Lee, 2012) in which the maximum over all scenarios is taken for each of the objective functions separately in a first step and the remaining (deterministic) multi-objective problem is solved in a second step. We show that this concept is the same as the set-based approach if the uncertainties in the objective functions are independent of each other. A concept in between is the concept of hull-based robust efficiency (Bokrantz and Fredriksson, 2013).

We finally generalize the concept of light robustness for single-objective optimization problems (Fischetti and Monaci, 2009, Schbel, 2014) to the multi-objective case. The basic idea of this concept is to ensure that a robust solution must not be too bad for some “nominal” scenario which may be chosen as the most likely or the undisturbed scenario. The concept hence requires that a certain quality for this nominal scenario has to be satisfied. Under all solutions which satisfy this quality, the most reliable solution should be taken. When transferring this concept to multi-objective optimization problems we follow an idea of (Kuhn et al, 2012) used for the special case of bi-objective optimization with only one uncertain objective function. For a general multi-objective problem we start with the Pareto set of the nominal scenario make each of these Pareto solutions more robust (while still providing good enough objective values) in a second step. This is done by using the concept of min-max robustness on the problem restricted to the required quality. In contrast to the other concepts of robust efficiency, the advantage of the concept of light robustness is that a frontier of robust Pareto solutions is obtained from which a practitioner can choose from.

4 - On the representation of the search

region in multi-objective optimization

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Given a finite set N of feasible points of a multi-objective optimization (MOO) problem, the search region corresponds to the part of the objective space containing all the points that are not dominated by any point of N . Many exact and approximate algorithms to solve MOO problems operate by iteratively generating points that are candidates to be included in the output. Denoting by N the set of candidate points at some step of such an algorithm, the search region is therefore the part of the objective space which may contain further nondominated points. This concept of search region is of outmost importance for the search process and the definition of a stopping criterion. However the above definition is generally not usable in algorithms, such as multi-objective branch and bound, two-phase method and methods based on solving budget-constrained programs. Another definition exists, which characterizes the search region as the set of all points that strictly dominate at least one vector from an auxilliary discrete subset of the objective space.

In this talk, we discuss the definition and the computation of this auxilliary set, which we call, in the minimization case, a set of (tight) local upper bounds. While this is intuitive and straightforward to compute in the bi-objective case, the arbitrary-dimensional case is less obvious. We first relate this issue to the state of the art in computational geometry and provide several equivalent definitions of local upper bounds that are meaningful in MOO. We discuss the complexity of this representation in arbitrary dimension, which yields an improved upper bound on the number of solver calls in epsilon-constraint-like methods to generate the nondominated set of a discrete MOO problem. Then we consider the computation of local upper bound. We note that, in the context of solution approaches to MOO, an incremental algorithm is required. We analyze and enhance a first incremental approach which operates by eliminating redundancies among local upper bounds. We also study some properties of local upper bounds, especially concerning the issue of redundant local upper bounds, that give rise to a new incremental approach which avoids such redundancies. Finally, the complexities of the incremen-

tal approaches are compared from the theoretical and empirical points of view.

★ FR-2- χ -HS6

◆ Environment, Infrastructure & Emerging Applications

Friday, 11:30–13:10 – Room HS 6

Session: IS-SUST: Use of MCDM to support sustainability evaluations: a way forward in multidisciplinary research

Chair: Marco Cinelli

1 - Stochastic Multi-Attribute Analysis (SMAA) for Life Cycle Assessment (LCA)

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This study implements Stochastic Multi-attribute Analysis (SMAA) to the interpretation stages of comparative Life Cycle Assessment (LCA). Comparative LCAs quantify the life cycle environmental impacts of equivalent products or technologies throughout the initial stages of raw material extraction, processing, manufacturing, distribution, use and final disposal. Data generated from a comparative LCA can help steer industry practices, inform public policy interventions and accelerate research prioritization for reduction of environmental impacts. However, while these comparative studies generate valuable data, the results can be difficult to interpret because of the existence of tradeoffs, data uncertainty, and multiple decision makers and stakeholders.

SMAA uses internal normalization by means of stochastic outranking and exploration of feasible weight spaces. This method is most effective at identifying relevant tradeoffs in a comparison due to its relative assessment and it generates more robust results because it allows for inclusion of uncertainty in parameters and weights. This approach represents a major advancement in LCA interpretation practice because it directly studies relevant differences as opposed to performances with respect to an external baseline. To demonstrate application of SMAA in LCA as compared to traditional methods of interpretation, this study performs a case study of a comparative LCA of five different photovoltaic technologies for a domestic installation.

2 - Sustainable planning in small areas: a multicriteria approach

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The aim of this paper is to show the usefulness of Spatial Multi-criteria Decision Analysis (MCDA) in measuring sustainability in a planning context, with particular regard to small areas, e.g. a single municipality. Using this type of approach, which combines the strengths of both MCDA and spatial analysis, produces better results in public policy decisions on sustainability. The model, called GeoUmbriaSUIT, has been implemented as a plugin within Qgis 2.2, and it is based on the TOPSIS algorithm as the MCDA methodology. In the case study here presented, we evaluated the level of sustainability of different municipalities, taking into account the three dimensions economic, environmental and social of sustainability. The results obtained are very useful in order to understand the specific needs of a certain area and to develop sustainable growth, implementing specific plans. Moreover, the results obtained with this model are very easy to be understood by the Decision Maker, thanks to the typology of outputs given by GIS, thus they are useful in a public policy context.

3 - Multicriteria Decision Aiding for strategic assessment in urban processes

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Decision problems in the domain of urban design represent “weak” or unstructured problems since they are characterized by multiple actors, many and often conflicting values and views, a wealth of possible outcomes and high uncertainty (Prigogine, 1997; Simon, 1960). Under these circumstances, the evaluation of alternative scenarios is a complex decision problem where different aspects need to be considered simultaneously, taking into account both technical elements, which are based on empirical observations, and non technical elements, which are based on social visions, preferences and feelings. It has been generally agreed that Multicriteria Decision Analysis (MCDA, Roy and Bouyssou, 1995; Figueira et al., 2005) can offer a formal methodology to deal with such decision problems, taking into account available technical information and stakeholders values. The present study not only uses MCDA in an innovative context, i.e. urban regeneration, but also aims at investigating the role of mixed-method research approaches for supporting decision making problems in the same context. As a matter of fact, the work that has been developed in this study calls for multi-level perspectives

and multi-actors evaluation and employs both qualitative driven approaches for exploring the general problem (i.e. stakeholder analysis) and quantitative driven approaches for better investigating alternative options and performances (i.e. MCDA). In particular, the study considers the problem of how to support urban regeneration processes using the Multi Attribute Value Theory (MAVT, Keeney and Raiffa, 1976), a particular kind of MCDA method. MAVT can be used to address problems that involve a finite and discrete set of alternative options that have to be evaluated on the basis of conflicting objectives. For any given objective, one or more different attributes or criteria (both qualitative and quantitative), which typically have different measurement scales, are used to measure the performance in relation to that objective (Keeney and Raiffa, 1976). The method involves different phases that can be described as follows: 1. defining and structuring the fundamental objectives and related attributes; 2. identification of alternative options; 3. assessment of scores for each alternative in terms of each criterion; 4. modelling preferences and value trade-offs; 5. ranking of the alternatives: a total score is calculated for each alternative by applying a value function to all criterias scores. This study thus integrates stakeholder analysis (Dente, 2014) and MAVT in order to better support the key phase of problem structuring and objectives identification. The use of multiple methods allowed the overall process to benefit of synergic effects. Starting from a real case concerning the requalification of a railway station in the metropolitan area of Torino (Italy), the work aims at exploring the contribution of MAVT for decision problems in the field of urban design and regeneration processes. Firstly, a stakeholders analysis was developed which allowed to identify the actors involved in the problem, as well as their values and objectives. Secondly, alternative requalification strategies for the area were generated and compared through MAVT on the basis of different attributes, such as social services, green areas, investment cost, real estate market effects, cultural heritage valorisation etc. Mention should be made to the fact that the evaluation model made use of an expert panels for the elicitation of the value functions and for the definition of the set of weights. The research has an innovative value because only few applications of MAVT exist in this specific decision context. The results of the performed analysis show that MAVT is efficient in representing the real problems of a territorial system. One of the most significant strengths of the MAVT methodology is represented by the fact that the DM and stakeholders gain more awareness of the elements at stake while structuring the model and thus learns about the problems while solving them. Thus, MAVT is not only an aid that can be used to select the best alternative, but also helps DMs to rationally structure the decision problem.

4 - The MCDM Application on the Behavior Framework to Rural Local Cultural Industries in Agriculture Technology Era

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Agriculture life is a symbol of traditional sector. Nowadays, the technology device leads the industrial integration and gets individual contact closer to each sector of our life. The development of rural local cultural industries tends to be a hot discussion in the agricultural technology era, while people have used to count on electronic products to foster their contacts and activities every certain minute. Therefore, resource allocation and integration become an important policy issue. This paper focuses on building the behaviours framework and developing hierarchical structure for rural local cultural industries. We invite experts to join the discussions, brainstorming activities, questionnaire survey, assess the criteria in different aspects; and then apply MCDM technique to prioritize the development decision mode. The results provide reasonable and feasible solutions for related institutes and organizations, whose usefulness is proven in practice.

Friday, 14:30–15:20

★ FR-3

♦ Closing Session

Monday, 14:30–15:20 – Aula

Session: Closing Session

Chair: Martin Josef Geiger

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