Scientific Program
Monday, 9:00-10:00

MON-1 - DMS4101
Session: Opening Welcome
Monday 9:00 - 10:00 - Room DMS4101
Chair: Sarah Ben Amor

Monday, 10:00-11:00

MON-2 - DMS4101
Plenary Session: Dr. Blair Feltmate
Monday 10:00 - 11:00 - Room DMS4101
Chair: Sandra Schillo

1 - Un-Natural Alliances: Financial and Ecological Expertise Must Align to Address the Contagion of Climate Change
Dr. Blair Feltmate, University of Waterloo, Canada

As a consequence of climate change, extreme weather events are on the rise — from floods, to droughts, wind, hail and fires. To date, means to adapt to these events have largely been considered in “professional isolation”, by those with either scientific backgrounds, or others working in business, the capital markets, or the legal profession. This presentation will focus on the need for these seemingly disparate entities to cooperate to address the climate file, as each brings to the solution matrix a unique and necessary skill that will ultimately serve the collective good. In the absence of creating such un-natural alliances, climate change and extreme weather events will not be meaningfully addressed.

This Keynote Speaker session is sponsored by INTACT.

MON-3 - CON-DMS4120
Contributed Session
Monday 11:30 - 13:10 - Room DMS4120
Session: Environment, Infrastructure and Emerging Applications
Chair: Francis Marleau Donais

1 - Multiple Criteria Decision Making using Convolutional Neural Networks Algorithm for Unmanned Electric Transport
Anatoly Levchenkov, Riga Technical University, Latvia
anatolijs.levcenkovs@rtu.lv
Mikhail Gorobetz, Riga Technical University, Latvia
mihails.gorobecs@rtu.lv

Modern electric transport becomes more popular because of the development of the electric industry and its innocence to the environment. One of the most topical problem is safety and the ability of intelligent electronic devices to intervene in transportation process to prevent accidents. The risk of crashes and road accidents is increasing proportionally to the increasing number of transport vehicles in the system. The most usual reason of the accidents is human factor. Authors propose to use intelligent devices for decision making based on convolutional neural network and fuzzy logic to reduce the influence of the human factor. The convolutional neural network is able to make an intelligent recognition of external potentially dangerous factors, such as obstacles, signals, humans and other. The intelligent control system shall assess the risk of the current situation and shall react automatically to reduce the risk and prevent possible crash in both emergency and even risky situations.

The main purpose of this research is to develop the structure of on-board active electric transport control system and to develop algorithm for convolutional neural networks and fuzzy logic controller to recognize object and evaluate the accidents and crash risk level of the situation and to prevent without human intervention, thus reducing the human factor. The following tasks are defined for goal achievement. The first tasks includes the development the structure of the on-board active electric transport control system and the development of the system mathematical model with convolutional neural network (CNN) and fuzzy logic (FL) submodels. The second task is the development of the algorithms of CNN and FL for the decision making about the necessary speed and trajectory. The third task is to implement and test the models and algorithms for microcontroller devices and to analyse the results.
Algorithm for the potential danger assessment on the electric transport consists of:
A. Initialization of parameters and features of objects;
B. Obtaining data from sensors and input devices
C. Performing functions of the convolutional neural network module:
   C1. Object detection using convolutional neural network with training;
   C2. Size, movement trajectory and speed of the detected object;
   C3. Estimation of the level of danger;
D. Performing functions of the fuzzy logic control module:
   D1. Initialization of the possible vehicle speed change;
   D2. Initialization of the possible vehicle trajectory change;
   D3. Initialization of the traffic rules;
   D4. Evaluation of the risk of decision;
   D5. Decision making about the selection of the action.

To perform tests of various situations, different combinations of recognized objects need to be taken. The main parameters for the evaluation of the danger of situation are: indication of the traffic light (permissive, permissive with need of speed decrease, restrictive, shunt from one route to another), restrictions and permissions made by road signs, existence of external subject near the road (people, animals, cars, fallen tree); speed of the external subjects vo, trajectory of the external subjects.

For the testing the algorithms of convolutional neural network for computing intelligence electric transport control system the prototype of the system is created.

2 - Best solid waste management scenario selection under DEMATEL and TOPSIS methods
Emre Çalışkan, Gazi University, Turkey
ecaliskan@gazi.edu.tr
Ümit Sami Sakallı, Kirikkale University, Turkey
ssakalli@kku.edu.tr
Erdem Aksakal, Atatürk University, Turkey
erdem.aksakal@atauni.edu.tr
Nowadays one of the issues that constitute major problems for environment is the solid waste. As being a major problem for environment, solid waste became a management style. In our modern challenging world, having an efficient management style is the first step to get over the problems. Solid waste management is used to refer to the process of collecting and treating solid wastes. It includes the collecting, treating, and disposing of solid material that is discarded because of no longer use/useful. Such processes bring about a number of various solid waste management scenarios which are evaluated through criteria or objectives. These scenarios affect population, relate to various problems, change costs levels and time needed to become effective. In this study, selecting the best solid waste management scenario among three different alternative scenarios within four main and eight sub-criteria is considered. The DEMATEL method preferred for evaluating criteria weights since it will not consider degree of importance. After having the weights, TOPSIS method is used for selection process.

3 - An Application of AHP Weighted Topsis Method for Livable City Selection
Mehmet Salih Goceri, Santa Clara University, USA
mgoceri@scu.edu
Ozgur Uysal, American College of the Middle East, Kuwait
Ozgur.Uysal@acm.edu.kw
Mehmet Sevkli, American University of the Middle East, Kuwait
mehmet.sevkli@aum.edu.kw
Ali Turkyilmaz, Nazarbayev University, Kazakhstan
ali.turkyilmaz@nu.edu.kz
In this paper, an application of AHP-weighted TOPSIS study for “city selection” is presented. The criteria for city selection process is based on a Turkish Statistical Institution (TUIK) indexing study pursued in 2015 for all the big cities in Turkey. It measures and compares the city lives of individuals and families using qualitative and quantitative indicators. Main dimensions of city life used in this TUIK research are: Working conditions, income and welfare, healthcare facilities, educational facilities, landscaping, security, access to infrastructure services and social life. The best cities are listed for each dimension and an overall rating is provided for the cities. In this paper, these 8 criteria are used throughout the study. Also, a survey is carried out with a population of 113 people to find out the relative importance of the 8 criteria them. The decision matrix and alternative weights of the criteria are found in this way.
The best 5 cities listed as the result of the TUIK research is considered in this study. These are denoted as A, B, C, D and E. The weights of the selection criteria is calculated by using the AHP method. Five expert opinions are taken for the relative qualitative comparisons of the criteria. The weight of the criteria obtained by the AHP method is then used in the TOPSIS method for the final comparison of the five cities. As a conclusion, using the AHP-based TOPSIS method, City D is identified to be the most livable city.

4 - Integrating sustainable transportation in decision-making processes: A comparison of Multi-Criteria Decision Making and Cost-Benefit Analysis

Francis Marleau Donais, Laval University, Canada
francis.marleau-donais.1@ulaval.ca
Irene Abi-Zeid, Laval University, Canada
irene.abi-zeid@osd.ulaval.ca
Edward Owen Douglas Waygood, Laval University, Canada
owen.waygood@esad.ulaval.ca
Roxane Lavoie, Graduate school of Land Management and Regional Planning, Université Laval, Canada
roxane.lavoie@esad.ulaval.ca

Transportation project assessments are complex processes where the evaluation of various socio-economic impacts often involve a large number of stakeholders. The recent evolution towards more sustainable development projects has greatly impacted how these projects are assessed (Haezendonck, 2007; Gudmundsson, Hall, Marsden, & Zietsman, 2016). In order to support rigorous decision-making, two approaches are commonly used by governments and cities: Cost-benefit analysis (CBA) and multi-criteria decision-making (MCDM) (Browne & Ryan, 2011). Although several studies comparing these approaches from an environmental perspective may be found in the scientific literature, very few papers have addressed the transportation planning perspective. In this paper, we argue that both MCDM scholars as well as researchers and practitioners from the transportation field should get more involved in the application of MCDM to support decision making in transportation projects. We show that MCDM can better integrate the various sustainability dimensions than CBA, by taking into account qualitative and non-monetary aspects present in a sustainable transportation context.

Based on a literature review related to MCDM and CBA in the transportation field and other fields of study, we compare these methods according to their main characteristics, their similarities, their differences, their strengths, their weaknesses and their anticipated benefits in a decision process. To include sustainability principles, we specifically seek to understand how these methods deal with non-quantitative aspects and how they can take into account diverse stakeholders’ perspectives.

Our results show that both methods can help improve the decision-making process by highlighting the trade-offs between alternatives (Annema, Mouter, & Razaei, 2015). However, we observe that CBA approaches cannot properly evaluate the social and environmentally related aspects (Ambrasaitė, Barfød, & Salling, 2011; Gudmundsson et al., 2016). Compared to MCDM, they tend to disregard and ignore more qualitative and subjective elements (Annema & Koopmans, 2015; Tudela, Akiki, & Cisternas, 2006). In fact, some transportation project assessments purposely exclude environmental and social aspects. As suggested in the environmental planning literature, we observe that by adopting a more global and holistic perspective, MCDM emerges as an efficient appraisal tool to integrate sustainable transportation (Hüging, Glesson, & Lah, 2014; Pryn, Cornet, & Salling, 2015). Following some authors that propose to combine the best of CBA and MCDM (Damart & Roy, 2009; Shiau, 2014; van Wee, 2012), we emphasize the need to develop new MCDM tools that better integrate sustainable elements in the transportation field decision-making process.

References
We consider decision processes consisting of a finite number of stages, determined by the decision maker. The decisions are made at the beginning of the consecutive stages and evaluated using many evaluation criteria. In the evaluation of the feasible process realizations we will use both stage criteria, which are related to the specific stages of the process, and multistage criteria, used to evaluate the overall realization of the process. Problems of this type are classified as problems of multiobjective dynamic programming. We consider the most frequently occurring situation, in which multistage criteria are sums of stage criteria.

When formulating the issue of process realization evaluation, we refer to the general notion of optimality in multiobjective problems. We assume that the components of the vector criteria function are the consecutive multistage criteria. As vector-optimal realizations we admit those which are non-dominated (in the criteria space) or efficient (in the decision space).

Among the varied topics dealt with currently there are many problems in which the hierarchization of the evaluation criteria is an essential element.
The issue of hierarchization of criteria has been presented many times in the literature dealing with multiobjective decision making, in particular in papers on goal programming. This hierarchization is understood in two ways. In the first approach, the criteria are assigned weight coefficients and the importance of a criterion is reflected by the appropriate value of this coefficient: the more important the criterion, the larger the value of the weight coefficient. In the second approach, hierarchy levels are introduced. Criteria on higher levels are regarded as more important than those on lower levels; criteria on the same level are equally important for the decision maker. For criteria situated at the same hierarchy level weight coefficients can also be used. When hierarchy levels are used, we can introduce a single hierarchy or a group hierarchy. In the former case, a hierarchy level contains only a single criterion. In the latter case, a hierarchy level can contain more than one criterion.

In a discussion of hierarchical problems with a single criteria hierarchy it is important to create an appropriate numbering of criteria. The criteria can be numbered so as to assign the number 1 to the most important criterion, the number 2 to the second-most important criterion - one that is less important than criterion number 1 but more important than all the remaining criteria, and so on. A similar method of numbering can be applied in the case of group hierarchy. Criteria from a more important group will have numbers lower than all the less important criteria; criteria from the same group are equally important. Therefore, the numbering of criteria within one group is ambiguous.

The issue of criteria hierarchization discussed above appears also when multistage decision processes are considered. In such cases, both stage criteria and multistage criteria can occur. When a hierarchy of stage criteria is established, we can hierarchize multistage criteria in the same way as described above. A different situation occurs when the importance of stage criteria for the decision maker vary from stage to stage. This is the case of a changeable stage hierarchy. We assume that at the given stage, stage criteria have been divided into a certain number of groups, depending on their importance. Each group contains criteria which are equally important for the decision maker. Moreover, a hierarchy of stage criteria can undergo changes in the consecutive stages.

The issue of hierarchization of multistage and stage criteria was discussed before by the present author. A change in importance of the criteria often influences decision making. Not infrequently, to achieve a better stage evaluation of a criterion which is important at the given stage, the decision maker is inclined to give up on the optimization of the realization of the multistage objectives. Obtaining such immediate profits can, however, have a very negative impact on the evaluation of the entire process. For that reason, in the case of criteria hierarchization, it seems justified to focus the analyses on the values of both the stage and multistage criteria.

The present paper attempts to answer the question about the method of controlling a multistage process so as to take into account at the same time both the tendency to multiobjective optimization of the entire process and the time-varying group hierarchy of stage criteria. We will discuss in detail one of many possible situations, in which the stage hierarchy varies in the consecutive stages and depends on the stage. We will present an interactive proposal of the solution of this problem, in which the decision maker actively participates in the process of finding the final realization of the process.

2 - Criteria Reduction Applied To Promethee II

Jean-Philippe Hubinont, ulb, Belgium
jhubinon@ulb.ac.be

Yves De Smet, ulb, Belgium
yves.de.smet@ulb.ac.be

In order to support human beings in decision making different methods have been developed these last decades especially in the frame of Multi-Criteria Decision Analysis (MCDA). Three major approaches are usually considered: Multi-Attribute Utility Theory (MAUT)[1]; outranking methods such as ELECTRE [2] or PROMETHEE [3]; interactive methods such as STEM [4]. Similarly to all these methods, a major concern is the robustness of the analysis[5]. It is a wide concept that includes the stability of the conclusions with regards to imperfect information regarding the evaluations, uncertainties about the possible parameters values characterizing
the method, etc. This paper deals with the PROMETHEE method and the concept of criteria reduction which is strongly linked to the concept of robustness. The idea is to evaluate whether some criteria could be ignored while obtaining the same conclusion. Either the complete same ranking or an identical subset of the same best alternatives for example. This is linked to the robustness concern because it implies a stability in the result considering different families of criteria. Three approaches are studied by comparing the ranking before and after reduction using the Kendall-tau correlation coefficient[6] as a basis of comparison. The first approach consists of modeling the problem into a linear program. The second approach is based on the principal component analysis[7] which is a tool of dimensional reduction. It is a distance based method much used in symmetric contexts which in the context of multi-criteria problems could be inappropriate due to the asymmetrical relations between the alternatives. Therefore, this study also investigates a new visualization tool (a 2D representation of the problem) more appropriate for a multi-criteria context. Finally the third approach attempts to use very simple statistical indicators as the variance and the correlation factor in order to reduce the amount of criteria and mostly, explain the reasons for it. This study first attempts to answer the question of criteria reduction in a multi-criteria context. Then it investigates a visualization tool more appropriate for a multi-criteria context.

References

3 - The WINGS methods - extensions and applications
Jerzy Michnik, University of Economics in Katowice, Poland
jerzy.michnik@ue.katowice.pl

WINGS can handle complex problems involving interrelated factors. It evaluates both the strength of the acting factor and the intensity of its influence. When WINGS is used as a multiple criteria decision analysis (MCDA) tool, the strength (or importance) of the factor plays the role of a criterion weight. WINGS enables the evaluation of alternatives when interrelations between criteria cannot be neglected. In particular, when criteria are independent, WINGS reduces to the additive aggregation, which represents the classical approach in MCDA.

In real-life situations, a decision maker takes into account positive and negative outcomes. Additionally, various uncertainties that accompany the decision problem require a serious reflection on potential (uncertain) consequences. The idea of applying multiple networks has been introduced by Saaty as a tool for enhancing the potential of his Analytical Network Process (ANP). In this paper we show that extending WINGS into multiple networks for benefits, opportunities, costs and risks greatly augments its ability to solve complicated problems. Practicality of the presented solution is demonstrated with the illustrative example of selecting innovation projects. Most of methods based on network analysis (ANP, DEMATEL, Reasoning Map) allows only positive influences (relations). This leads to some complications in using these methods and limits their
applicability. We show that the WINGS method can be extended to a form in which the negative influences are included. The extended WINGS method can be considered as a valuable alternative to Fuzzy Cognitive Map which is widely used for solving problems with interdependencies between components of a system. A utility of such extension is illustrated by examples of problems from public relations and regional strategy."

4 - Comparison of the GAIA and DRSA approaches on the example of the classification of municipalities with respect to employment in the territory of Northern Quebec

Bryan Boudreau-Trudel, Universite du Quebec en Abitibi-Temiscamingue, Canada
bryan.trudel@uqat.ca
Kazimierz Zaras, Universite du Quebec en Abitibi-Temiscamingue, Canada
ekazimierz.zaras@uqat.ca

This investigation presents a comparison of two approaches, Graphical Analysis for Interactive Aid (GAIA) and Dominance-based Rough Set Approach (DRSA).

The two approaches are applied to the explanation of the ranking obtained by the multi-criteria method Preference Ranking Organization Method for the Enrichment of Evaluations (PROMETHEE).

Employment is characterized by the three attributes: the unemployment rate, the employment rate and the participation rate. The resulting classification provided to the DM is the aggregated information on the ranking of 52 municipalities in northern Quebec.

First, to help decision-making, the municipalities were assigned from the multi-criteria classification to one of four categories: (A) those are the best in the region in terms of the perspective considered, (B) those who need support to pass in the class A, (C) those requiring assistance to be classified in category B, and (D) those are the worst in the region and require special assistance in terms of the perspective considered.

After, to make the decision about improving the position of the classified municipality, the DM needs more information that will answer the questions: what criteria are relevant to the given municipality? What criteria are in conflict? What are the critical values of the criteria? To answer these questions, it was proposed to apply two explanatory methods, GAIA and DRSA. In this paper, it is shown that these two methods provide convergent and complementary information, which allows enriching the answers on the questions asked by the DM."

MON-3-CON-DMS4140
Contributed Session
Monday 11:30 - 13:10 - Room DMS4140
Session: AHP/ ANP I
Chair: Jacek Szybowski

1 - A Risk Assessment Approach in a Turkish Aviation Company in the Context of Fatigue Risk Management System

Tugba Demirel, Istanbul Technical University, Turkey
tugbakrac@gmail.com
Ilker Topcu, Istanbul Technical University, Turkey
ilker.topcu@itu.edu.tr

In most of the studies, according to the statistical data 80% of the fatal accidents in the aviation industry is caused by human error and 20% of this 80% is related with fatigue. In order to manage fatigue in aviation industry, which is seen as a risk factor for safety, first of all, fatigue should be assessed. While doing this measurement, it should be considered that there are interrelationships between the factors and every factor does not have the same importance. In most of the studies, fatigue assessment is based on risk factors and mainly focused on high risk group factors. However, important factors like quality and quantity of sleep and circadian body clock are not considered. Also in these studies, if there are multi factors classified as high risk factor group, no priority is set among these factors.

In this study, “Fatigue Risk Management System” (FRMS), which is applied by many aviation companies worldwide, is applied to a Turkish aviation company. The planned FRMS risk assessment process cycle will be accomplished with continuous improvement and proactive control of identification of fatigue hazard factors. In this scope, the importance of the fatigue factors is assessed by Analytic Network Process (ANP) approach with respect to interrelationships among related factors and a fatigue risk assessment process is defined to identify the
fatigue of cockpit and cabin crew members in aviation industry with the most accurate way.

The decision analysts, the authors of this study, interact with experts to establish the fatigue risk assessment process. Experts of this study are a first officer with medical background, two captain pilots with flight experience more than twenty years, and four cabin crew members with different professions. By considering the previous studies in the literature and the opinions of these experts, factors related to the fatigue of cockpit and cabin crew members is identified, and then these factors are classified under three main clusters such as individual, environmental, and work related issues. Some of the individual factors considered in this study are age, gender, body mass index, sleep quality, sleep quantity, and sleep disorders. Second cluster which is environmental factors include weather conditions, working environment conditions, time zone differences, disruption of circadian body clock, and social interaction. The last but not least cluster, namely work related factors, is composed of working stress, late arrival flight duty, early duty, changes in the schedules, traveling time between home and workplace, consecutive night duty planning, intensity of food, and beverage services during short-haul flights.

With an additional interaction with experts, the interrelations among related factors are identified. Based on the responses, a relationship matrix is constructed. As well known, for each parent element, a factor affected by sub-elements, pairwise comparison questions are prepared, cluster by cluster, to compare relative impact of sub-elements affecting this parent element. As a result, decision analysts come up with a pairwise comparison questionnaire. The pairwise comparison questions are posed to fifteen cockpit crew members and twenty cabin crew members who are employees of a Turkish aviation company. In accordance with ANP, paired comparison judgments are arranged in corresponding pairwise comparison matrices. Then, eigenvectors of these pairwise comparison matrices computed are placed to a supermatrix. After converting supermatrix to a column stochastic weighted supermatrix, the supermatrix is raised to a significantly large power in order to have a limit matrix where the converged or stable values exist. The limit matrix exhibit the desired priorities of the factors from the point of view of cockpit and cabin crew members.

A Fatigue Risk Management System methodology will be established by considering current regulations and fatigue risk factors which are mostly contributing to the fatigue of the cockpit and cabin crew members. As a result of this methodology, more efficient and flexible schedules will be obtained which considers optimum flight time, duty time, and rest time.

2 - National Prisons Location in Colombia
Gustavo Bautista, Universidad del Valle, Colombia
gbautistacasanova@gmail.com
Pablo Manyoma, Universidad del Valle, Colombia
pablo.manyoma@correounivalle.edu.co

Overcrowding in the prison system is a phenomenon that occurs when demand for space exceeds quota offer by the system. Different reports from national and international agencies state that overcrowding has serious health problems, internal violence, indiscipline, lack of services and self-esteem problems, among other consequences [1]. In Colombia, overcrowding rate is approximately 60%. The penitentiary policy has focused on expanding supply of quotas for prisoners, through investment in expansion or construction of national prisons (ERON in Colombia), as a measure to reduce overcrowding rate [2]. Installation of an ERON can generate a problems series in its immediate environment, such as: feeling of insecurity in the community, migratory processes, large people agglomerations, greater availability of water, greater generation of solid waste and others.

Penitentiary establishments around the world belong to so called undesirable facilities, whose main characteristic is population rejection. Location models seek to locate such facilities as far as possible from urban centers, but because of need for service they provide, they should be located in such a way that operating costs are not high [3]. Through the AHP the importance of the criteria selected to be taken into account in the location of the site was established. In addition, as a complement, the TOPSIS method was used to order the alternatives. Objective is to select possible sites for location of an ERON in Valle del Cauca region. Decision criteria are taken from the Manual Minimum Standards for
Design of the Prison and Prison Services Unit (USPEC) [4]. On table 1, it can observed brief description of each criteria (sub-criteria) selected. Alternatives are all municipalities of Valle del Cauca, 42 in total, without specifying the possible area of location within it.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Description of Subcriteria</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technicians</td>
<td>Flood hazards or mass movements (C1): should be located in an area of low risk to natural events. The condition of the municipality in general is evaluated. It is be minimized.</td>
<td>1: Low  2: Medium  3: High</td>
</tr>
<tr>
<td>Manual</td>
<td>Closeness to second level health centers (C2): equipped with four specialists: anesthesiologist, surgeon, gynecologist and internal medicine. It is be minimized.</td>
<td>Travel time</td>
</tr>
<tr>
<td></td>
<td>Closeness to security entities (C3): proximity to the Armed Forces. It is be minimized.</td>
<td>Travel time</td>
</tr>
<tr>
<td></td>
<td>Manual Closeness to judicial authorities (C4): proximity of judicial authorities for prisoner prosecution. It is be minimized.</td>
<td>Travel time</td>
</tr>
<tr>
<td>Socio-economic</td>
<td>Close to Family (C5): facility must be located near the places of origin of the prisoners. It is be minimized.</td>
<td>Travel time</td>
</tr>
<tr>
<td></td>
<td>Improvement of Life Quality (C6): will be measured directly proportional to the Unsatisfied Basic Necessity</td>
<td>Best: highest NBI per municipality  Worst: lowest NBI</td>
</tr>
</tbody>
</table>

Table 1. Decision-making process – Criteria

After performing the comparison matrices, we obtained vector of importance of the criteria used. On table 2, it can be seen that criterion 1 and 2 obtained more than 50% of the total.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>C7</th>
<th>C8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Importance</td>
<td>37%</td>
<td>21%</td>
<td>4%</td>
<td>3%</td>
<td>5%</td>
<td>15%</td>
<td>7%</td>
<td>5%</td>
</tr>
</tbody>
</table>

Table 2. Priority Vector

Finally, table 3 shows ranking of best 10 alternatives (municipalities), where a prison establishment can be located. This was done using the vector of weights with implementation of TOPSIS method.

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Ri</th>
<th>Alternative</th>
<th>ERON built</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0,842</td>
<td>Zarzal</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>0,815</td>
<td>Cali</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>0,815</td>
<td>El Cerrito</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>0,808</td>
<td>Ginebra</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>0,798</td>
<td>Tulua</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>0,791</td>
<td>La Union</td>
<td>No</td>
</tr>
<tr>
<td>7</td>
<td>0,789</td>
<td>Roldanillo</td>
<td>Yes</td>
</tr>
<tr>
<td>8</td>
<td>0,778</td>
<td>Palmira</td>
<td>Yes</td>
</tr>
<tr>
<td>9</td>
<td>0,772</td>
<td>Pradera</td>
<td>No</td>
</tr>
<tr>
<td>10</td>
<td>0,772</td>
<td>Yumbo</td>
<td>No</td>
</tr>
</tbody>
</table>

Table 3. Ranking of best solutions

The City of Zarzal is best option for construction of a new ERON, according to the chosen criteria, although El Cerrito and Ginebra are a good option due to its proximity to Cali (regional capital city) and they do not have an ERON. In order for the municipalities with the highest NBI index to benefit from the construction of an ERON, the criterion should have a greater weight as a product of the AHP method. For last but not least, one way to continue the research is to use indicators that show benefits of locating such establishment in a community. For example, it can be
demonstrate increasing basic needs index, through construction of necessary service facilities by prison.

References

3 - Using AHP Weighted TOPSIS Method for Selection of Retail Store In Turkey
Mehmet Goceri, Istanbul University, USA
mgoceri@gmail.com
Tugba Goceri, Fatih University, USA
tbgoceri@gmail.com

In this paper, AHP-weighted TOPSIS has been used to select the best retail stores in Turkey. The criteria for retail store selection have been found in a survey. Afterwards, a second survey method has been carried out in order to determine the weight of each criteria. The results of this study produced an opportunity to see the most important criteria for customers to select the retail stores as well as the best retail stores in Turkey.

4 - On the convergence of the inconsistency reduction algorithm in pairwise comparisons matrices
Jacek Szybowski, AGH University of Science and Technology, Poland
szybowski@gmail.com

We present the algorithm of the inconsistency reduction in pairwise comparisons (PC) matrices whose limit is a consistent matrix. The algorithm bases on the linearization of the sets of PC matrices and its subset of consistent matrices. The main idea is to use the orthogonal projections on linear subspaces corresponding to the most inconsistent triads. The proof of the convergence was completed in 2010. However, the limit matrix of the process has not been sufficiently studied. It appears that it is not only the closest consistent matrix to the input one in the linearized space, but also the one induced by the hierarchy vector of geometric means of its rows. Furthermore, this vector is invariant for each step of the algorithm.

We also compare the normalized vector of geometric means of a PC matrix rows (GM) with the principal eigenvector (EV), used in the AHP method of prioritization introduced by Saaty in 1977. It appears that GM and EV are equal, hence induce the same hierarchy, not only for consistent PC matrices, but also for any PC matrices of size three. On the other hand, we demonstrate the example that they may differ for higher dimensions of PC matrices.

MON-3-CON-DMS4170
Contributed Session
Monday 11:30 - 13:10 - Room DMS4170
Session: Multi Objective Optimization
Chair: Lakmali Weerasena

1 - New achievement scalarizing functions in multiobjective optimization
Yury Nikulin, University of Turku, Finland
yurnik@utu.fi
Outi Wilppu, University of Turku, Finland
outi.wilppu@utu.fi
Marko Mäkelä, University of Turku, Finland
marko.makela@utu.fi

In our latest research [2,3], we introduce new families of parameterized achievement scalarizing functions (ASFs) for multiobjective optimization. With these functions we can guarantee the (weak) Pareto optimality of the solutions produced and under mild
assumptions every (weakly) Pareto optimal solution can be obtained. Parameterization of this kind gives a systematic way to produce different solutions from the same preference information. For the newest concept of two-slope parameterized ASFs introduced in [3], with two weighting vectors depending on the achievability of the reference point there is no need for any assumptions about the reference point. In addition to theory, in [3] we give the graphical illustrations of parameterized ASFs and analyze the quality of the solutions produced in convex and nonconvex test problems.

Synchronous approach in the context of interactive multiobjective optimization originates from [1], where only a few most widely used types of scalarizing functions were considered. For the purpose of simultaneous and synchronous generation of several Pareto optimal solutions, it looks potentially beneficial to use a larger variety of functions – it can be achieved by the usage of parametrized ASFs which give the decision maker more diversified Pareto optimal solutions for further analysis. This means that the method developers do not make the choice between different scalarizing functions but calculate the results of different scalarizing functions and leave the final decision to the decision makers. Simultaneously, a better view of the solutions corresponding to the individual preferences of the decision maker expressed during each iteration of the interactive process.

NIMBUS is a Nondifferentiable Interactive Multiobjective Bundle-based optimization System that has been developed at the University of Jyväskylä, Department of Mathematical Information Technology with the fourth version of the web interface available recently for online usage (see [4]). In our future plan, we are going to consider possibility of extending the classes ASFs used in NIMBUS system by including parameterized ASFs, and then test the efficiency of a new synchronous approach on the set of traditional benchmarks [1]. Preliminary results obtained in [2] encourage us to follow towards this direction.

References
4. The (synchronous) version 4.1.2 of the interactive multiobjective optimization system NIMBUS https://www.nimbus.it.jyu.fi/index.html

2 - Sensitivity analysis for mixed integer programming
Kim Allan Andersen, Aarhus University, Denmark kia@econ.au.dk
Trine Krogh Boomsma, Copenhagen University, Denmark trinekrogh@gmail.com
Lars Relund Nielsen, Aarhus University, Denmark larsrn@econ.au.dk

Using multiobjective methods, we show how sensitivity analysis for mixed integer programming problems can be performed. We show exactly how much a given objective function coefficient can be changed without changing the optimal solution. We also show how much a given objective function coefficient can be changed such that the optimal value of the mixed integer linear programming problem is worsened with at most a given amount. At the expense of more computing time, we show how more objective function coefficients can be changed simultaneously. Preliminary computational results are presented.

3 - Pareto suboptimal solutions to large-scale multiobjective multidimensional knapsack problems with assessments of Pareto suboptimality gaps
Ignacy Kaliszewski, Systems Research Institute, Polish Academy of Sciences, Poland ignacy.kaliszewski@ibspan.waw.pl

When solving large-scale multiobjective optimization problems, solvers often get stuck with the memory or
time limit. In such cases one is left with no information how far are the feasible solutions obtained before the optimization process has stopped to the true Pareto front.

In this work we show how to provide such information when solving multiobjective multidimensional knapsack problems by a commercial mixed-integer linear solver.

We illustrate the proposed approach on bicriteria multidimensional knapsack problems derived from singleobjective multidimensional knapsack problems from Beasley OR Library.

4 - An Approximation Algorithm for the Multi-Objective Combinatorial Optimization Problems
Lakmali Weerasena, University Of Tennessee Chattanooga, USA
lakmali-weerasena@utc.edu

Multi-Objective Combinatorial Optimization (MOCO) problems are challenging multi-objective optimization problems, have received growing interests in the literature. A generic algorithm is presented to approximate the Pareto sets of the MOCO problems. The proposed algorithm applies a branching approach of the feasible region of the MOCO problem into sub-regions and is enhanced with a search strategy of the sub-regions. The search strategy can be varied based on the structure of the MOCO problem. The key idea is to partition the search region into sub-regions based on the neighbors of a reference solution. Numerical experiments are conducted using some well-known MOCO problems to check the performances the proposed algorithm.

Monday, 14:30-16:10

MON-4-INVI-DMS4120
Invited Session: Advances in Multicriteria Optimization under Uncertainty (Engau)
Monday 14:30 - 16:10 - Room DMS4120
Chair: Alexander Engau

1 - Computing robust solutions to problems with parameter uncertainty via interactive multiobjective optimization
Yue Zhou-Kangas, University of Jyväskyla, Finland
yue.y.zhou-kangas@jyu.fi
Anita Schöbel, Georg-August University Goettingen, Germany
schoebel@math.uni-goettingen.de
Kaisa Miettinen, University of Jyväskylä, Finland
kaisa.miettinen@jyu.fi
Karthik Sindhya, University of Jyväskylä, Finland
karthik.sindhya@jyu.fi

For multiobjective optimization problems, there is a set of mathematically equally good Pareto optimal solutions and they are not comparable without additional information. Usually, the preferences of a decision maker are utilized to compare Pareto optimal solutions and find the most preferred one for the needs of the decision maker.

Multiobjective optimization methods can be classified according to the role of the decision maker in the solution process. The class of interactive methods can best support the decision maker to find the most preferred solution by allowing her/him to iteratively specify her/his preferences and learn about attainable solutions as well as the feasibility of one's preferences until the most preferred solution is found.

Even though conventional interactive methods consider only deterministic multiobjective optimization problem, many practical problems involve uncertainties which can originate from various sources. The uncertainties can render the computed solution to unexpected and undesired degradations on their quality (i.e., the objective function values). Thus, a sufficient immunity to the uncertainties which can be called robustness of the solutions should be considered and presented to the decision maker at the same time as their quality during the interactive solution process. As a final result, the decision maker should find a most preferred solution with a satisfactory balance on the quality and the robustness. As said, not much attention has been paid in the literature to supporting the decision maker in terms of solving uncertain multiobjective optimization problems.

In this research, we concentrate on supporting the decision maker to find a most preferred robust solution. We first discuss the major challenges in the interactive solution process of uncertain multiobjective optimization problems. Then we present a variant of the synchronous NIMBUS method, with in which, we utilize the robust
counterpart of a scalarizing function to compute the robust Pareto optimal solutions. To help the decision maker to make an informed choice of the solution, we visualize the solutions during the interactive solution process. As with all interactive methods, the visualization of the information exchanged plays an important role. The need is even more obvious here when the decision maker must understand different types of information. We demonstrate this robust variant of synchronous NIMBUS with an example problem.

2 - Uncertain Data Envelopment Analysis
Matthias Ehrgott, Lancaster University, United Kingdom
m.ehrgott@lancaster.ac.uk
Allen Holder, Rose-Hulman Institute of Technology, USA
holder@rose-hulman.edu
Omid Nohadani, Northwestern University, USA
nohadani@northwestern.edu

Data Envelopment Analysis (DEA) is a nonparametric, data driven method to conduct relative performance measurements among a set of decision making units (DMUs). Efficiency scores are computed based on assessing input and output data for each DMU by means of linear programming. Traditionally, these data are assumed to be known precisely. We instead consider the situation in which data is uncertain, and in this case, we demonstrate that efficiency scores increase monotonically with uncertainty. Hence, inefficient DMUs are interested in leveraging uncertainty to counter their assessment of being inefficient. Using the framework of robust optimization, we propose an uncertain DEA (uDEA) model for which an optimal solution determines 1) the maximum possible efficiency score of a DMU over all permissible uncertainties, and 2) the minimal amount of uncertainty that is required to achieve this efficiency score.

We show that the uDEA model is a proper generalization of traditional DEA and provide a first order algorithm to solve the uDEA model with ellipsoidal uncertainty sets. Finally, we present a case study applying uDEA to the problem of deciding efficiency of radiotherapy treatments.

3 - Robust Solutions to Uncertain Multiobjective Linear Programs
Garrett Dranichak, Clemson University, USA
GDRANIC@g.clemson.edu
Margaret Wiecek, Clemson University, USA
wmalgor@g.clemson.edu

Decision making in the presence of uncertainty and multiple conflicting objectives is a real-life issue, especially in the fields of engineering, public policy making, business management, and many others. The conflicting goals may originate from the variety of ways to assess a system's performance like cost, safety, and affordability, while uncertainty may result from inaccurate or unknown data due to imperfect measurements or estimates from models, limited knowledge, and future changes in the environment. It is then of interest to incorporate both uncertainty and various conflicting criteria into models, as well as to study aspects of these challenging problems.

In this talk, we focus on the integration of robust and multiobjective optimization in order to address decision making under uncertainty and conflicting criteria. Although the uncertainty may present itself in many different ways due to a diversity of sources, we address the situation of uncertainty only in the coefficients of the objective functions, which is drawn from a (possibly unbounded) polyhedral uncertainty set that reduces to a finite uncertainty set or set of scenarios. We focus on this situation since if we consider the feasible region to be uncertain as well, then a different feasible set results for each uncertainty realization so that any solution must be in their intersection. Redefining the original feasible region to be this intersection, we are able to restrict uncertainty to only the objective function coefficients.

Among the numerous concepts of robust solutions that have been proposed and developed, we concentrate on a strict or strong concept referred to as highly robust efficiency. Highly robust efficient solutions are efficient with respect to every realization of the uncertain data. In particular, we study highly robust efficient solutions to objective-wise uncertain multiobjective linear programs (UMOLPs). Here, objective-wise refers to the fact that the uncertainties of the cost vectors are independent of each other, which is realistic in practice since it is unlikely that
conflicting objectives will depend on the same uncertainty.

We present results on the existence and recognition of highly robust efficient solutions. Since the concept of highly robust efficiency is very demanding, it is important to study existence and recognition methods. If the set of highly robust efficient solutions is nonempty, then we have a desirable solution to provide to decision makers, which we consequently need to be able to recognize and obtain. Using polyhedral cones associated with multiobjective linear programs (MOLPs), such as the cone of improving directions, its strict polar cone, and the normal cone, we provide necessary and/or sufficient conditions for highly robust efficient solutions to UMOLPs. These conditions are accompanied by our work on properties of strict polar cones for general polyhedral cones. Moreover, we examine properties of and bounds on the highly robust efficient set. Several properties of the highly robust efficient set are transferred from properties of the efficient set of an MOLP, while the important property of connectedness is not transferable. As a result, the computation of the highly robust efficient set is very challenging. Nevertheless, upper bounds on this set may be obtained. Two types of bounds (or supersets) are available in the form of efficient sets associated with two auxiliary MOLPs. The objective or cost matrix of one consists of every realization of the uncertain data and provides a bound for general UMOLPs, while the other bound addresses a specific class of UMOLPs. Finally, for UMOLPs that exhibit certain behavior, we construct a robust counterpart, which is a deterministic MOLP, using data of the original uncertain problem. This robust counterpart is easily solvable and its efficient solutions are highly robust efficient to the UMOLP. We support all our findings with examples.

4 - Multi-Criteria Trade-Offs for Optimization Problems under Uncertainty
Alexander Engau, Lancaster University Management School, United Kingdom
aengau@alumni.clemson.edu

We extend the theoretical analysis and propose new methodological approaches for improved trade-off solutions and their risk analysis for general optimization problems under uncertainty. Our results use several methods and notions from multiobjective programming including scalarizations and the concepts of robust and proper efficiency. Their potential impact will be demonstrated on applications of financial portfolio selection and price-aware electric vehicle charging.

MON-4-INV-DMS4130
Invited Session: Data-Driven Preference Learning and Optimization (Li)
Monday 14:30 - 16:10 - Room DMS4130
Chair: Jonathan Li

1 - A unifying framework for multi-attribute decision-making under preference ambiguity
Wenjie Huang, National University of Singapore, Singapore
wenjie_huang@u.nus.edu
William Benjamin Haskell, National University of Singapore, Singapore
isehwb@nus.edu.sg

We are interested in “ambiguity” in choice over multi-attribute prospects, and we create a framework for understanding preferences in this setting. As our main contribution, we give a general representation result for multi-attribute choice functions under ambiguity that leads to a practical computational scheme. We show that our framework covers several existing decision-making paradigms, and we demonstrate its effectiveness through numerical experiments.

2 - An extension of PROMETHEE to hierarchical multicriteria clustering
Jean Rosenfeld, ULB, Belgium
Jean.Rosenfeld@ulb.ac.be
Yves De Smet, ulb, Belgium
yves.de.smet@ulb.ac.be

Many engineering decision problems can be modeled as the optimization of a set of alternatives according to multiple conflicting criteria[7][4]. In Multiple Criteria Decision Aid (MCDA) one usually distinguishes three main so-called problematics [8]: the selection of a subset among the best alternatives (choice problem), the assignment of alternatives into predefined classes (sorting problem) or the ranking of the alternatives.
from the best to the worst ones according to a complete or a partial order (ranking problem). More recently, researchers have started to investigate a new kind of problem: multicriteria clustering i.e. the identification of groups of alternatives that share similar multicriteria profiles. Due to the multicriteria nature of the problem, these clusters are often (completely or partially) ordered. This is referred to as relational clustering (in opposition to non-relational clustering where no order relation exist between the groups).

To do multicriteria clustering, many MCDA methods exist. One may cite; Multi-Attribute Utility Theory (MAUT), outranking methods as ELECTRE methods or PROMETHEE, etc.[1][5]

In this contribution, we will focus on PROMETHEE methods. These have been applied in a wide range of application fields such as nance, health care, sport, transport, environmental management, etc. To our point of view, this success is due to (1) their simplicity and (2) the existence of user-friendly software [6]. Let us stress that the PROMETHEE methodology has already been used to do clustering [2][3].

1 In this contribution, different hierarchical methods of complete ordered clustering using PROMETHEE II have been developed. The performances of these methods have been tested according to different indicators (quality, convergence). It is a first contribution for hierarchical multicriteria clustering using PROMETHEE which makes the link between different fields (multicriteria, clustering and ranking methods). The first contribution is a classic hierarchical model divided in two approaches: a top-down and a bottom-up methods. These methods have been developed in order to optimize, at each step, the structure of the clustering by maximizing the intra-cluster homogeneity and the inter-clusters heterogeneity.

Then we developed a general quality indicator for complete ordered clustering which helped us to compare different methods and different partitions. It has been done in order to maximize the intra-cluster homogeneity and the inter-clusters heterogeneity in a single term.

Finally, a hybrid method has been developed which brings together the results of the top-down and the bottom-up approaches. It uses an adjacency matrix which gathers information of both hierarchical methods to make ordered subgroups of data. Then these subgroups are merged until it gets the desired number of clusters. The best solution among all the possibilities is selected according to the quality of the distribution.

These three methods have been evaluated and they give interesting results. In particular the hybrid method which gives most of the time better results than other extensions of PROMETHEE to multicriteria clustering and the other hierarchical methods according to the quality indicator.

The hierarchical models developed in this contribution give promising results. Moreover, the analysis of the performance of the model on real-world datasets are encouraging. The comparison of the proposed model with the known P2CLUST method has underlined a strong interest in using such an approach to characterize complex multicriteria clustering problems.

References
clustering problems: PROMETHEE TRI and PROMETHEE CLUSTER.


3 - Preference robust optimization for decision making under uncertainty

Erick Delage, HEC Montréal, Canada
erick.delage@hec.ca

Jonathan Li, University of Ottawa, Canada
Jonathan.Li@telfer.uottawa.ca

Decisions often need to be made in situations where parameters of the problem that is addressed are considered uncertain. While there are a number of well-established paradigms that can be used to design an optimization model that accounts for risk aversion in such a context (e.g. using expected utility or convex risk measures), such paradigms can often be impracticable since they require a detailed characterization of the decision maker's perception of risk. Indeed, it is often the case that the available information about the DM’s preferences is both incomplete, because preference elicitation is time consuming, and imprecise, because subjective evaluations are prone to a number of well-known cognitive biases. In this talk, we consider the context of risk measure minimization and introduce preference robust optimization as a way of accounting for ambiguity about the DM’s preferences. An optimal preference robust investment will have the guarantee of being preferred to the largest risk-free return that could be made available. We show how preference robust optimization models are quasiconvex minimization problems of reasonable dimension when parametric uncertainty is described using scenarios and preference information takes the form of pairwise comparisons of discrete lotteries. Finally, we illustrate numerically our findings with a portfolio allocation problem and discuss possible extensions.

4 - Identifying risk functions for decision making under uncertainty: an inverse optimization approach

Jonathan Li, Telfer School of Management, University of Ottawa, Canada
Jonathan.Li@telfer.uottawa.ca

Decision making under uncertainty can often be formulated as optimization problems where the parameters are uncertain and the goal is to seek solutions that minimize risk associated with the uncertainty. It is however non-trivial to define or quantify the risk so that it can be consistent with one's true risk preference system, i.e. how risk is actually perceived. In this talk, we address this issue through the lens of inverse optimization. Specifically, given solution data from some (forward) risk-averse optimization problems we develop an inverse optimization framework that generates a risk function that renders the solutions optimal for the forward problems. The framework incorporates the well-known properties of convex risk functions, namely, monotonicity, convexity, translation invariance, and law invariance, as the general information about candidate risk functions, and also the feedbacks from individuals, which include an initial estimate of the risk function and pairwise comparisons among random losses, as the more specific information. We show how the resulting inverse optimization problems can be reformulated as convex programs and are polynomially solvable if the corresponding forward problems are polynomially solvable. We illustrate the imputed risk functions in a portfolio selection problem and demonstrate their practical value using real-life data.
1 - The Therapeutic Choice Problem: A Multi-Criteria Application on Atrial Fibrillation
Emmanuel Kabura, Canada Border Services Agency, Canada
Emmanuel.Kabura@gmail.com
Sarah Ben Amor, Telfer School of Management, Canada
benamor@telfer.uottawa.ca

The choice of the best therapeutic option for the atrial fibrillation (AF) is a medical decision problem of stature. Three major trials, ARISTOTLE, RE-LY and ROCKET-AF, were done onto the following four new oral anticoagulants aiming to increase the atrial fibrillation (AF) care: Apixaban, Dabigatran 110mg, Dabigatran 150mg and Rivaroxaban. The results for these clinical trials were not conclusive as per the best therapeutic option. A Multi-Criteria decision approach for the problem of the therapeutic choice applied to the case of atrial fibrillation is developed in order to evaluate the four therapeutic options. A PROMETHEE-GAIA Multi-Criteria decision support tool was developed to evaluate and compare the four new anticoagulants on the basis of five essential criteria established according to a process of concerted dialog with experts: efficacy, safety, renal function, adherence and price. The results of the evaluation led to a ranking of the therapeutic options by their order of performance in the management of atrial fibrillation patients: Apixaban, Dabigatran 150mg, Rivaroxaban, Dabigatran 110mg.

2 - Automated Pathologist Scheduling at the Ottawa Hospital
Jonathan Patrick, University of Ottawa, Canada
patrick@telfer.uottawa.ca
Wojtek Michalowski, University of Ottawa, Canada
wojtek@telfer.uottawa.ca
Diponkar Banerjee, The Ottawa Hospital, Canada
dbanerjee@eoirla.ca
Amine Montazeri, Carefor Health and Community Center, Canada
amine@gmail.com

Pathology is an area of medicine where pathologists diagnose the nature of disease based on specimens taken from patients' organs. Specimens are divided into sub-specialties based on the organ of origin. Based on past specific sub-specialty training, each pathologist is required to assess specimens from only a subset of all the sub-specialties. A typical pathology department in a teaching hospital will provide each pathologist with a monthly schedule that assigns which sub-specialties (from among his/her sub-specialty training) each pathologist will cover each day of the month. Thus, at the beginning of each month, the department administrative assistant or manager uses a rule-based manual system to solve the pathologists' assignment problem where s/he assigns a fixed number of pathologists to each sub-specialty based on the expected daily specimen load over the next month while respecting constraints due to maximum workload allowances (in order to reduce errors due to fatigue) and pathologists' availability and sub-specialty training. Since the complexity of the assignment problem is significant, finding a feasible assignment manually is a time-consuming process that takes multiple iterations over a number of days to complete. Moreover, every time there is a need for a revision, a new schedule needs to be created taking into account all the above constraints. The goal of this research is to develop an optimization model and an associated decision support tool that will automate the monthly scheduling of pathologists in such a way as to optimize a weighted sum of pre-determined performance metrics while respecting the constraints outlined above. The proposed model is rooted in the classical assignment problem but is extended to account for a number of specific requirements and performance metrics unique to pathology. A model that optimizes the assignment schedule for the Division of Anatomical Pathology in the Department of Pathology and Laboratory Medicine (DPLM) at The Ottawa Hospital covering 30 pathologists and 26 sub-specialties was solved using IBM ILOG CPLEX Optimization Studio. The model is embedded in a decision support tool that provides a significant amount of flexibility to the user and allows the DPLM clinical manager to easily input the necessary data and assess the performance of the resulting schedule on the
basis of the predefined metrics. We present results demonstrating the improvement in the schedules produced by the model as compared to manual schedules produced in the past. The model and associated decision support tool is now used each month by the clinical manager and has greatly reduced the time required to perform the pathologist assignment task.

3 - Formulation supply chain risks for pharmaceutical industry: MCDM approach, applications and pitfalls
Ali Rajabzadeh Ghatari, Tarbiat Modares University, Iran
alirajabzadeh@modares.ac.ir
Fatemeh Godarzi, Tarbiat Modares University, Iran
sf_goudarzi@yahoo.com

Increasing concern about the health care system in developing countries has generated a great deal of interest to develop the efficiency of pharmaceutical industry as an important sector of the health care system. Recognition of risk and identifying the strategies, which mitigate them, are the key abilities to manage the supply chain properly. Based on the literature and the analysis of questionnaire and interviews, the list of risks, sub risks, risk mitigation strategies and tactics excluded. 9 main categories and 38 Sub-categories of risks have been identified as the most important and impressing ones, affecting the supply chain and its performance. Supply chain risks are classified in nine categories as follows: the regulatory pressures, political challenges, financial limitations, business risks, product flow risks, information and technology issues, human resource and cultural matters and natural disasters increase.

The fuzzy TOPSIS as a common technique of the MADM model is used for making priority of critical factors. This paper is based on the results of literature review, acquiring experts’ opinion, statistical analysis and using the MADM techniques for analyzing data gathered from distributed questionnaires. Novelty of research is in steps of fuzzy TOPSIS and formulation risks in pharmaceutical supply chain. However, Political, financial and legal risks have the top priority among risk categories. The main category includes political, financial, legal, environmental and cultural risks. In addition, business, production flow, information and technology, and human resource risks in order.

4 - Physician Scheduling Problem in an Emergency Department of a Public Hospital
Ozgur Yannaz, Istanbul Technical University, Turkey
ozguryanmz@gmail.com
Ozgur Kabak, Istanbul Technical University, Turkey
kabak@itu.edu.tr

Efficient schedule of workforce is a very significant issue since it has a considerable effect on productivity and health of employees, and the quality of the service provided. Studies on scheduling health care services are mainly related to nurse and physician scheduling problems. Physician scheduling problems are harder comparing to the nurses’ due to the complexity and varying nature of working conditions according to the department and also the contractual agreements of the physicians. At the same time, a schedule not prepared properly leads to various problems related to the financial issues, physical and mental illnesses for physicians, and lack of caring patients.

In this study, the aim is to make a contribution to health care service area and to offer a model for the authorities to provide better conditions for physicians and to provide a qualified and reachable health care service to people. Preparing schedule manually is a tough and tiring job for people making schedules because there are many constraints and objectives to consider. For that matter, a multi objective mathematical model is proposed to obtain optimal schedules under different scenarios of patient demand. The objectives used in the mathematical model are balancing workload of physicians, maximizing physicians’ preferences, and minimizing regular and overtime assignment cost. Making schedule in reference to personnel’s preferences and considering the balance while allocating the existing work load have an importance in terms of both the motivation and the happiness of employees and by doing that, a significant contribution to the quality of health care service can be realized. These objectives are tried to be optimized with respect to the constraints including the legal working hours determined by the government and labor unions, patient demand, resting periods, etc. The model is implemented in an emergency department of a public hospital.
departments work 24 hours a day, 7 days a week. These departments offer the required health care services to the patients with urgent conditions, so it is very crucial for saving lives. Recklessness, lack of attention and interest are intolerable behaviors considering a little mistake causes some vital consequences for patients. In the emergency department considered in this study, there are two types of shifts: 8-hour shifts and 24-hour shifts. The planning period is considered as a 1-month period. The constraints to be taken into consideration are daily physician demand, weekly and monthly working hours determined by the agreements, and the specific assignment rules which are followed by the selected emergency department. For instance, physicians cannot work on consecutive night shifts, cannot be assigned to more than one shift per day, can be assigned to at most ten night shifts, can be assigned to at least two weekend shifts, must be assigned to at least one weekend shift, and if they are already assigned to a night shift, then they cannot be assigned any shifts on the 2 successive days. The constraint related to the daily patient demand should be met because all patients have to take a proper health care service whenever they need. The model composed of these constraints and the objectives mentioned above is solved through a multi objective mathematical modelling approach according to different patient demand levels in order to obtain the optimum schedule both for the physicians and the patients and the most suitable demand level is determined by analyzing the outcomes of the model.

MON-4-CON-DMS4170
Contributed Session
Monday 14:30 - 16:10 -- Room DMS4170
Session: Risk Management
Chair: Hsu-Shih Shih

1 - Risk-aware vessel routing using multi-objective ant colony optimization
Nicolas Primeau, University of Ottawa, Canada
nprim050@uottawa.ca
Rami Abielmona, School of Information Technology and Engineering (SITE), University of Ottawa, Canada
rabielmo@ieee.org

Rafael Falcon, Larus Technologies Corporation, Canada
rfalcon@ieee.org
Emil Petriu, University of Ottawa, Canada
petriu@uottawa.ca

With water covering roughly 71% of the earth’s surface, maritime freighting is inevitable in today’s globalized supply chains. Typical maritime freighting operations transport cargo from one area of the world to another for further processing or for consumption. Current efforts are being made on streamlining freighting operations leaving them increasingly susceptible to disruptions, a major problem of supply chain management. Weather events, breakdowns and congestion are a few of the many causes of supply chain disruptions.

The Internet of Things (IoT) is a new paradigm in which networking capabilities are added to any thing to make it accessible. This ability can lead to smarter environments, but produces a glut of data that may not be relevant. The maritime domain has not escaped this trend and an emerging maritime IoT (mIoT) is allowing new opportunities in maritime freight optimization and disruption mitigation.

The likelihood of a disruption and its effects should be respectively predicted, reduced, and mitigated. The solution to this problem has multiple facets, all of which fall in the domain of risk management. Situational awareness is paramount to all aspects of this problem, while multi-criterion decision analysis (MCDA) is needed to choose context-appropriate actions.

The following presents a situationally aware multi-objective approach to reduce the risk of disruptions in the maritime freighting portion of supply chains by harnessing the mIoT by allowing cargo vessels at sea to determine their path based on risks, cost, or time. Risk computations are done via a previously presented Risk Management Framework (RMF) that has been used in various applications. The routing will be done via multi-objective ant colony optimization (MO-ACO) in combination with a distributed mapping of the environment.

MO-ACO is a class of multi-objective variants of the nature inspired ACO metaheuristic method. ACO is based on the capability of ants to determine optimal paths to food sources by dropping pheromones on the
return trip, indicating the suitability of the path. Solutions are decomposed into parts represented as nodes in a graph linked via weighted edges. A solution is a sequence of nodes taken by a virtual ant. Pheromones are dropped on the edges of the path inversely proportional to its cost, allowing future generations of ants to follow objective-effective paths. ACO has successfully been applied to problems such as the traveling salesman problem.

Optimal paths according to objectives should be available. A vessel carrying important cargo may prefer to follow a safer path, while another might prefer an economical one. Vessels can create or update nodes as they progress on their journey, yielding a sequence of nodes with a cost. The vessels effectively act as virtual ants and an ACO algorithm can be leveraged to determine optimal paths for other vessels by employing an appropriate pheromone scheme. Due to the immensity of the maritime environment, an enormous amount of data, and a dynamic graph, traditional methods would not be suitable for this multi-objective shortest path problem.

The vessels compute their risk of being affected by a certain event, such as storms, an iceberg, or maritime debris (e.g. dropped containers, buoys). This risk is broadcasted as part of their automatic identification system (AIS) messages. The latter are required by most commercial vessels, except smaller crafts that do not meet the criteria established by the Maritime International Organization. These messages are picked up by satellites when in open sea and using terrestrial networks of transceivers when closer to shorelines. The environment is continuous but can be discretized with nodes representing agglomerations of points from correlated tracks based off AIS messages. Vessels act as virtual ants, following paths based on their preferred objectives. Pheromones for recently visited nodes are periodically updated indicating the suitability of the path per the objectives. Some visibility is allowed, meaning that a vessel may choose another path based on its immediate knowledge of the objective values. Soft optimal paths emerge from this behaviour, solving the multi-objective problem distributively and dynamically.

Vessels will often need to create new paths composed of nodes that may not have been previously linked. In these cases, a way to determine the weights and pheromones of the edge between two previously unlinked nodes must be considered. The formulation of this problem solves this issue, since these risks, positions, and pheromones can be shifted to the nodes. The edge attributes such as risk, pheromone, and distance can all be computed from its connected nodes. Maritime accidents can cause important delays in freighting operations. In such a scenario, nearby ships would compute a heightened risk of collision with maritime debris and transmit this within their AIS messages. The trajectories of vessels running the routing application detailed above can then be modified by taking these new risk values into consideration. As alternative paths are explored, vessels drop pheromones which are a function of risk, time, and cost. Consequently, better paths will start to be preferred and mitigate the delays caused by the original disruptive event.

A short proposal on a multi-objective risk-based routing method for vessels in the maritime domain was detailed. A risk heatmap is first created with the risk updates of the vessels then used by a routing algorithm along with information such as distance to determine a soft optimal path via a multi-objective metaheuristic method based on the ACO algorithm. The method remains simple yet yields powerful emergent routing behaviour that can reduce the likelihood of disruptions while keeping costs down, resulting in efficient supply chains. Future work will focus on implementing and simulating the method with data from real sources.

2 - Multi Criteria Decision Parameters in Evaluation of Temporary Housing Units
Nil Akdede, Middle East Technical University, Atilim University, Turkey
nilakdede@gmail.com
Bekir Özer Ay, Middle East Technical University, Turkey
ozer@metu.edu.tr

Disasters caused by natural hazards or socio-political crises threaten the life of human beings and pose substantial challenges for communities. Damage on built environment, mass migration, homelessness, destruction of social life are some of the issues that the communities have to confront with when mitigating a detrimental disaster. Considering the institutional context of the disaster management, the structure takes the responsibility of
the incident into two main bodies: relief oriented and development oriented approaches. While relief oriented body aims to reduce or prevent the loss of lives with short-term humanitarian assistance, development oriented body defines its frames as long-term assistance with respect to economic, social and physical structures. Among this multi-institutional and branched structure, decision making and taking action are squeezed between these two main contradictory approaches: short-term necessities and long-term requirements. Although the aim and the principles of disaster management is relatively well-defined, the situation of chaos constrains the decision makers to improvise the post-disaster activities in a rush due to the absence of up-front planning. This usually directs decision makers to apply “fast and frugal heuristics” for deciding urgently in post-disaster phase. Moreover, the restricted time may result in focusing on only one and perhaps subjectively selected attribute of the problem so that remained attributes such as social, environmental and economic objectives could be overlooked.

Architectural design inevitably involves a decision-making process since the responsibility of architects is to convert the design problem into a well-structured quest for the given input variables such as location, climate and culture within a certain time. In this respect, temporary housing is one of the most contradictory architectural design problems as it has a crucial role on the recovery period of community by completing not only the physical reconstruction but also the psychological rehabilitation until the ordinary daily life has been get back on the rails. In current practice, to overcome sheltering problem of victims, ready-made or instantly developed temporary housing units are applied by top-down decisions. Nevertheless, temporary housing projects that are evaluated with ad hoc decision making approaches generally yield various social, environmental and economic problems. There are several studies in literature that investigate cases where the temporary housing failed to meet the instant and/or future needs of the habitants or have negative environmental effects. An alternative approach could be the use of multi criteria decision making methods that are capable of evaluating the optimum temporary housing design alternative very quickly provided that all essential attributes of the problem such as production technique, material, modularity, cost, and sustainability have been worked in pre-disaster phase. However studies on this topic in the literature is very limited. Thus, this study investigates the potentials of multi criteria decision methods in temporary housing projects and in particular the evaluation criteria. This way, an alternative tool that considers time and space constrained conditions and necessities in a systematic and swiftly way has been demonstrated. In this perspective, we believe that such decision making models configured with well-defined criteria can be very useful in post disaster temporary housing evaluation.

3 - ST-VIKOR: Accounting for Stochastic Data and Risk Attitudes in Multi-Criteria Decision Making

Madjid Tavana, La Salle University, USA
tavana@lasalle.edu
Debora Di Caprio, York University, Canada
dicaper@mathstat.yorku.ca
Francisco Javier Santos Arteaga, Free University of Bolzano, Italy
fsantosarteaga@unibz.it

Multi-criteria decision making (MCDM) techniques are used to rank sets of alternatives characterized by multiple and often conflicting criteria. Classical MCDM methods generally assume that the ratings of the alternatives and the weights of the criteria are known precisely. However, decision makers (DMs) face different degrees of risk and uncertainty throughout their decision making processes when dealing with real-world data. MCDM models have been adapted to account for different types of information frictions, which are generally modeled through stochastic analysis or fuzzy set theory. The former approach applies when a probabilistic data set represents the risk faced by the DMs, while the latter approach is more appropriate when the observations retrieved are vague and ambiguous.

The VIKOR method is a MCDM technique designed to rank a set of alternatives in the presence of conflicting criteria by proposing a compromise solution. This method has been used to solve different types of MCDM problems both in crisp and fuzzy environments. It has also been integrated with other
MCDM techniques such as the fuzzy analytic hierarchy process (AHP). A detailed literature review regarding recent applications of VIKOR can be found in Tavana et al. (2016). These latter authors extended the basic structure of VIKOR and developed a method to solve MCDM problems with stochastic data. Their model considered several stochastic criteria, whose weights were determined via the fuzzy AHP. The decision framework developed by Tavana et al. (2016) constitutes the base on which the current model is built. In particular, we define an extended version of the VIKOR method introduced by Tavana et al. (2016) that accounts for differences in the risk attitudes of the DMs when ranking stochastic alternatives. Our formal framework allows for modifications in the rating behavior of the DMs that depend both on whether they are risk seekers or averters and the coefficient of variation exhibited by each alternative. That is, ST-VIKOR allows the DMs to select the alternative that is more in accordance with their subjective preferences and risk attitudes while accounting for the uncertainty inherent to the data retrieved to evaluate each alternative. Tavana et al. (2016) also compared empirically their method with a stochastic version of the super-efficiency data envelopment analysis (DEA) model of Khodabakhshi et al. (2009). We use the same banking industry study to illustrate how differences in the risk attitudes of the DMs condition the rankings obtained. We conclude that if the DMs do not know the exact distribution from which the observations are being drawn or are not neutral to the inherent risk, their resulting rankings will differ from the ones provided by more neutral models such as super-efficiency DEA. It should be emphasized that the rankings obtained are determined by the volatility exhibited by the data retrieved from the different alternatives together with the risk attitude of the DMs. That is, ST-VIKOR improves upon any other MCDM method that imposes a given probability density on the data or does not account for the subjective risk preferences of the DMs. Thus, there is a substantial amount of potential applications of the current model to diverse research areas ranging from economics to knowledge based and decision support systems.

References


4 - Recycling Fund Management on Environmental and Economic Goals under Uncertainty

Hsu-Shih Shih, Tamkang University, Taiwan
hshih@mail.tku.edu.tw

This study focuses on how to efficiently manage a recycling fund through environmental and economic goals under an uncertain environment. Targeting the aspect of a long-term accumulated fund, instead of on a yearly basis, we find that flexibility in managing the fund provides a buffer against the uncertainties on the fund’s cash flow.

In order to monitor the fund use in an uncertain environment, Taiwan’s Recycling Fund Management Board (RFMB) has an environmental goal that maximizes the recycling rate by a subsidy to the recycling industry so that there is less damage to the environment. The recycling industry aims to maximize its profits and thus intends to improve its recycling quality by all means. These two goals are usually in conflict, and their tradeoffs can be examined based on two models. The first model, the yearly balance model, is the current setting by RFMB whereby the fund is collected and offset as a yearly subsidy. The second model proposed by our study, the multi-period model, considers the accumulation of the fund for its expenditure over a period of years. Following the pattern of the historical data from RFMB, we develop four scenarios covering possible sales volumes of electronics products to estimate the fund incomes in future years. The numbers of waste electronics products in the future are also estimated from a survey from local customers on discarded probabilities. Through a discounting factor and an inflation rate, the cash flows are integrated into the analysis. The results herein show tradeoffs between the goals of both models on the recycling fund management of the
electronics products. Taking into consideration of a minimal requirement for promoting recycling quality, we develop a compromised recycling rate. In addition, the multi-period model provides a better outcome than the yearly balance model for any situation under four scenarios and two fund settings - offset yearly and earmarked. The set-up of the earmarked fund also performs well. Finally, we suggest RFMB take a further step on considering the proper balance between both goals in using the multi-period model for recycling fund management in the long run.

Monday, 16:40-18:20

MON-5-INV - DMS4120
Invited Session: Multi-criteria Decision Support for Humanitarian Relief (Aktas, Kabak, Cevik, Topcu)
Monday 16:40 - 18:20 -- Room DMS4120
Chair: Hafize Yilmaz

1 - A Decision Support Model for Warehouse Location in Humanitarian Relief Logistics
Irem Karacakaya, Istanbul Technical University, Turkey
karacakayai@itu.edu.tr
Ilker Topcu, Istanbul Technical University, Turkey
ilker.topcu@itu.edu.tr

Disasters are natural, technological, or human-based events that interrupt the daily life and cause physical, economic, social, and environmental loss in people's lives. The number of natural disasters and the number of people affected by these disasters in the world are increasing every year. For this reason, effective and efficient operations should be carried out while the disaster takes place. The necessary relief items for beneficiaries should be handled in the right place and right time. For this reason, effective and efficient operations should be carried out in the event of a disaster. The necessary relief items for beneficiaries should be transported to the right place and time.

The disaster of these events is tried to be reduced by disaster relief management. Disaster relief management includes taking necessary precautions, making plans for interventions, coordinating and directing resources. Disaster management includes activities carried out before and during disaster rather than after disaster. For maximizing the effectiveness of humanitarian aid supply chain in the best way requires disaster prevention and preparation.

Humanitarian relief logistics is the process of planning, implementing, storing, and controlling the flow of products, materials, and information from the beginning to the end in an effective and low cost manner in order to meet the needs of the victims.

With humanitarian logistics, humanitarian aid materials such as food, beverages, medicines, clothing, and housing, which are needed by the victims, are stored in disaster logistic warehouses and delivered from here to the disaster areas in a timely and desired amount.

Among the different forms of preparedness for disaster relief management, pre-purchasing of stock in a pre-positioned warehouse is considered to be best for maximizing the effectiveness of humanitarian aid supply chains. In emergency situations and after disasters, the location of the warehouses in which aid materials are delivered have a major role to provide quick and effective disaster response.

The purpose of this study is to present a multi criteria decision support model based on AHP for the selection of the most suitable location for humanitarian relief warehouse. This study identifies the criteria and sub-criteria considered for the selection humanitarian relief warehouse location. Due to the anticipated earthquake in Istanbul, the case study will be conducted for the selection of the location in this region.

2 - On the Disposal Planning of Debris and Waste from Large-Scale Disasters
Yeboon Yun, Kansai University, Japan
yeboon@kansai-u.ac.jp
Takamasa Akiyama, Kansai University, Japan
akiyama@kansai-u.ac.jp
Hiroaki Inokuchi, Kansai University, Japan
inokuchi@kansai-u.ac.jp
Min Yoon, Pukyong National University, South Korea
myoon@pknu.ac.kr

The Great East Japan Earthquake and Tsunami, March 11, 2011 caused a great deal of damage; more than 400,000 buildings were demolished, and the toll of the dead and missing is about 18,000. This leads to a huge amount of debris and waste. In addition, it has been
predicted that Great Nankai and Tonankai Earthquakes will occur with a probability 0.6-0.7 in the next 30 years. After large-scale disasters occur, the local governments of Japan try to restore people to daily life as soon as possible. For that purpose, immediate disposal of debris and waste is indispensable for early reconstruction and restoration. Therefore, in this paper, we propose a process of debris and waste disposal for disasters. Next, we propose disposal planning considering uncertainties, which is formulated as a multi-objective optimization problem. Finally, we investigate the effectiveness of the proposed planning through several scenarios based on some data from the Great East Japan Earthquake and Tsunami.

3 - A New Multiobjective Hesitant Fuzzy Model for Determining Distribution Centers in Humanitarian Logistics
Hafize Yilmaz, Istanbul Technical University, Turkey yilmazhaf@itu.edu.tr
Özgür Kabak, Istanbul Technical University, Turkey kabak@itu.edu.tr

One of the most important parts of disaster response is humanitarian logistics including processes and systems involved in resources 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. It has additional uncertainties with compared to business logistics because of unusable routes, safety issues, changing facility capacities and demand uncertainties.

The location problem in disaster management aims at designing a network for distributing humanitarian aid such as water, food, medical goods and survival equipment. It mainly includes determining number and position and the mission of required humanitarian centers within the disaster region. Central distribution centers are constructed permanently to pre-position essential relief goods and usually it is assumed that they are not in the hot (disaster affected) zone while local distribution centers are constructed in the hot zone after a disaster and relief goods are delivered to victims from these temporary centers.

This study proposes a hesitant fuzzy multiple objective decision model to locate disaster response distribution centers that will be used for supplying relief goods 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 in a fuzzy environment. First objective minimizes distances among local and main distribution centers while the second objective minimizes maximum distance among demand points and local distribution centers. Third objective takes into account a set of criteria to select main distribution center location and provides selecting more appropriate candidate points. The fourth objective minimizes unmet risk of total demand. Lastly, the fifth objective is about equity and ensures fair distribution among demand points. Main distribution center point weights regarding determined criteria and demand of the demand points are formulated as hesitant fuzzy parameters to deal with uncertainties. A new algorithm is developed to solve the proposed hesitant fuzzy mathematical programming model. The applicability of the model as well as the solution algorithm is illustrated on different data sets.

As a further study, the model will be solved for determining the locations of the disaster response distribution centers in the city of Istanbul. Istanbul is a mega-city where a large earthquake is expected to occur in the next 30 years. Therefore, the application of the proposed model will make a significant contribution to plans of mitigation efforts for such a disaster in Istanbul.

MON-5-INV-DMS4130
Invited Session: Methodological Issues for Practical Applications of MCDM/A Models (Almeida-Filho, Ferreira)
Monday 16:40 - 18:20 -- Room DMS4130
Chair: Adiel de Almeida-Filho

1 - Some experiments involving the crowding distance metric and the FITradeoff method for negotiation processes
Rodrigo José Pires Ferreira, Universidade Federal de Pernambuco, CDSID - Center for Decision Systems and Information Development, Brazil
rodrigo@cdsid.org.br
In a negotiation process, negotiators have different preferences over criteria and yet they have to select one compromise solution in order to satisfy all interested parties by agreeing finally to a deal. This paper presents some computational experiments in a negotiation model based on the crowding distance metric and the FITradeoff method in order to support a negotiation process. A two-stage model is proposed which considers basic preference information from negotiators in order to reduce the number of non-dominated alternatives. First, an evolutionary algorithm is used to obtain a population with disperse alternatives in accordance with the crowding distance metric. Secondly, the FITradeoff method is applied. In the experiments carried out, two negotiators are considered: a buyer and a seller whose objective is to hire the setting up of continuous flight augering on a construction site. It is assumed that five criteria are important in order to define the best solution: price; time needed before starting the service; time to conduct the service; service quality; and availability for maintenance. In a negotiation process with multiple criteria, the Pareto Front can consist of a huge number of solutions which are not useful for evolutionary algorithm approaches. In such cases, the FITradeoff method can avoid the need to estimate the precise values of criteria weights. The experiments showed that the number of non-dominated alternatives were reduced significantly after the second step and on using a negotiation process based on the FITradeoff method. The main advantage of the model proposed is that it considers basic preference information from negotiators in order to reduce the number of non-dominated alternatives that have to be evaluated. The model was tested with a significant number of instances, and it seems that the potential benefit of using the algorithm merits consideration. The FITradeoff Software is available for download on request at www.fitradeoff.org/download.

In this work, we propose a new multiple criteria decision aiding method for dealing with nominal classification problems (pre-defined and non-ordered categories). This kind of problems are frequently encountered in several fields, such as genetics, medicine, psychology, economics, business and finance management, education and training, physics, geology, among others. Addressing a multiple criteria nominal classification problem consists of assigning each action, assessed according to multiple criteria, to at least one category. The method we present includes the possibility of taking into account interaction between criteria. We propose to use the most representative actions as the set of reference actions to characterize a category. The proposed method follows a decision aiding constructive approach. Thus, the set of reference actions of each category should be previously co-constructed through an interaction process between the analyst and the decision maker.

Assigning an action to a given category depends on the comparison of such an action to the set of reference actions, according to a membership degree. The values of the membership degrees are defined for each category by the decision maker. The method fulfills a set of structural requirements (its fundamental properties): possibility of multiple assignments, independence, homogeneity, conformity, and stability with respect to the merging and splitting operations. These fundamental properties and their proofs are also provided. Some potential applications are introduced in order to show the main features of nominal classification problems. A numerical example is presented to illustrate how the proposed method can be applied. Robustness concerns are also considered in our work.
Portfolio selection is recognized as the birth-place of modern finance. Weighted-sums methods or e-constraint methods are normally utilized for portfolio optimization, but the results are only approximations of efficient frontiers. One concern of portfolio selection is efficiency-diversification discrepancies that efficient frontiers lack diversification. Scholars typically analyze the discrepancies by using weighted-sums methods or e-constraint methods, studying only a specific portfolio, and utilizing small-scale portfolio selection. Some scholars find that portfolio selection is not consistently better than naive diversification. We utilize parametric quadratic programming, exhaustively sample US stocks, build batches of 5-stock problems up to 1800-stock problems, obtain the structure of (whole) efficient frontiers, and propose new diversification measures on the basis of the structure. We find that 1. setting upper bounds can be more effective in changing diversification status than setting right-hand sides or setting the numbers of constraints can, 2. portfolio selection can substantially outperform naive diversification at least in theory so the cost of naive diversification can be prohibitive, and 3. efficiency-diversification discrepancies can arise due to efficient frontiers' nature of having relatively small numbers of stocks and can not be easily reconciled.

When planning personal finance, the individual would consider the suitability of a range of banking products or investment private equity during his or her life based on several objectives. Currently, banks provide a wide range of investment options, including funds, shares, and ETFs that can be accessed by personal investor even with a small budget such as US$ 500.00. In the other hand, since the mean-variance approach, portfolio optimization has been developed and recent literature addresses two main streams: (i) the incorporation of alternative risk measures and (ii) the development of new models and innovative problem formulation to enable additional characteristics that the investor wish to consider or that financial services are obliged to comply due to regulation. This research work focuses on the latter issue in portfolio modeling for private banking by integrating throughout a decision process framework to support portfolio selection. This work proposes a hybrid approach, integrating fuzzy MCDM/A towards portfolio optimization. The proposed portfolio selection framework consists of three steps. In the first step, the problem is structured in terms of regulation aspects, while in the second step the alternatives are classified by a novel fuzzy MCDM/A procedure (Fuzzy TOPSIS-Sort) according to investor profiles, and finally, in the third step, the results of the second step are integrated into a multiple objective optimization model. A numerical application emulating a real world situation is presented to illustrate the proposed approach enabling to validate the proposed framework.
1 - Multi-Objective Optimisation for the Design of Sustainable Food Systems in the context of Dietary Guidelines
Sonja Rohmer, Operations Research and Logistics, Wageningen University, Netherlands
sonja.rohmer@wur.nl
J.C. Gerdessen, Operations Research and Logistics, Wageningen University, Netherlands
joke.vanlemmen@wur.nl
G.D.H. Frits Claassen, Operations Research and Logistics, Wageningen University, Netherlands
frits.claassen@wur.nl

Food plays a major role in our everyday life and contributes vital nutrients to ensure every day survival. As such it is at the basis of human existence and part of basic human needs. However, current consumption and production patterns are considered unsustainable and have a severe impact on the environment, in the form of global warming, the extinction of species and depletion of resources, thus, not only destroying the planet we live on but also the livelihood of future generations. Given it's globalised nature, abundance of choice and interrelations between products the food system as well as dietary choices have gained in complexity and as a result become less transparent with regards to their environmental impact. Consequently, decisions on supply chain configurations and dietary guidelines can no longer be made in isolation but need to take a more realistic, comprehensive and hence integrated approach.

The aim of this research is to propose a multi-objective model for the design of sustainable food systems under consideration of dietary guidelines. The model includes sourcing, processing and transport aspects while incorporating production and dietary consumption decisions within one common framework. Minimising both cost and environmental impacts (e.g. land use, climate change, fossil fuel depletion, etc.), the study investigates trade-offs between the conflicting objectives and examines possible shifts between different environmental burdens. The findings of this research are illustrated using a nutritional case study and based on real-life LCA data.

2 - Goal programming models to estimate national inventories of livestock emissions
Baldomero Segura, Universitat Politècnica de València, Spain
bsegura@upvnet.upv.es
Marina Segura, Universitat Politècnica de València, Spain
masema@upvnet.upv.es
Concepción Maroto, Universitat Politècnica de València, Spain
cmaroto@eio.upv.es
Concepción Ginestar, Universitat Politècnica de València, Spain
cginesta@upvnet.upv.es

European countries have commitments to reduce greenhouse gases (GHG) and pollutant emissions under different protocols and the European Union National Emission Ceiling Directive. These commitments require the assessment and annual reporting of national gaseous emissions, as well as their future projections in established formats, according to IPCC Guidelines and the air pollutant emission inventory guidebook from the European Environment Agency (EEA) (2013). Due to their negative effects on health, environment and climate, the European Union estimates pollutant emissions from the following sectors: energy, industrial processes and product use, agriculture, waste and other. The main pollutants are nitrogen oxides, non-methane volatile organic compounds, sulphur oxides and ammonia, agriculture being almost the only source for the last pollutant, with 94% of the total (EEA, 2016). Emissions from livestock can be mitigated through improvements in animal management techniques including nutrition, housing and waste management.

The general approach to calculating emission inventories is to multiply activity data by emission factor, which quantifies the emission per unit activity. Although there are some differences between GHG and pollutant inventories, both are based on three methodologies, known as tiers, depending on available information. Tier 1 methods are the simplest ones and apply a linear relation between activity data from statistical information and default emission factors. In Tier 2 the only difference to Tier 1 is that the emission factors are country-specific. Finally, Tier 3 is based on
more complex models and/or data from the facility level. To our knowledge, livestock emission inventories apply tier 1 or 2 approaches, which are mainly based on manure management, even though the influence of animal diet is well known. Thus, we believe that optimization models could provide an advanced methodology in order to estimate livestock emissions.

As feed intake is an important variable in predicting emissions, which depend on animal nutrition (energy, gross protein, fibre...), the objective of this research is to design and explore the potential contributions of goal programming models to improve the quality and accuracy of livestock emissions at country level.

We have developed goal programming models with which we can estimate the most important emission factors from diet in intensive animal production. These models were then applied to Spanish livestock, analysing the solution sensitivity to model data. The variables of the models are the quantity of feed that each animal category consumes in a year. The goals and constraints take into account the minimum and maximum nutrition requirements, such as energy and protein. There are nutrients with minimum and maximum values, for example protein. Others have either minimum or maximum values. The technical coefficients are the amount of nutrients that each unit of feed has. The aspiration levels are the total quantity of nutrients that the animal categories need in one year. We have other types of constraints, for example sets of raw materials, such as cereals, which have minimum and maximum values.

We have used LINGO to formulate the goal programming models, to solve them and to analyse the solutions. Its modelling language enables the expression of series of similar constraints in a single compact statement, so that the models are much easier to maintain and scale up. Another convenient feature of this modelling language is data section, which allows us to isolate the model data from the formulation. LINGO reads our data from a separate spreadsheet file, making it much easier to update the model.

In conclusion, we have developed an appropriate model that produces relevant information for improving the accuracy of emissions inventories, which are simple and easy to manipulate and communicate. The models are complete as they include all significant aspects. At the same time, they are adaptive and robust because reasonable changes in inputs and the structure of the problem will not invalidate them. Finally, these models provide suitable tools to study, at low cost, the effects on greenhouse gases and pollutant emissions of changes in feed price, expert nutrition recommendations and agricultural policy."

3 - A Parametric Method to Determine the Optimal Convex Surrogate Upper Bound Set for the Bi-Objective Bi-Dimensional Knapsack Problem

Anthony Przybylski, Université de Nantes, France
anthony.przybylski@univ-nantes.fr
Kathrin Klamroth, University of Wuppertal, Germany
klamroth@math.uni-wuppertal.de
Britta Schulze, University of Wuppertal, Germany
britta.schulze@math.uni-wuppertal.de

In this work, we propose a new method to determine the optimal convex surrogate upper bound set (OCSUB) for the bi-objective bi-dimensional knapsack problem.

The surrogate relaxation is a relaxation classically applied to the single-objective bi-dimensional knapsack problems. The idea is to aggregate the constraints using a multiplier, and to solve next the obtained (single-dimensional) problem to obtain an upper bound. The quality of the upper bound depends of course on the choice of the multiplier. The dual surrogate problem consists in finding one multiplier, allowing to obtain the best possible bound.

It is immediate to extend the surrogate relaxation to the bi-objective case. Given a multiplier, we obtain a bi-objective single-dimensional knapsack problem, which can be solved to obtain an upper bound set for the set of nondominated points of the initial bi-objective bi-dimensional knapsack problem. As to determine the set of nondominated points of a bi-objective combinatorial optimization problem is expensive, it has been proposed in (Cerqueus et al., 2015) to consider only its convex relaxation. Again, the quality of the obtained upper bound set depends on the chosen multiplier. The main difference with the single-objective case is that the upper bound sets obtained using different multipliers may not be comparable. Therefore, to obtain the best possible
upper bound set will generally require to merge several upper bound sets obtained using different multipliers. The best possible upper bound set that can be obtained this way has been called optimal convex surrogate upper bound set in (Cerqueus et al., 2015) and it has been shown that it can be obtained using a finite number of multipliers.

Cerqueus et al. (2015) have proposed the first method to determine the OCSUB, based on an analysis of the multiplier set, and on the solution of convex relaxations of surrogate relaxations. We propose a parametric method for the computation of the same upper bound set. The main idea is to obtain the single-objective upper bound, defined by the dual surrogate problem, for all possible weighted sum problem. This is realized by starting from an exact method for the single-objective dual surrogate problem, proposed by Fréville and Plateau (1993), and by the design of a sensitivity analysis method. New insights on the way the OCSUB is built are shown, and new explanations about the reason why a classical dichotomic scheme cannot be applied here are given. Experimental results on various instances of bi-objective bi-dimensional knapsack problem show that our new method improves the computational time by several orders of magnitude.

4 - Food security and environmental risks assessment of livestock production by using GIS and PROMETHEE

Concepción Maroto, Universitat Politècnica de València, Spain
cmaroto@eio.upv.es

Aurea Gallego, Universitat Politècnica de València, Spain

Consuelo Calafat, Universitat Politècnica de València, Spain

Israel Quintanilla, Universitat Politècnica de València, Spain

Marina Segura, Universitat Politècnica de València, Spain
masema@upvnet.upv.es

Livestock farming provides quite valuable products for human consumption, generating environmental risks, which together with food security are increasing concerns for society, as shown the strict regulations on livestock sector in the European Union. Farms must comply with many requirements related to land use, animal welfare and public health, as well as minimize environmental and social risks in order to preserve the soil, water and air quality.

The objective of this research is to assess the intensive livestock production taking into account criteria corresponding to food security and animal health, as well as other environmental and social criteria. From farm-level data obtained by using GIS methodology, PROMETHEE has been applied in order to generate indicators, which are useful to evaluate the livestock production sustainability in the Comunitat Valenciana, a Mediterranean region located in eastern Spain. GIS allows showing the results spatially, so pointing out the territory areas with more pressure. We have focused on the intensive productions of swine and poultry, because they are the most important with more than 2000 farms in total, many of which are independent of the land as a production factor. The trend is to increase the number and size of swine and poultry facilities with a high level of technology and skilled labour.

The sectorial criteria take into account the locations of the farms according to the land use classification (rural, protected, urban, landscape ...), the legal minimum distances between farms and urban areas, the minimum legal distances between farms of the same species, as well as between farms of different livestock species. The minimum distance between a farm and the urban centre, fixed by law, depends on its number of inhabitants. Based on these distances we have established several areas of influence according to the associated biosecurity risk. To assess the compliance degree of the farms with respect to the required distances between livestock facilities, the species, size and number of farms closest to the legal minimum are considered. The risk of contamination of aquifers is the environmental criterion included, as affecting to groundwater quality. Finally, this research also takes into account the impact of odours, which may affect nearby towns, as a social criterion.

In short, after obtaining indicators to measure the four sectorial criteria, aquifer vulnerability and nuisance due to odour for every farm, we have applied PROMETHEE in order to generate a global indicator for livestock production by using D-Sight software. The weights of criteria are elicited by applying Analytic Hierarchy Process (AHP) from a group of
experts in the following areas: animal science, agricultural economics and environmental science. Expert Choice allowed us to aggregate their judgements with the geometric mean and finally determine the weights of criteria required in the PROMETHEE method. According to the results, the sectorial criteria are the most important, in particular the distance between farms of the same species followed the distances to the nearest population centres. The odour problems are the least important. Finally, GIS enables us to represent the global indicator for every farm geographically, highlighting the areas with more problems. We have quantified the conflicts arising from land use and environmental issues due to intensive livestock production, providing relevant information to design agricultural policies in order to improve the food security and social welfare and minimize environmental risk in the region.

MON-5-CON-DMS4170
Contributed Session
Monday 16:40 - 18:20 -- Room DMS4170
Session: Multi Objective Optimization
Chair: Petra Weidner

1 - A new decision maker model for automatic testing of interactive methods
Vesa Ojalehto, University of Jyväskylä, Finland
vesa.ojalehto@jyu.fi
Dmitry Podkopaev, Systems Research Institute, Polish Academy of Sciences, Poland
dmitry.podkopaev@gmail.com
Kaisa Miettinen, University of Jyväskylä, Faculty of Information Technology, Finland
kaisa.miettinen@jyu.fi

We concentrate on multiobjective optimization problems, which are computationally and cognitively challenging due to the complex underlying models and big numbers of objectives. Such problems often appear in modern industry and management, and are better dealt with using interactive methods. Proper testing of the strengths and weaknesses of interactive methods, as well as their comparative studies are hindered by the necessity of intensive involvement of a decision maker (DM) in any method test. No wonder that the amount of reliable information about the quality of interactive methods is neglectable. As a workaround, one can replace a human DM with a mathematical model and a procedure mimicking the DM's behavior. For non-ad hoc interactive methods, the DM's preference information can be derived from a value or utility function.

Several interactive methods require the DM to express preference information in terms of reference points consisting aspiration levels and, thus, we focus on testing such methods. However, it is not straightforward to derive aspiration levels from a model replacing the DM and there is no universal, easy-to-use tool for testing methods. We develop such tools and present a universal framework for testing interactive methods by deriving DM’s preferences from models, and propose such a model based on simple, understandable principles. This model converts preferences defined as a value function into preference information in terms of reference points. It can incorporate and parametrize different aspects of DM’s behavior, which have not been addressed before in such studies. We present the framework, the DM model and some results of computational experiments.

2 - The Multiobjective Shortest Path Problem is NP-hard, or is it?
Fritz Bökler, TU Dortmund, Germany
fritz.boekler@tu-dortmund.de

To show that multiobjective optimization problems like the multiobjective shortest path or assignment problems are hard, we often use the theory of NP-hardness. In this talk we rigorously investigate the complexity status of some well-known multiobjective optimization problems and ask the question if these problems really are NP-hard. It turns out, that most of them do not seem to be and for one we prove that if it is NP-hard then this would imply P = NP under assumptions from the literature. For the Multiobjective Shortest Path problem, we provide a new solid proof of NP-hardness. We also reason why NP-hardness might not be well suited for investigating the complexity status of intractable multiobjective optimization problems.

3 - The Rectangular Knapsack Problem: Hypervolume Maximizing Representation
Britta Schulze, University of Wuppertal, Germany
schulze@math.uni-wuppertal.de
Carlos M. Fonseca, University of Coimbra, Portugal
cmfonsec@dei.uc.pt
Luís Paquete, University of Coimbra, Portugal
paquete@dei.uc.pt
Stefan Ruzika, University of Koblenz-Landau, Germany
ruzika@uni-koblenz.de
Michael Stiglmayr, University of Wuppertal, Germany
stiglmayr@math.uni-wuppertal.de
David Willems, University of Koblenz-Landau, Germany
davidwillems@uni-koblenz.de

We investigate a variant of the quadratic knapsack problem, the cardinality constrained rectangular knapsack problem. This problem consists of a quadratic objective function, where the coefficient matrix is the product of two vectors, and a cardinality constraint, i.e., the number of selected items is bounded. In the literature, there are rather few results about the approximation of quadratic knapsack problems. Since the problem is strongly NP-hard, a fully polynomial-time approximation scheme (FPTAS) cannot be expected unless P=NP. Furthermore, it is unknown whether there exists an approximation with a constant approximation ratio. However, the cardinality constrained rectangular knapsack problem is a special variant for that we present an approximation algorithm that has a polynomial running time with respect to the number of items and guarantees an approximation ratio of 4.5. We show structural properties of this problem and prove upper and lower bounds on the optimal objective function value. These bounds are used to formulate the approximation algorithm. We also formulate an improved approximation algorithm and present computational results.

Further ideas concerning this concept and possible extensions are discussed.

4 - A general approach to the determination of properly efficient solutions in multicriteria optimization

Petra Weidner, HAWK University of Applied Sciences and Arts Hildesheim/Holzminden/Göttingen, Germany
weidner@hawk-hhg.de

Properly efficient solutions are weakly efficient points with respect to cones that contain the domination set in its interior. Since weakly efficient solutions can be handled in algorithms with less effort than efficient solutions, the determination of properly efficient solutions offers a possibility for the effective calculation of efficient solutions. In the presentation, a scalarization is presented that can generate the properly efficient point set and contains many scalarizing problems that are familiar in multiobjective optimization.

Tuesday, 9:00-10:00

TUE-1- DMS4101

Plenary Session: Dr. Jyrki Wallenius
Monday 9:00 - 10:00 - Room DMS4101
Chair: Roman Slowinski

1 - A Voting Advice Model and Its Application to Parliamentary Elections in Finland

Jyrki Wallenius, Aalto University School of Business
Dr. Jyrki Wallenius, Aalto University School of Business, Finland

Voting Advice Applications (VAAs) are online decision support systems that try to match voters with political parties or candidates in elections, typically based on how each responds to a number of policy issue statements. Such VAAs play a major role in many countries. In this keynote, I will describe the development and large-scale application of a new innovative matching algorithm for the most widely used VAA in Finland. The work is joint with Tommi Pajala, Pekka Korhonen, Pekka Malo, Aalto University School of Business, Ankur Sinha, Indian Institute of Management, and Akram Dehnokhalaji.
Kharazmi University, Iran. We worked closely with the owner of the VAA, the largest daily newspaper in Finland, Helsingin Sanomat. Their previous algorithm, what one might call “naive” approach, was improved by including measures of candidate’s political power and influence, using proxy variables of media visibility and incumbency status. The VAA was implemented for the 2015 parliamentary election in Finland; our matching algorithm was used by 140,000 voters (26.7% of the electorate) in the Helsinki election district. The innovative algorithm generated recommendations that many voters were happy about, followed by users’ incidental comments that this was the first time the VAA recommended candidates they wanted to vote for. This showed the importance of catering to different kinds of voters with a model not previously considered by any VAA in any country. I conclude my presentation by a discussion of a number of important MCDM issues that needed to be addressed in our study.

Tuesday, 10:30-12:10

TUE -2-INV -DMS4120
Invited Session: Spatial Multiple Criteria Decision Making: insights and new directions of research (Ferretti)
Tuesday 10:30 - 12:10 - Room DMS4120
Chair: Valentina Ferretti

1 - A theoretical framework to synthesize the multicriteria spatial risk in the case of multiple nuclear release scenarios
Oussama Raboun, Institut de Radioprotection et de Sureté Nucléaire, France
o.raboun@gmail.com
Céline Duffa, Institut de Radioprotection et de Sureté Nucléaire, France
celine.duffa@irsn.fr
David Ríos Insua, Instituto de Ciencias Matemáticas, Spain
david.rios@icmat.es
Eric Chojnacki, Institut de Radioprotection et de Sureté Nucléaire, France
eric.chojnacki@irsn.fr
Alexis Tsoukias, Paris Dauphine University, France
alexis.tsoukias@lamsade.dauphine.fr

The French Institut de Radioprotection et de Sureté Nucléaire (IRSN) developed many predictive tools to model the fate of radionuclides, in particularly Cesium, in case of a nuclear accident in marine area. However, if such accident occurs, public authorities may need additional operational tools for impact assessment to make informed decisions given the circumstances about issues, such as banning certain economical activities, setting a new water management policy at each relevant zone, or even, evacuating people, to name but a few.

In this work, we established a formal approach synthesizing multicriteria spatial risk in the case of multiple attribute evaluations (describing various axes of the evaluation) and potentially uncertain information over scenarios, corresponding to four release positions and three sea conditions, aiming to provide the decision maker with three types of indicators to represent respectively the expected impact of a released concentration of Cesium on each economical and environmental attribute, the different possible scenarios inducing an equivalent impact and the general expected situation in the marine area. As a motivating case study, we shall focus on a possible release from a nuclear submarine at the Bay of Toulon. To afford IRSN with a theoretical framework allowing during the multicriteria spatial aggregation process to take into account different sources of uncertainties providing from different release positions and different sea currents, we set up a decision aid problem and three different aggregation procedures corresponding to the three types of indicators. First, we discretized a map of the Bay of Toulon into forty five cells and we defined five criteria to evaluate each cell. Then, we built a procedure to assess the impact functions, with respect to the expert evaluation, for each attribute based on the concentration of Cesium and the twelve scenarios of release. Since our objective is to assign each cell or each map to a predefined category according to its level of impact, we have to deal with a rating problem statement.

To afford the decision maker with the three types of indicators we developed three aggregation procedures. The first type of indicators consists on aggregating spatial evaluations of cells and uncertainties induced by different scenarios of release. This kind of indicators is useful to evaluate which sector of activity is the most impacted. The second type provides the
decision maker with maps of reference for each equivalence class of release scenarios. Such indicators allow us on one hand, to be independent from the relevant scenarios while keeping the same level of informativity. On the other hand, it allows illustrating the scenarios that have an equivalent impact and represent them through representative maps, such as pure maps or clustered maps. The third type of indicator represents the general state of the Bay of Toulon, aggregating criteria and spatial information. It allows us either to have a synthetic overview on the Bay of Toulon or to identify the worst scenario, the worst cell in the map or the worst map.

The first aggregation procedure aims to construct a method to synthesize the impact of an accidental nuclear release over each attribute. This aggregation procedure is based on the evaluation of the expected loss or the relative loss due to the accident, i.e. the difference between the evaluation of the Bay of Toulon when there is no accident and the expected evaluation of the whole area from the perspective of each attribute. Note that in this approach we evaluate each cell separately and we assume that there is no interaction between cells.

In the second and third approaches, we consider the problem with multiple criteria in which we deal with the global case.

The second aggregation procedure aims to provide the decision maker with some maps of reference for each subset of scenarios belonging to the same equivalence class. The procedure consists on solving the multicriteria problem for each cell, using ELECTRE Tri method, which leads to a coloring map for each scenario (each color represents a different category). Then, we shall use the theory of the Choquet integral in order to evaluate maps, considering the possibility of interactions between contiguous cells. The last step of this approach consists on comparing maps using Choquet values and a threshold of indifference in order to define some equivalence classes described by some maps of reference.

The last aggregation procedure evaluates the situation in the Bay of Toulon using the expected utility value. Assuming we are able to define a utility function aggregating performance matrices, representing the evaluation of each cell by multiple criteria, we consider lotteries on the occurrence of each scenario, then we compute the expected utility. The major issue in this approach is how to define the utility function. One extreme is the one above which just follows Von Neumann & Morgenstern (VNM) axioms. At the other extreme, by assuming sufficiently strong independence conditions we would have a linear utility function; we remove uncertainty through an expected value and summarize the spatial information. Intermediate models would make different type of utilities depending on either the cells have the same importance under the same criteria or not. Whatever the aggregation, we may compute the difference between the utility under normal circumstances and the expected utility under an accident.

The work carried out highlights three models of aggregation corresponding to three types of indicators. As a result, this theoretical framework allows the decision maker to choose the corresponding indicator adapted to his needs.

2 - Information representation in decisions under risk

Ayşegül Engin, University of Vienna, Austria
ayseguel.engin@univie.ac.at

Rudolf Vetschera, University of Vienna, Austria
rudolf.vetschera@univie.ac.at

The very early literature on information presentation already emphasized that there is not one ideal form of information representation, but that the form in which information is presented has to fit both the characteristics of the problem and of the decision maker. However, over time, the fit of problem representation to problem characteristics received considerably more attention in literature than the fit to characteristics of the decision maker. This paper focuses on the relation between problem representation and cognitive style of the decision maker and its effects on the decision performance. It furthermore takes into account that decision making depletes limited cognitive resources of human decision makers. Having to deal with an inadequate problem representation, which does not fit to the problem or the decision maker's cognitive style, increases the cognitive load on the decision maker and thus depletion of resources. Therefore, differences in problem representation might not only influence performance on the decision problem at hand, but also performance on subsequent decision problems.
Therefore, in the present paper, we study the effect of fit or misfit between problem representation and decision makers' cognitive style on performance in the context of a sequence of decision problems. This allows us to detect delayed effects of information presentation in matching or mismatching form on the performance in subsequent problems. As the emphasis of this study is on the effects of information presentation, we focus on the acquisition of information needed for decision making rather than information processing. Our experiment therefore uses a decision task that requires subjects to obtain a considerable amount of information, but that does not require highly elaborate calculations. Since decisions under risk are an important class of decision problems, the task employed in this study is also a decision problem under risk, and specifically a ranking problem. A ranking task forces decision makers to evaluate every alternative, in a choice task, decision makers who follow a simple aspiration based strategy could stop their search after finding one satisfactory alternative without analyzing all alternatives. By using a ranking task, we therefore ensure that all subjects have to process the same amount of information. The task consists in ranking of two to seven lotteries according to their expected value, where each lottery involves two outcomes of equal probability. 227 business administration students participated in the experiment. Results show that a matching representation with respect to the cognitive style of the decision maker improves significantly the decision performance in a cognitively non-depleted state. However, we also find strong effects of depletion, so that subjects who first have to deal with a problem presented in a mis-matching format no longer exhibit superior performance in a subsequent task, even if that task is presented to them in a matching form.

3 - Spatial decision models for comparing maps
Valérie Brison, Université de Mons, Belgium
valerie.brison@umons.ac.be
Marc Pirlot, Université de Mons, Belgium
marc.pirlot@umons.ac.be

Many decision problems occur in a geographic or environmental context. In this work, we address the issue of comparing maps. Imagine we have two maps representing the suitability of a region for a given use, but not at the same time. During the time period, the state of the territory has evolved. Our objective is to help a decision maker to determine whether the global state of the territory has improved or deteriorated during the time period. For this purpose, we have developed three models to help a decision maker expressing his/her preferences over such maps, and consequently help him/her evaluating, for example, the results of a policy applied to the territory under study. The first model we propose assumes that the only thing that matters is the proportion of the surface area assigned to each category of the maps assessment scale. The second model allows to consider some geographic aspects. For example, the fact that good zones are close to or far away from a watercourse or a village can have an importance. The third model allows to take contiguity into account. Indeed, the fact that good zones are grouped together or scattered over the map may matter.

We established the precise conditions (axioms) under which these models can represent the decision maker's preference. We designed elicitation methods based on the models' axiomatic characterization. Our models can also be useful to compare several land-use scenarios as will be illustrated on the results of the ESNET (Ecosystem Services NETworks) project. This project, which we have collaborated on, aimed at assessing the effects of different environmental policies on the ecosystems of the Isère department (France). We also use this project to show that other interesting aggregation problems occur in geographic contexts. For example, starting from a map each pixel of which is evaluated on some scale, how can we aggregate these evaluations to assign a single one to each commune? Or, starting with several maps representing the evaluation of a territory w.r.t. several criteria, how can we aggregate these evaluations to produce a single map representing the overall state of the territory for some purpose?

4 - Unlocking SWOT Analysis: the effect of combining it with spatial analytics and multi-criteria decision aiding
Valentina Ferretti, London Schoold of Economics and Political Science, United Kingdom
V.Ferretti@lse.ac.uk
Elisa Gandino, Technical University of Torino, Italy
gandelisa@gmail.com
This study develops a participatory multi-methodology intervention designed and deployed to support planning and management of a new World Heritage site, i.e. the vineyard landscape of Langhe, Roero and Monferrato in Northern Italy. The proposed framework develops through four subsequent phases and experiments a multi-methodology approach combining SWOT Analysis (Strengths, Weaknesses, Opportunities and Threats) with spatial analytics and Multicriteria Decision Aiding in Phase 1 (problem identification - knowledge phase), Stakeholders’ Analysis with Spatial Multicriteria Decision Aiding in Phase 2 (problem formulation - planning phase), and Stakeholders’ Analysis with Choice Experiments during Phase 3 (problem solving - design).

The focus of the presentation will be on the design and development of the spatially weighted SWOT analysis. Indeed, SWOT analysis is now a commonly applied tool in many different contexts and recent applications have shown its contribution in supporting strategic planning procedures and sustainability assessments. However, SWOT analysis commonly lacks the possibility of comprehensively appraising the strategic decision-making situation. It is often left at the level of only pinpointing the factors. In addition, the expression of individual factors is often of a very general nature and brief. In our study, we showed how SWOT analysis can be elaborated in order to provide a more comprehensive decision support tool, by spatially resolving each SWOT indicator.

The whole study has been developed in close collaboration with the La Morra Municipal Authority, one of the stunning components of the Core World Heritage site. The purpose of this study was to develop an integrated aid to support policy decisions by investigating the combined and synergic effects of the aforementioned tools. The ultimate objective was to propose practical recommendations for a sustainable development strategy of the complex area under consideration (Phase 4, implementation). As a legacy, the developed framework left the involved organizations with a transferable and operable working tool for the public sector administration.

The obtained results illustrate the importance of integrated approaches for the development of accountable public decision processes and consensus policy alternatives.

TUE -2-INV-DMS4130
Invited Session: Military-related applications for MCDM (Ghanmi)
Tuesday 10:30 - 12:10 - Room DMS4130
Chair: Ahmed Ghanmi

1 - A Multi-Objective Evolutionary Approach to Optimal Base Locations
Slawomir Wesolkowski, Canada, Canada
s.wesolkowski@gmail.com
Michael Mazurek, University of Waterloo, Canada
s.wesolkowski@ieee.org

Several federal organizations provide responses to Search and Rescue (SAR) incidents within Canada: the Canadian Coast Guard, Royal Canadian Mounted Police, the Canadian Forces (CF), Meteorological Service of Canada, Parks Canada, and Transport Canada. There are also several local authorities and volunteer groups across Canada, such as the Civil Air Search and Rescue Association (CASARA). CASARA is a network of units based at local airfields that are distributed throughout Canada. CASARA units must have at least one fixed-wing aircraft, a group of volunteers to operate the asset(s) and should be able to respond to a wide variety of SAR events.

Given that CASARA units are important to SAR operations, their location would significantly impact on SAR operations effectiveness. Previous studies have used various methods to find optimal configurations of CASARA units, most recently including a multi-gender genetic algorithm (MGGA). In this study, a multi-gendered adaptation of the non-dominated sorting genetic algorithm II (NSGA-II) is developed and applied to the CASARA basing problem, with the goal of finding basing assignments that are Pareto-optimal on three objectives: the number of CASARA units, area covered and coverage redundancy (total area covered by two or more units).

The solutions returned by NSGA-II are compared to those found by MGGA in the previous study. The two algorithms return solutions of similar quality, i.e. the solutions are mostly non-dominated with each other. However, the two algorithms return solutions in different areas of the objective space. Thus, by applying NSGA-II to this problem, a new set of options for a decision-maker is found. Notably, the
multi-gendered NSGA-II is able to find solutions with a high coverage redundancy. By initially seeding NSGA-II with previously found solutions, the final population returned is affected, and the final solutions returned have properties similar to the previous solutions. To further analyze the solutions returned by NSGA-II, they are sorted by normalized weighted sums of their objective scores, for a variety of different weighting vectors. This illustrates a better understanding of the trade-offs which happen among different solutions in the decision space.

Generally, the solutions found provide a big improvement over the current basing configuration. Specifically, those solutions with high coverage redundancy provide more options for planning locations for volunteer CASARA units, since volunteers may not be found at some proposed locations. Considering basing configurations with a high redundancy is one way to increase the probability that SAR incidents within range of one or more CASARA units will actually be responded to by these units.

By applying NSGA-II to this problem, a new set of options is found, which in turn gives more choice to decision makers. Ranking the solutions by various weighted sums provides a way to better understand the decision space, allowing a decision-maker to make an informed decision.

2 - The inclusion of social networking analysis to consensus ranking solutions
Adrienne Turnbull, DRDC Centre for Operational Research and Analysis, Canada
adrienne.turnbull@forces.gc.ca
Shadi Ghajar-Khosravi, DRDC Toronto Research Centre, Canada
Shadi.Ghajar@drdc-rddc.gc.ca
Peter Kwantes, DRDC Toronto Research Centre, Canada
Peter.Kwantes@drdc-rddc.gc.ca
Ed Emond, DRDC Centre for Operational Research and Analysis, Canada
ed.emond@drdc-rddc.gc.ca

This paper will outline the use of social networking analysis (SNA) as part of a multi-criteria decision analysis (MCDA) consensus ranking solution. Defence Research and Development Canada (DRDC) often uses a specific method and tool, MARCUS [1], when a collection of projects need to be ranked and prioritized based on a list of criteria. This tau-x method has been successful for years, yet a recent application showed a gap in the criteria. While MARCUS provides a solution which can incorporate the rankings of a multitude of viewpoints, such as subject matter expert evaluation of projects based on their environmental, health, and safety impacts, there had previously been no way within MARCUS to evaluate interdependencies of the projects. This paper will include a theoretical example where multiple departments evaluate a list of projects, and the interdependencies between them are evaluated using SNA centrality measures (i.e., indegree, outdegree, PageRank, reach, and fragmentation) as one of the MCDA criteria. These centrality measures objectively measure the structural importance of projects within the conceptualized dependency network.


3 - On the Use of MCDM in Defence Acquisition Projects
Gregory van Bavel, Centre for Operational Research and Analysis, Canada
gregory.vanbavel@forces.gc.ca
Ahmed Ghanmi, Centre for Operational Research and Analysis, Canada
ahmed.ghanmi@forces.gc.ca

Project management offices at the Department of National Defence are required to make decisions that must satisfy multiple criteria that are stipulated by defence acquisition projects. Some of the criteria may be unique to the defence-related goods or services to be acquired, such as a minimum level of blast resistance. Other criteria may be common to everyday consumers, such as the maximum affordable price. This paper presents a number of examples of defence acquisition projects in which Multiple Criteria Decision Making (MCDM) proved useful. In several examples, such as fixed-wing search and rescue, naval
ships, in-service support, MCDM provided the basis for the development of fair, transparent, and defensible bid evaluation plans. The cost-risk analyses of the joint-support ship and the arctic offshore patrol ship included the quantitative assessment of several criteria requested by the decision makers. In the case of rotary-wing search and rescue aircraft, MCDM gave decision makers a range of options that will provide guidance under various economic conditions and procurement arrangements. MCDM was used to advise decision makers how many personnel from various skillsets are required for an equipment management team that is to modernize the fleet of logistics vehicles. This paper identifies common elements among the diverse applications of MCDM and, based on that evidence, gives practical recommendations.

TUE -2-CON-DMS4140
Contributed Session
Tuesday 10:30 - 12:00 - Room DMS4140
Session: Group Decision Making / Negotiations
Chair: Özyay Özaydın

1 - Exploring Key Factors and Strategies in Corporate Social Responsibility (CSR) for the hi-tech industry
Chia-Chi Sun, Tamkang University, Taiwan
139866@gms.tku.edu.tw

With the growing awareness of Corporate Social Responsibility (CSR), increasingly more companies are becoming aware that business cannot be limited to just maximizing stakeholders’ profit. An enterprise should include social responsibility to protect the environment and develop people’s talents. Maintaining business competitive power and sustainability while bringing contributions to society has become the new corporate performance target. In Taiwan, the hi-tech industry is an important economics index. Although some hi-tech companies have executed CSR, many of them have not. The reason is mainly due to not knowing how to begin executing CSR or they do not know the proper strategy. This study used the hi-tech industry as the sample for a Decision Making Trial and Evaluation Laboratory (DEMATEL) to analyze the CSR key factors and strategy. The result confirms that business leaders should start from the “Environment” and focus on “building a green supply chain,” “protecting stakeholders’ rights and interests” and “building enterprise CSR culture” as the strategy to execute CSR.

2 - A multiple attribute group decision making approach for incomplete information.
Bilal Ervural, Istanbul Technical University, Turkey
bilalervural@gmail.com
Özgür Kabak, Istanbul Technical University, Turkey
kabak@itu.edu.tr

Decisions in the real world are mostly made by a group of decision makers. The presence of more than one decision maker provides some advantages since each decision maker has different personality, experience, motivation, and ability. However, dealing with the heterogeneous information that emerges from the differences of the decision makers makes the decision process extremely difficult. In recent years, multi attribute group decision making (MAGDM) problems with incomplete information has been a challenging research topic. In an MAGDM environment, decision makers provide evaluations regarding the performance of alternatives under multiple criteria. In this respect, in some MAGDM problems the information subjective information, provided from the decision makers as well as the objective information may be incomplete due to lack of expertise, lack of knowledge, unavailability of required data, high cost of gathering data etc.

In this study, a novel MAGDM approach based on the Cumulative Belief Degree (CBD) is proposed. The proposed approach aims to cope with incomplete information in MAGDM problems. It enables the aggregation of decision maker opinions in different formats as well as at different scales, in addition to objective criteria when the decision maker weights are available. Basically, the information provided by the decision makers is transformed to belief degrees. Belief degrees are then converted to CBDs, to facilitate mathematical operations and to handle any missing data without losing available information. Since it gives a final score as a distribution to linguistic levels, it provides more information related to the
performance of an alternative, which enriches the interpretation of the results.

The algorithm for the proposed approach is developed in the following three main stages: (1) problem structuring stage (2) assessment stage and (3) selection stage. In the first stage, the problem is structured by determining the decision goal, forming a committee of decision makers, and identifying alternatives and criteria. In order to obtain the decision matrix for each decision makers, decision makers state evaluations for each alternative with respect to their criteria set. Decision makers can make evaluations differently from belief structures. In the second stage, the decision maker evaluations are transformed to belief structures according to the proposed transformation formulas. After decision makers evaluations have been obtained and transformed to belief structures, the steps of the CBD approach are applied in order to find the collective preferences. In the last stage, alternatives are ranked and/or the most appropriate alternative is selected. For this, two approaches are developed. The aggregated score approach is for assigning a score to each alternative for direct ranking. First, the weight of each linguistic term is assigned and then the scores of the alternatives are calculated. The second approach is linguistic-cut approach that can provide a result for a certain satisfaction level. Using this approach different results for different satisfaction levels can be generated.

The proposed approach is aim to process different kinds of available information provided by decision makers, as well as the scores from objective criteria, without losing any information. In order to achieve this aim, transformation formulae and aggregation formulae are proposed. Decision maker evaluations given in different formats and scales such as direct value assessments, interval value assessments, classical fuzzy sets, hesitant fuzzy sets, intuitionistic fuzzy sets, linguistic terms are transformed to belief structure. Besides, aggregation formulae are proposed to combine decision maker evaluations and find collective preference. Finally, the validity of the proposed approach is illustrated using an example. In conclusion we argue that the proposed approach presents a general methodology that can be applied to both homogeneous and heterogeneous MAGDM problems as well as the problem with incomplete information. For future research, the proposed approach can be compared with alternative methods by applying complex real life problems.

3 - The efficacy of using the UTA* technique for prenegotiation preparation
Gregory Kersten, Concordia University, Montreal, Canada
gregory@jmsb.concordia.ca
Ewa Roszkowska, University of Bialystok, Faculty of Economic and Management, Bialystok, Poland erosz@o2.pl
Tomasz Wachowicz, University of Economics in Katowice, Department of Operations Research, Katowice, Poland tomasz.wachowicz@ue.katowice.pl

Multiple Criteria Decision Aiding (MCDA) techniques can be used in the prenegotiation preparation phase to support the parties in eliciting their preferences, evaluating the negotiation template and building the quantitative negotiation offer scoring systems. Such scoring systems are used by the negotiators in actual conduct of negotiation to evaluate the negotiation offers, measure the scale of concessions made by the parties or plan their own concession paths. They can also be used by third parties, such as mediators, arbitrators or electronic negotiations support systems, to provide the negotiating parties with additional information and support, i.e. in depicting the negotiation history and negotiation dance graphs or in determining fair solutions or the improvements of the negotiated agreements [2]. Hence, from the viewpoint of the negotiation support it seems crucial to provide the negotiators with the formal decision support tools that are capable to map their intrinsic preferences over the negotiation issues into the quantitative scoring systems in the most accurate way that would assure the reliable decision support during the actual negotiation phase.

Traditionally, the negotiation offer scoring systems are determined by means of direct rating methods, like in Inspire, SmartSettle or NegoCalc systems [1; 4]. However, there is a number of research that report on various problems with building and effective using of scoring systems determined by means of direct rating, SAW, SMART or even swaps approaches (e.g. [5]). The potential determinants can be both the holistic
judgements related to fast thinking; and the cognitive demand of the scoring procedures. Our recent studies confirm that there is a big group of decision makers who prefer to express their preferences verbally, not operating with numbers directly, but expecting to obtain the scoring systems with a certain level of rating precision [3].

The goal of our research was to find whether the UTA* method can be effectively applied to build the negotiation offer scoring systems. More precisely, we analyzed if UTA*, that requires a holistic preference declaration provided by means of the rank order of full packages (without the necessity of operating with quantitative judgments), could result in the scoring system no significantly less accurate than the ones obtained by means of the direct rating technique (SMARTS- or SAW-like). We measured the accuracy of the scoring systems obtained by means of both approaches by determining how concordant they were with a predefined reference scoring system. Hence, we organized the online bilateral negotiation experiment, in which the agents were negotiating the contract on behalf of their principals. The structures of principals’ preferences were predefined and the agents were supposed to follow them while building their scoring systems. Simultaneously, we used the principal’s preferences to build the reference scoring system. To find the level of accuracy of the agent’s scoring systems with the principals’ one we introduced two measures of accuracy: (1) the ordinal accuracy and (2) the cardinal accuracy indexes.

In this paper we present the results of two studies that differ in the preferential information revealed to the agents. In Study 1 the negotiators are provided with a detailed private info, with the principal’s preferences described verbally and visualized graphically; while in Study 2 more vague preferences definition was used. In Study 1 the negotiators used the direct rating technique implemented in Inspire to determine their individual scoring systems. Then, based on this preferential information provided by agents the corresponding scoring systems were determined in laboratory using the UTA* solver. The accuracies of the scoring systems obtained by means of direct rating and the UTA* method were compared. This way we verify the general applicability of UTA*, assuming the users are able to provide the same and consistent preferential information both for direct and holistic approach. Then we compared these results with the UTA*-based scoring systems determined from the rank orders of offers defined individually by the negotiators to measure the actual efficacy of the UTA* approach in defining the negotiation offer scoring systems. Different configurations of the UTA* model were used. We changed the number and form of predefined offers as well as the technical parameters, such as various values of the alfa coefficient and number of the breakeven points. Similar analysis was conducted in Study 2, where the structure of principal’s preferences had been described only verbally, and hence the direct ratings became not so evident.

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References

4 - A Decision Support Model to Improve Efficiency of Kapıkule Border Crossing

Özay Özaydın, Doğuş University, Turkey
oozaydin@dogus.edu.tr
Mine İşık, Boğaziçi University, Turkey
mineisik@boun.edu.tr
Bora Çekyay, Doğuş University, Turkey
Economic growth is stimulated by increases in production, consumption, and trade. One of the factors affecting the increase in trade is the developments in supply chain management. Especially, improvements in logistics that can be considered as the backbone of international trade would directly affect the international trade.

In a country with better road infrastructures as well as predictable and quick customs clearance, there will be shorter and more certain delivery times, which will develop the logistics sector and will cause that country to gain competitive advantage. Hence, a country has to focus on improving customs, logistics quality, and timeliness of its logistics operations.

Logistics performance is inevitably highly dependent on government interventions such as investing in improved road infrastructures, developing regulatory transport service regimes, and implementing efficient customs clearance procedure. Governments play an important role in designing operations, processes, and infrastructures for modern and efficient customs and cross-border transport. Nevertheless, customs is not the only agency involved in border management, collaboration among all border management agencies and related stakeholders is of particular importance.

Turkey is an important logistics center in Europe that exhibits high trade values with her regional partners, has a large population, diversified economy and strategic geographical location. She is considered as a central actor in the trade between Europe, the Commonwealth of the Independent States and the Middle East. The trade via road transport between Turkey and Europe is carried out via several border crossings. Among these, KapoÅŸule border crossing is Europe’s biggest international cross-border linking Turkey to Europe via Bulgaria through a major highway.

In the last several years, due to the increase in the trade between Turkey and Europe, the capacity of the KapoÅŸule Border Crossing became inadequate to process a high number of trucks that transport the trade goods between Turkey and Europe. In congested times, it lasts 2-3 days for a truck to cross the border that results in late deliveries and uncertainties in the lead times. Turkish and European companies have concerns that this situation may negatively affect the international trade between Turkey and Europe.

The study aims to investigate the means of increasing the efficiency of KapoÅŸule Border Crossing. For this purpose, a simulation model is developed to represent the border crossing with all its processes, and a decision support model is proposed to prioritize the strategies to focus on improving KapoÅŸule Border Crossing. The research is within the scope of a project entitled “Turkey and Bulgaria; Bridging EU to Asia and the Middle East - Synchronization of Border Crossings between Turkey and Neighboring Countries”.

At the first stage of the research, all the processes related to the export and import activities are specified, and the data is gathered through several site visits, in-depth interviews with the border crossing authorities and quantitative data collection through official reports.

Subsequently, a simulation analysis is conducted using ARENA software to simulate all the export and import operations at the border and to highlight the bottlenecks.

In the next step, several scenario analyses are conducted to develop important strategies to enhance the current processes of border crossing that will decrease passing times and shorten the queues of waiting trucks.

Finally, a group-decision support model is developed to rank the strategies to focus on according to their order of importance in a way to increase the efficiency at the border.

For this purpose, the perspective of different stakeholders is taken into account. By this way, the opinions and priorities concerning the different group members are assessed. Each member defines criteria and model parameters, and then a multi-criteria
decision aid method is used to get the personal ranking. Subsequently, each stakeholder is considered as a separate criterion, and the preferential information of each is aggregated in a final collective ordering.  

**TUE -2-CON-DMS4170**

Contributed Session  
Tuesday 10:30 - 12:10 - Room DMS4170  
Session: Fuzzy Approaches, Decision Making under Fuzziness  
Chair: Renato Krohling  

**1 - Environmental Policies vs. Harsh Economic Realities: Using the Constrained Rationality Framework to Model and Analyze the Strategic Environmental Conflict between Ontario and an International Chemical Company, as an Example. Majed Al-Shawa, Strategic Actions, Canada malshawa@strategic-actions.com**

In 1989, the Ontario Ministry of Environment (MoE) discovered that a carcinogen was contaminating the underground aquifer at the small but prosperous town of Elmira, located in the rich agricultural land of Southern Ontario, Canada. Immediately, the pesticide and rubber products plant of Uniroyal Chemical Ltd (UR), which had a history of environmental problems, was the main suspect. As a result, the MoE issued a Control Order, under the Environmental Protection Act of Ontario, requesting UR to implement a long term collection and treatment system. UR refusal to cooperate led to a showdown between the MoE and UR with both players pressured by residents of Elmira, economical and environmental interest groups, and the local township and regional governments. Should the MoE stick to its guns and stand by its established environmental policies, demanding a clean up, and therefore risk UR abandoning the facility at Elmira and losing all the jobs there? What will the effect be on international manufacturers and investors to whom Ontario publicized itself as an investor and business friendly place? Should the MoE cave in to the harsh economic realities of the late 1980s and cancel its already issued control order against UR, and therefore risk signalling to all industries that there will be no consequences to their bad environmental practices? What will such decision tell the citizens of Ontario, who elected the most environmentally friendly political party in Ontario’s history, about how much the government values their safety and health.  

The showdown between the MoE and UR is similar to many strategic new and old multi-agent adversarial competitive decision making conflicts, especially environmental conflicts. Conflicts that are mostly ill-structured and have complex decision making situations, in which decision makers (agents) have conflicting strategic goals and constraining realities. Conflict’s outcomes rely on the rich contextual knowledge of the situation and its players. Agents' preferences are usually not clear, or hard to validate, and their options/moves are hard to completely capture and model. Most conflicts modelling and analysis tools assume predetermined agents' preferences, criteria, or utility functions, and predetermined set of alternatives to evaluate. This leads to a lack of applicability of such tools to model and analyze real-life strategic conflicts, and predict their outcomes.  

Constrained Rationality is a formal qualitative value-driven enterprise knowledge management framework, with a robust multi-agent decision support methodological approach, that addresses such challenges by: 1) using agents’ contextual knowledge about their own individual and collective conflicting goals and constraints to suggest the set of options the agents have and the set of states the conflict could have; 2) eliciting the agents’ preferences over the conflict's states utilizing the framework’s qualitative fuzzy modelling and reasoning mechanisms; and 3) defining a set of modelling and analysis concepts to conduct stability, equilibrium and sensitivity analysis for the resolution of the conflict.  

We use the Constrained Rationality framework to model the strategic environmental conflict between Ontario’s MoE and UR, including the players conflicting goals and constraints; analyze the players options and strategies including the possible cooperation between them; and then discuss the most stable equilibrium end states of this conflict, and similar ones. We, then, compare the analysis produced by the framework's contextual game models and analysis with how the conflict actually ended; and conclude by discussing our findings and lessons learned.  

**2 - An ordinal multi-criteria decision-making process in a qualitative scale setting**
Majority Judgment (MJ) is a voting system introduced and analyzed by Balinski and Laraki in 2007 (A theory of measuring, electing and ranking. Proceedings of the National Academy of Sciences of the United States of America 104, pp. 8720-8725) and 2011 ( Majority Judgment. Measuring, Ranking, and Electing. The MIT Press, Cambridge). Under MJ, agents evaluate each alternative with a linguistic term of a fixed ordered qualitative scale and, then, alternatives are ranked according to the medians of the obtained assessments. When the number of assessments is even, MJ only considers one of the medians, the lower median. We note that if the upper median is chosen, the outcome could be different to the one obtained when choosing the lower median. This asymmetry and loss of information could be relevant when the number of assessments is low. The authors also propose two different tie-breaking processes for obtaining a final ranking on the set of alternatives.

In this contribution, we propose a multi-criteria decision-making procedure that enhances and extends MJ. In our proposal, agents evaluate the alternatives regarding several criteria by assigning one or two consecutive terms (in the case of they hesitate) of an ordered qualitative scale and, then, alternatives are ranked according to the medians of their assessments after the replications. When the number of assessments is even, we take into account the two medians of the corresponding assessments, avoiding a loss of information. This richer information requires to consider an appropriate linear order on the set of feasible pairs of medians. Since some alternatives can share the same median(s), we propose a suitable tie-breaking process for ordering the alternatives. It is important to note that alternatives with different assessments never are in a final tie.

We establish some properties of the proposed multi-criteria decision-making procedure and we also illustrate it through a real case study.

3 - Flexible Goal Programming with Quasi-concave Utility Functions
Sakina Melloul, Institute of Economics, and Management, University Centre of Maghnia, Algeria., Algeria
ssmellouli@yahoo.fr
Hocine Mouslim, Faculty of Economics , Business, and Management, Tlemcen University, Algeria., Algeria
houssine.mouslim@mail.univ-lemcen.dz

The situation of multiple choices for a target/aspiration level of an objective exists in many managerial decision making problems. In such situations, the New Multi-Choice Goal Programming (N-MCGP) presented by Jadidi in 2015 is considered as a novel and powerful technique to help Modern Managers (MMs) in order to solve this type of multi-criteria management problems by using Linear Utility Functions (LUFs). In other words, the new technique of MCGP with LUFs reflects a good approximation of these decisions making situations. However, in practice, there are many situations where Modern Decision Makers (MDMs)/(MMs) can not present their preferred functions as linear in form. In this paper, an efficient methodology is presented based on the technique of Quasi-concave Utility functions (Qu-UFs) in which the concept of Flexible GP (Fi-GP) is introduced for modeling and characterizing the flexibility of (MDMs)/MMs’ preferences instead of using their classical crisp preferences to solve this type of problems. The formulated problem is treated as a nonlinear goal programming problem involving mixed flexible and crisp deviations under uncertainty. This new formulation provides (MMs) with more flexibility of control over their preferences. Finally, a numerical example is given to illustrate the efficiency and flexibility of the proposed model.

4 - Z-TODIM: TODIM with Z-numbers
Renato A. Krohling, UFES - Universidade Federal do Espírito Santo, Brazil
krohling.renato@gmail.com
Z-numbers are composed of two parts, the first one is a restriction on the values that can be assumed, and the second part is the reliability of the information. As human beings we communicate with other people by means of natural language using sentences like: the journey time from home to university takes about half hour, very likely. In this paper, we present an approach that is able to handle with Z-numbers in the context of Multi-Criteria Decision Making (MCDM) problems. Firstly, Z-numbers are converted to fuzzy numbers using a standard procedure. Next, the Z-TODIM is presented as a direct extension of the fuzzy-TODIM. The proposed method is applied to two case studies and compared with the Z-TOPSIS. Results obtained show the feasibility of the approach.
DEA assesses the efficiency of DMUs in turning inputs into outputs. This is done by benchmarking the efficiency of DMUs against each other, therefore comparing operating units with each other which ensures benchmarks are truly achievable. DEA identifies a frontier of best performance defined by so-called efficient DMUs, which non-efficient DMUs are benchmarked against.

We will give a brief generic introduction to basic DEA models and we will discuss the analogy between DEA and multiobjective optimisation. We will also provide a brief overview of an open-source python DEA package developed at the Department of Engineering Science (University of Auckland) available at https://pypi.python.org/pypi/pyDEA and https://github.com/araith/pyDEA. A case study is used to demonstrate the application of DEA to a real-world benchmarking problem.


3 - DESDEO - Open source framework for interactive multiobjective optimization

Vesa Ojalehto, University of Jyväskylä, Finland
vesa.ojalehto@jyu.fi

Kaisa Miettinen, University of Jyväskylä, Finland
kaisa.miettinen@jyu.fi

Even though interactive multiobjective optimization methods have been widely discussed in the literature, their implementations are rare and to our knowledge none of them are openly accessible, i.e., open source. Furthermore, there does not exist any openly accessible frameworks suitable for developing interactive multiobjective methods. Such frameworks are rare also on the field of multicriteria decision making in general, except the evolutionary field where releasing source codes related to the research is a more common practice.

In this talk, we introduce the ongoing work on developing an open source decision support framework DESDEO for computationally demanding multiobjective optimization problems. The aim of our work is to bring interactive methods closer to other researchers and practitioners world-wide. Currently, we concentrate on facilitating the development of implementations of interactive multiobjective optimization algorithms. To this end, we have identified the underlying structures typically required by interactive algorithms, such as constructing single objective scalarized subproblems using the preference information obtained from the decision maker and how to solve those subproblems.

One of the fundamental design ideas of the framework is to allow reusing and extending different components of the framework. For example, the same preference information can be utilized to construct several different scalarized subproblems, and each of those subproblems can be solved with the same single objective optimization algorithm, provided that the algorithm is suitable for the type of problem being solved. Similarly, the modular design allows the utilization of different metamodeling approaches when dealing with computationally demanding problems. We have also taken into account the iterative nature of interactive methods, where the overall structure allows us to share different user interface components between different methods.

The existing components included in the framework are already suitable for developing and experimenting with interactive multiobjective optimization methods. We have released a web application utilizing the framework at https://desdeo.it.jyu.fi/. In addition to a user interface, the application includes interactive multiobjective optimization methods and a set of sample problems as well as links to the source code of the framework.

In this talk, we describe how new methods can be implemented within the framework (by utilizing the components available). We also show how different interactive methods can be utilized for solving a multiobjective problem connected to the framework. This means that different methods can be conveniently used to solve the same problem, and it is also possible to change the method used during the solution process, if the decision maker so desires. One can, for example, apply a different method in the learning and decision phases.

We also describe the future developments planned for the DESDEO framework, such as graphical components for visualizing obtained results, a
framework for comparing different methods with each other, new tools aimed at computationally demanding optimization problems and approaches for data driven decision support applying interactive methods.

4 - Collaborative management of ecosystem services in Natural Parks

Marina Segura, Universitat Politècnica de València, Spain
masema@upvnet.upv.es

Concepción Maroto, Universitat Politècnica de València, Spain
cmaroto@eio.upv.es

Concepción Ginestar, Universitat Politècnica de València, Spain
cginesta@upvnet.upv.es

Valerie Belton, University of Strathclyde, United Kingdom
val.belton@strath.ac.uk

Inmaculada Marqués, Universitat Politècnica de València, Spain
imarques@esp.upv.es

Management of protected areas has been mainly focusing on conservation and recreation objectives. Nevertheless, the governance of Natural Parks has evolved in order to involve stakeholders, as well as to include other ecosystem services, defined as the benefits that people obtain from ecosystems. Previous research has pointed out that there is a great number of decision support systems to manage provisioning services from forests, in particular for wood, which is a market service, but there is a lack of tools to manage non-market services, such as climate regulation, clean air or flooding control.

The objectives of this paper are to select and prioritize projects, as well as to develop new indicators based on the main functions of ecosystems to classify the territory inside protected areas. Both purposes take into account the ecosystem services provided and the social preferences in order to implement a collaborative decision making by involving the points of view of stakeholders. This problem has been solved in a forest Natural Park of a Mediterranean Region. In this case study the ecosystem services are the criteria on which the collaborative decision making is based and which have been identified by the stakeholders previously.

Analytic Hierarchy Process (AHP) is the most applied multiple criteria approach in natural resource management, in particular, when stakeholders’ preferences should be elicited, mainly to obtain the weights of criteria needed in other approaches. This method presents good properties, such as an inconsistency measure of judgements and a robust procedure for obtaining the preferences of a group of people through the geometric mean in order to aggregate the individual preferences. If the judgements of all group members are consistent, the aggregated preferences are always consistent, which is very relevant for collaborative decision making. This approach is also easy to understand and can be implemented in the Excel spreadsheet.

In practice, it is not advisable to use a multicriteria method that allows selecting for example a project in which very good production services were able to compensate some others with unacceptable performances, such as environmental services. Thus, PROMETHEE, as an outranking method, is proposed to prioritize projects and classify areas according to their ecosystem services performance. In short, PROMETHEE needs the weights of criteria (obtained by AHP in this case study), which represent the priorities of ecosystem services according to stakeholders’ preferences, as well as indicators to measure the performance of alternatives (projects or areas) for every ecosystem service. This method compares every pair of alternatives for each criterion and assigns a preference value, taking into account the size of the difference in their behaviour. In this way, it removes the scale effect when the ecosystem services are measured in different units. By applying PROMETHEE, based on quantitative and qualitative data, new indicators for each main group of relevant ecosystem services is obtained. That is production, maintenance and direct to citizens services. In addition, this approach provides information about the conflicts between criteria and allows sensitivity analysis to check the impact of the weights on the solution.

When applying AHP in order to elicit stakeholders’ preferences, it is difficult to complete pairwise comparisons in a consistent way, especially for people without expertise or training in this technique. Therefore, it is important to have a graphic tool, which allow answering the survey of the pair comparisons
easily, obtaining the inconsistency index online and facilitating the revision of their answers. This case study provides a friendly implementation with macros in Excel, which enables the users to elicit and then revise their judgments when their inconsistency index is not acceptable, increasing a lot the percentage of consistent surveys.

Firstly, we have implemented AHP in Excel in order to perform the pairwise comparisons in a graphical and friendly way by non-expert users. Secondly, when a person completed the questionnaire, the results are shown numerically and graphically together with the Inconsistency Index of judgements. If Inconsistency Index is not acceptable for decision making, the application allows revising judgements. Thirdly, the Excel application aggregates judgements from a group of people by geometric mean in order to derive priorities for collaborative management. In this study PROMETHEE is applied by using D-Sight software, although we will also provide its implementation in Excel for illustrative purposes.

Finally, our Excel application based on AHP facilitates obtaining consistent individual preferences, carries out inconsistency analysis and then shows the results by stakeholders’ groups and global results, saving time and costs. PROMETHEE enables to select and prioritize projects and generates indicators to classify areas of the territory according to their main ecosystem services. These indicators are shown in graphs, which are simple for every decision maker, stakeholder and citizen to understand, providing relevant information for decision making in the collaborative management of Natural Parks.

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**TUE -3-INV-DMS4130**

Invited Session: Constructive Preference Learning in MCDA I (Kadzinski, Slovinski)

Tuesday 13:30 - 15:10 - Room DMS4130

Chair: Milosz Kadziński

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1 - Heuristics for selecting pair-wise elicitation questions in multiple criteria choice problems

Milosz Kadziński, Poznan University of Technology, Poland

milosz.kadzinski@cs.put.poznan.pl

Krzysztof Ciomek, Poznan University of Technology, Poland

k.ciomek@gmail.com

Tommi Tervonen, Evidera Ltd., Finland

Tommi.Tervonen@evidera.com

We present a set of heuristic approaches for selecting pair-wise elicitation questions in an interactive process for multiple criteria choice problems. Our heuristics aim at minimizing the number of question-answer iterations leading to the univocal recommendation of the Decision Maker's (DM's) most preferred alternative. To identify the myopically best question at a given stage of interaction, the proposed approaches ask the DM to compare a pair of alternatives that contributes to the greatest reduction of uncertainty with respect to the indication of the best alternative by all compatible value functions. This uncertainty is measured either in terms of the number of potentially optimal alternatives, or the entropy of first rank acceptabilities, while assuming different a priori unknown probabilities of the DM's answers. We discuss results from extensive experiments on artificially generated and real-world decision problems. Depending on the complexity of the considered problem instances, we either perform a comprehensive analysis of the question-answer interaction trees constructed by the heuristics, or traverse their paths randomly by simulating a numerous set of decision policies. We demonstrate that the greatest benefits from using our questioning procedures can be observed for problems involving numerous alternatives and few criteria, and when the applied piece-wise linear value functions consist of a small number of characteristic points. The study allows us to identify two approaches that perform well in the average or the least advantageous elicitation scenario.

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2 - Heuristics for selecting assignment-based elicitation questions in threshold-based value-driven multiple criteria sorting

Krzysztof Ciomek, Institute of Computing Science, Poznań University of Technology, Poland

k.ciomek@gmail.com

Milosz Kadziński, Poznan University of Technology, Poland

milosz.kadzinski@cs.put.poznan.pl
We consider an interactive preference elicitation process for multiple criteria sorting. The assumed classification model is composed of an additive value function and a vector of thresholds separating the pre-defined and ordered classes. We introduce a set of heuristic procedures for selecting -- in each stage of interaction -- an alternative that the Decision Maker (DM) should assign to its desired class. The proposed procedures aim at minimizing the number of alternatives that should be critically judged by the DM until the recommendation arrived with all compatible classification models is decisive enough.

To identify the best assignment-based question, we evaluate each candidate alternative in terms of either an ambiguity in its possible assignments at the current stage of interaction or its potential contribution to the reduction of uncertainty in the assignments for all alternatives once the question is answered by the DM. The accounted uncertainty measures build on the possible and necessary assignments as well as stochastic class acceptabilities and assignment-based pair-wise outranking indices.

The proposed heuristics are experimentally tested on problems involving artificially generated and real-world data. We show that competitive results can be obtained with the procedures that select the next question based on the analysis of current results as compared to the procedures looking ahead the next stage which takes significantly more time. The greatest benefits of using our heuristics can be observed for problems with few classes and criteria, numerous alternatives, and inflexible marginal value functions. In the basic scenario, we continue the elicitation process until each alternative is precisely assigned to some class, but we also demonstrate the impact of terminating it once the uncertainty in the recommended assignment is vastly reduced though not nullified. Moreover, we discuss how the performance of heuristics deteriorates when they do not consider all alternatives as potential candidates for the next question and when the DM refuses to evaluate the first alternative indicated by the heuristic.

3 - Accounting for information diffusion to enhance stability in the inferred preference models
Mohammad Ghaderi, ESADE Business School, Spain
mohammad.ghaderi@esade.edu
Francisco Ruiz, BarcelonaTech, Spain
francisco.javier.ruiz@upc.edu
Nuria Agell, ESADE Business School, Spain
nuria.agell@esade.edu
Milosz Kadziński, Poznan University of Technology, Poland
Milosz.Kadzinski@cs.put.poznan.pl

Preference disaggregation approach in multiple criteria decision aiding offers powerful tools to better understand preferences of consumers. These techniques mainly focus on the indirect preference information (a set of pairwise comparisons for instance) that is supplied by the decision maker, and estimate a value function that is compatible with the decision maker’s choices.

We argue that choices of a consumer, on the other hand, is greatly influenced by the preferences of the other consumers through the interaction and information sharing in the media and social networks. We provide a framework for estimating preference model of a consumer by considering his/her choices, as well as preferences of the other consumers from the same network. We claim that accounting for preferences of the other consumers will enhance the stability in the inferred preference model for a consumer. We conduct an extensive simulation analysis to test our framework in various settings characterized by factors such as different levels of heterogeneity in preferences of the members from the same network, as well as the size of the network.

4 - On the effectiveness of debiasing overprecision in probabilistic estimates of multiple impacts
Valentina Ferretti, London School of Economics and Political Science, United Kingdom
V.Ferretti@lse.ac.uk
Sale Guney, USC, USA
sguney@usc.edu
Gilberto Montibeller, University of Loughborough, United Kingdom
G.Montibeller@lboro.ac.uk
Detlof von Winterfeldt, University of Southern California, USA
detlof@aol.com

The appraisal of complex policies often involves alternatives that have uncertain impacts, such as in health, counter-terrorism, or urban planning. Many of
these impacts are hard to estimate, because of the lack of conclusive data, few reliable predictive models, or conflicting evidence. In these cases, decision analysts often use expert judgment to quantify uncertain impacts. One of the most pervasive cognitive biases in those judgments is overconfidence, which leads to overprecision in the estimates provided by experts. In this paper we report on our findings in assessing the effectiveness of best practices to debias overconfidence in probabilistic estimation of impacts. We tested the use of counterfactuals, hypothetical bets, and automatic stretching of ranges in three experiments where subjects were providing estimates for general knowledge questions. Our findings confirmed results from previous research, which showed the pervasiveness and stickiness of this bias. But it also indicated that more intrusive treatments, such as automatic stretching, are more effective than those merely requiring introspection (e.g. counterfactuals).

TUE-3-CON-DMS4140
Contributed Session
Tuesday 13:30 - 15:10 - Room DMS4140
Session: Uncertainty, Stochastic I
Chair: Sarah Ben Amor

1 - Data-driven multiple criteria analysis of human life satisfaction
Dong-Ling Xu, Decision and Cognitive Sciences Research Centre, the University of Manchester, United Kingdom
L.Xu@mbs.ac.uk
Jian-Bo Yang, Decision and Cognitive Sciences Research Centre, The University of Manchester, United Kingdom
Jian-Bo.Yang@Manchester.ac.uk
Lin Yang, London School of Economics and Political Science, United Kingdom
L.Yang10@lse.ac.uk

Human life satisfaction is related to many factors or criteria, in particular income, education and health. While there are theories that explain the interrela**relationship** between human life satisfaction and these criteria, it is of interest to analyse such interrelation as well as interdependence among these criteria using large datasets. In this paper, a Maximum Likelihood Evidential Reasoning (MLER) framework is introduced as a data analysis tool and applied to analyse the British Household Panel Survey data, in order to generate panoramic insights into how these criteria such as income and education interact with each other in shaping people’s feelings towards life satisfaction. The paper is also intended to show how the contributions of various levels of income and education to people’s life satisfaction can be estimated by developing an optimisation model in the framework of MLER.

2 - Min-max-min and min-max-max scalarization for multi-objective robust combinatorial optimization problems
Lisa Thom, University of Goettingen, Institute for Numerical and Applied Mathematics, Germany
l.thom@math.uni-goettingen.de
Marie Schmidt, Erasmus University Rotterdam, Rotterdam School of Management, Netherlands
schmidt2@rsm.nl
Anita Schöbel, Georg-August University Goettingen, Germany
schoebel@math.uni-goettingen.de

When applying optimization techniques to real-world problems, one often encounters the difficulty, that not all parameters are known in advance. Robust optimization is one way to handle these uncertainties, without having to assume any information on probability distributions. Single-objective robust optimization has become popular during the last decades, but the first generalizations to multiple objectives have been introduced only a few years ago. Since then, the new field of multi-objective robust optimization has gained more and more attention in the community.

The (single-objective) concept of min-max robust optimization aims to find a solution that minimizes the objective function in the worst case. One generalization to multi-objective optimization, which we call point-based min-max robust efficiency, was first introduced by Kuroiwa and Lee (2012). They consider the worst case in each objective independently, which results in a deterministic multi-objective problem with bottleneck objective functions, called the robust counterpart. To find solutions to this problem, common scalarization methods can be used.
A second generalization of min-max robust optimality for multiple objectives has been developed by Ehrgott et al. (2014). They look at the outcome set of a solution under every scenario and compare these sets to each other to find so-called set-based min-max robust efficient solutions. To find these solutions, they also develop two scalarization methods, based on methods for deterministic problems (weighted sum and epsilon constraint scalarization). They show that none of their methods is capable to find all set-based min-max robust efficient solutions even in simple cases.

In this talk we introduce two new scalarization methods for multi-objective uncertain problems: min-max-min and min-max-max scalarization. Here, we only optimize over the objective function with minimal respectively maximal value. For deterministic problems the latter one reduces to a min-max problem and is known as max-order scalarization. We show, that solutions for the min-max-min and min-max-max scalarization are (weakly) set-based min-max robust efficient and that solutions for the min-max-max scalarization are even (weakly) point-based min-max robust efficient. Furthermore, we show that the min-max-min scalarization approach provides new possibilities for finding set-based min-max robust efficient solutions: With this approach we can find solutions, that are neither found with help of the multi-objective weighted sum nor the epsilon constraint scalarization method.

We also show connections to other robustness concepts. A scalarization method is useful if it can be implemented efficiently. We show that this can be done for the case of multi-objective combinatorial optimization problems with cardinality-constrained uncertainty in the objective function. Cardinality-constrained uncertainty (also called bounded, banded or budgeted uncertainty) was first introduced by Bertsimas and Sim (2003) for single-objective optimization. They propose to only consider scenarios where at most a bounded number of elements differ from their expected cost. This leads to less conservative solutions that are of high practical use. We extend this concept to multi-objective optimization by restricting the number of deviations from the expected costs over all objectives and elements.

For this uncertainty concept, we develop a mixed-integer linear programming (MILP) formulation for the min-max-min scalarization. We first show that, in contrast to single-objective cardinality constrained uncertainty, by relaxing and dualizing the max-part we get a MILP that provides only an upper bound on the optimal objective value, but is not equivalent to the original problem. However, we can show the equivalence of the max-part to a k-min problem which finally gives us a MILP formulation for the min-max-min scalarization.

### 3 - An evidential reasoning approach based on attribute reliability and risk attitude

Chao Fu, Hefei University of Technology, China
wls_fuchao@163.com

In multiple attribute decision analysis (MADA), attribute weight is an important concept, which attracts much attention. The weight of an attribute is used to characterize how the performance on the attribute affects the overall performance in comparison with other attributes under consideration. The meaning, effect, application requirements, and verification criterion of attribute weight in MADA are clear in literature. This does not, however, mean that the weight of an attribute alone is surely capable of giving a complete picture about what roles the attribute plays in MADA. For example, the ability of the performance on an attribute to correctly profile the overall performance may not be completely represented by the weight of the attribute. This brings forth another important concept in connection with an attribute apart from the weight of the attribute, called the reliability of the attribute. Meanwhile, of particular importance is the risk attitude of a decision maker in decision making. The risk attitudes of the decision maker influence how he or she makes decisions when facing uncertain outcomes. Although risk attitudes of a decision maker have been analyzed in existing studies, they are not linked with attribute reliability in MADA, as it is a new concept.

To address the new concept of attribute reliability and link it with the risk attitudes of a decision maker, we propose a new evidential reasoning (ER) approach, which is a type of multi-attribute utility function method for MADA. We use two examples to explain the linkage between the risk attitudes of a decision maker and attribute reliability.
maker and the degree to which the individual assessment on an attribute profiles the overall assessment, or attribute reliability. Note that the change in attribute reliability rather than individual assessment is used to reflect the influence of the risk attitudes of a decision maker on decisions made. Under the conditions, on the basis of the best (or positive ideal) individual assessment on an attribute, the combinational reliability of the attribute with the consideration of the risk aversion of a decision maker is defined. The combinational reliability of an attribute is further used to define its estimation, which is profiled by the similarity between the individual assessment and the aggregated assessment generated by combining individual assessments on each attribute together with the weights and the combinational reliabilities of attributes using the ER rule. An optimization model is then constructed to minimize the maximum difference between the combinational attribute reliability and its estimation, by which the combinational reliability of each attribute can be generated. Conversely, on the basis of the worst (or negative ideal) individual assessment on an attribute, the combinational reliability of the attribute with the consideration of the risk proneness of a decision maker is defined. Its estimation is similarly defined and used to construct an optimization model to minimize the maximum difference between the combinational attribute reliability and its estimation in order to generate the combinational reliability of each attribute. When the risk attitude of a decision maker is identified, within the post-optimal solution space of the constructed optimization model with the consideration of his or her risk attitude, two optimization models are then developed to generate the minimum and maximum expected utilities of each alternative. The expected utilities are further used to generate solutions to MADA problems by depending on decision rules adopted. A material supplier selection problem is analyzed by the new ER approach to demonstrate the generation of attribute reliabilities and the process of finding solutions to MADA problems with attribute reliabilities and the risk attitudes of a decision maker taken into account.

4 - SMAA: A comprehensive literature review on methodologies and applications

Renata Pelissari, Methodist University of Piracicaba, Brazil
renatapelissari@gmail.com
Maria Celia de Oliveira, Mackenzie Presbyterian University, Brazil
marolivei@unimep.br
Sarah Ben Amor, University of Ottawa, Canada
BenAmor@telfer.uottawa.ca
André Luiz Helleno, UNIMEP, Brazil
alhelleno@unimep.br

Multi-criteria decision making (MCDM) has been one of the very fast growing areas of Operational Research (OR), in regard to designing mathematical and computational tools for supporting the subjective evaluation of performance criteria by decision-makers. In recent years, several MCDM methods have been proposed to deal with uncertain data. The Stochastic Multicriteria Acceptability Analysis (SMAA) is one of the most recent MCDM methods that handles uncertainty and imprecision on criteria measurements and preferences. Significant amount of articles about SMAA has been published in the past few years showing the importance of the topic. The purpose of this paper is to conduct a systematic literature review on methodologies and applications of SMAA. Besides it aims at providing recommendations on which SMAA method to use in different MCDM contexts by defining a SMAA framework. In 2007, Tervonen and Figueira have presented a study on methodologies and applications based on SMAA entitled ‘A survey on stochastic multi-criteria acceptability analysis methods’. However, this study was based on 25 papers that had been published until then. Now, ten years later, we can find about 84 papers, a large increase that justifies the development of a new review study. Our review methodology is based on both qualitative and quantitative content analysis and consists of five (5) steps which are i) Papers selection, ii) categorization of the papers selected, iii) Description of the methods and applications, iv) Statistical analysis and iv) SMAA framework proposal. Several on-line databases were used to search and select articles related to the SMAA method, including Scopus, Web of Science, Emerald, Science Direct and World Scientific Net. 84 papers were selected. The selected papers, published in 51 international journals
since 1998, year in which the SMAA has come up, were analyzed and categorized into 3 categories: (1) theoretical study versus applied work, (2) type of used SMAA method and (3) integration with other techniques or MCDA methods. For the purpose of this study, theoretical articles are those that, although also presenting some application, have as an objective the development of a new model or technique related to SMAA or the alteration, improvement and extension of an existing SMAA model. On the other hand, the papers considered as an application are studies that aim at solving a problem by applying an existing SMAA based model. As a result, forty-two papers out of the papers reviewed (50%) were considered as theoretical papers and they were categorized into two types of studies: (i) variants of the SMAA method and (ii) techniques and software to operate SMAA methods. The others forty-two papers (50%) were considered as applied studies. The applications of SMAA methods were numerous. After a detailed study on the applications, the papers were categorized into 11 application areas, which were found to be similar in some respects. Environment Management was considered as the most popular topic in SMAA applications with 15 papers (43%). Business, Strategic and Financial Management was the second most popular topic with 8 papers. The mostly used methods have been the traditional SMAA (53% of selected papers) and the variants SMAA-2 (24%), SMAA-O (11%) and SMAA-TRI (6%). The other variants, such as SMAA-3, SMAA-AHP, SMAA-PROMETHEE, have been only associated with theoretical papers. After describing and discussing each of the selected articles according to the classification set out above, some statistical information about the articles is presented. Articles are analyzed regarding publication year, country of author affiliation, main authors and publication journal. The European Journal of Operation Research is the journal with most publications, with 22 papers (26%), and 81% of these papers are theoretical. The most productive authors are from Finland, with 38% of all selected papers. R. Lahdelma is the main author and he has contributed with 32 papers, followed by P. Salminen (24 papers) and T. Tervonen (12 papers).

Lastly, we provide a framework which is an extension of the framework proposed by Tervonen 2007, based on the surveyed 84 papers, with recommendations on which SMAA method to use in different MCDM contexts and application areas. The review and the framework serve as a guide to decision-makers, researchers and those interested in how to use a particular SMAA method. We hope this paper will be a valuable reference of SMAA methods for researchers and practitioners in the field of MCDA, and SMAA in particular, and that it helps to promote the future of SMAA research.

TUE-3-CON-DMS4170
Contributed Session
Tuesday 13:30 - 15:10 - Room DMS4170
Session: Multi Objective Optimization
Chair: Martin Josef Geiger

1 - Partial Scalarization for Multi Objective Problems with Integer Variables
Pascal Halffmann, University of Koblenz-Landau, Germany
halffmann@uni-koblenz.de
Stefan Ruzika, University of Koblenz-Landau, Germany
ruzika@uni-koblenz.de
Florian Gensheimer, University of Koblenz-Landau, Germany
gensheimer@uni-koblenz.de
David Willems, University of Koblenz-Landau, Germany
davidwillems@uni-koblenz.de
Tobias Dietz, University of Koblenz-Landau, Germany
tdietz@uni-koblenz.de
Anthony Przybylski, University of Nantes, France
anthony.przybylski@univ-nantes.fr

Scalarization techniques such as weighted sum and epsilon-constraint are well-known and commonly used methods in order to find optimal solutions for multi objective (mixed-) integer linear problems. Recent advances for bi objective problems gave rise to bi objective algorithms with a competitive running time. In this work, we propose a technique, defined as partial scalarization, that transforms a multi objective problem into a lower dimensional but still multi objective problem. This allows us to get more
nondominated points per scalarization in the exchange of a higher computation time, which is still competitive regarding the mentioned advances. Especially, we focus on a partial scalarization method that generalizes the weighted sum scalarization. We give both theoretical and practical results on notions like nondominance, supported and unsupported solutions. Furthermore, we present a geometric interpretation of our technique and regarding the mixed-integer case, interdependencies between the Pareto fronts for the original and scalarized problem. Based on these results, we propose a new algorithm to find extreme supported nondominated solutions for tri objective problems. For this method, we provide an analysis of the algorithm and both its correctness and running time. Further presented work includes partial scalarization for other techniques such as epsilon constraint, Tchebychev-type methods and hybrid methods."

2 - vOptSolver, a "get and run" solver of multiobjective linear optimization problems built on Julia and JuMP
Xavier Gandibleux, University of Nantes, France
Xavier.Gandibleux@univ-nantes.fr
Gauthier Soleilhac, Université de Nantes, France
Flavien Lucas, University of Nantes, France
Flavien.Lucas@univ-nantes.fr
Anthony Przybylski, University of Nantes, France
anthony.przybylski@univ-nantes.fr
Stefan Ruzika, University of Koblenz-Landau, Germany
ruzika@uni-koblenz.de
Pascal Halffmann, University of Koblenz-Landau, Germany
halffmann@uni-koblenz.de

Again too often, solvers dedicated to multiobjective optimization require an advanced skill in informatics, already for the installation needs, but also to formalize the problem, to provide a numerical instance, to solve it, and to collect the results. Developed as software prototype within the context of the ANR-DFG research project, vOptSolver aims to provide a free, open source and "user-friendly" solver of multiobjective linear optimization problems for multi-objective versions of mixed integer linear programs (MOMILP), but also linear programs (MOLP), discrete programs (MOIP) and combinatorial problems (MOCO).

To achieve this goal, vOptSolver is designed and implemented using (1) Julia language (https://julialang.org/) -a high-level, high-performance programming language for numerical computing- and (2) JuMP (Julia for mathematical optimization) -a domain-specific modeling language for mathematical optimization embedded in Julia-. Julia will be familiar for the practitioners of Matlab, Fortran, Python, C/C++, Pascal, etc. And JuMP will be familiar for the practitioners of GMP, AMPL, MPL, GAMS, etc. JuMP allows the use of several open-source and commercial optimization software packages (such as GLPK and CPLEX), and switch from one to another easily.

vOptSolver handles structured and non structured MOP, and integrates ad-hoc and generic algorithms to solving respectively these two classes of MOP. The algorithms integrated are implemented in the following languages: Julia, C, or C++ (the integration of C/C++, as well Fortran is very easy as it has been conceived in the specifications of the Julia language). vOptSolver is platform independent, it has been validated today on macOS and Linux-Ubuntu. It can be also used in JuliaBox (https://juliabox.com/), the cloud version of Julia available from any internet browser.

The first release of vOptSolver (https://gitlab.univ-nantes.fr/vopt1/vOptSolver) is ready and it will be opened to the public for the conference time. In this talk, the current version of vOptSolver will be presented, examples will illustrate its use. This version integrates exact algorithms for computing a complete set of non-dominated points for structured and non-structured optimization problems with two objectives. In the future, approximated algorithms (metaheuristics and approximation algorithms) will be also integrated. As open source software, all contributors are welcomed for improvements of existing components, and to integrate new components into the solver.

3 - Multi-Objective Optimization Repository (MOrepo)
Lars Relund Nielsen, Aarhus University, Denmark
larsrn@econ.au.dk
Kim Allan Andersen, Aarhus University, Denmark
The MCDM society would benefit from a joint multi-objective (MO) optimization repository with MO optimization instances and algorithms. In this talk, we will present our ideas about the open-source Multi-Objective Optimization Repository (MOrepo) and give an overview over current features and progress. The talk is also open for discussion about feature requests etc.

4 - Multi-Objective Vehicle Routing with Inventory Constraints
Martin Josef Geiger, University of the Federal Armed Forces Hamburg, Germany
m.j.geiger@hsu-hh.de

The talk describes our findings for a complex practical vehicle routing problem, taken from the recent VeRoLog Solver Challenge 2017. Here, a multi-period vehicle routing problem with pickups and deliveries must be solved while considering multiple aspects, namely the minimization of the routes, the number of vehicles, and the number of products delivered and collected from the customers. The problem description stems from a practical case in which testing equipment is delivered to and picked up from (milk) farmers over a longer planning horizon. While the setting of the 2017 Challenge integrates all aspects into a single cost function, our approach decomposes the different criteria and tackles the problem in a multi-objective formulation. For each sub-aspect, such as the scheduling of the orders/ the routing of the vehicles, heuristics are proposed and implemented into a running system. A visual user interface, specifically developed for the problem at hand, depicts the obtained results and allows for a detailed inspection of the routing/scheduling. Experimental investigations show that the coupling of the periods (i.e., the days) is crucial, and that the results obtained from this multi-objective formulation are competitive even for the single-objective case of the VeRoLog Solver Challenge 2017 (which currently is still on-going).

Tuesday, 15:40-17:20
TUE-4-INV-DMS4120
Invited Session: AHP/ANP Theory and Applications in Supply Chain Management and Industrial Engineering I (Karpak, Buyukozkan, Guleryuz)
Tuesday 15:40 - 17:20 - Room DMS4120
Chair: Seyhan Nisel

1 - Prioritization of Factors Affecting Dimensions of Sustainable Supply Chain Management
Gunes Kucukyazici, Okan University, Turkey
gunes.kucukyazici@okan.edu.tr
Sarah Ben Amor, University of Ottawa, Canada
BenAmor@telfer.uottawa.ca
Ilker Topcu, Istanbul Technical University, Turkey
ilker.topcu@itu.edu.tr

A supply chain is a collection of organizations which consists of a firm, suppliers of the firm, customers of the firm, suppliers of the firm’s suppliers, and customers of the firm’s customers. Beamon (1998), Min and Zhou (2002), Kainuma and Tawara (2006), Faisal (2010) and Gold, Seuring and Beske (2010) define a supply chain as all activities, which are relevant to the transformation of forward and backward flow of goods, services and information from sources of materials to end users. Bose and Pal (2012) describe these activities as a regular forward supply chain. Supply chain management (SCM) integrates all internal and external activities of a firm along a supply chain. Since too many organizations are involved as the members in a supply chain, and each one of them has its own objectives; there may be a conflict of interest between the members from time to time, so it is of strategic importance to manage a supply chain as a whole. Seuring (2009) claims the performance of a supply chain to be extremely important as a result of being dependent on the competition power of the weakest actor in the supply chain. Therefore, SCM aims to make sure that each company and the supply chain has a better performance in the long-run (Beamon, 1998; Min and Zhou, 2002; Kainuma and Tawara, 2006; Seuring,
Faisal (2010) and Seuring (2013) claim that SCM is expected to be integrated with sustainable practices, such as recycling or remanufacturing of the products, environmental friendly packaging, waste disposal, etc. Sustainable management of supply chains has gained much attention in a wide variety of industries for all sizes of companies. Sustainability leads companies to the improvement of efficiency and innovation. Faisal (2010) defines sustainability as the combination of human, economic and environmental concerns so as to create an eternal life in the global ecosystem. A sustainable SCM (SSCM) contributes to sustainable development by providing economic, social, and environmental benefits. Clift and Wright (2000), Cruz and Matsypura (2009) and Carter and Easton (2011) claim that poor SSCM performance may result in loss of reputation, since consumers may have environmental pressure on the members due to the increasing importance on the protection of the global ecosystem (Clift and Wright, 2000; Cruz and Matsypura, 2009; Faisal, 2010; Carter and Easton, 2011; Seuring, 2013).

According to Gold, Seuring and Beske (2010) and Carter and Easton (2011), SSCM is related to organizations’ survival in the long-run by generating valuable resources and gaining competitive advantage. Strategic aims of supply chain members should be merged with the goals of the three dimensions of SSCM, which are called as the social, environmental, and economic dimensions (Clift, 2003). The merge will enable the organizations to gain a competitive market position, which will persuade them to continue being a member of the supply chain. Gold, Seuring and Beske (2010) have found the SSCM literature still to be limited in their research (Seuring and Beske, 2010; Carter and Easton, 2011; Gold, Clift, 2003). Seuring (2013) concludes that the social dimension of SSCM is generally too simplified in the literature as a result of the lack of research on social characteristics of the supply chain. The environmental dimension is mainly based on categories assessing the life-cycle of the supply chain, however environmental impacts are not clearly analysed in many studies. The economic dimension is mainly based on cost- or revenue-based approaches. However, there is still a lack of research on the struggle of companies which are trying to put green or sustainable supply chains into practice. In addition to Seuring (2013), Segura and Maroto (2017) suggest developing decision support systems which include a sustainability dimension of suppliers, and which can represent a competitive advantage for many companies.

In order to emphasize the importance of creating synergy and providing better SCM, supply chain research should include multi-objective and multi-criteria decisions. According to Beck and Hofmann (2012), the research fields of Multi-Criteria Decision Making (MCDM) and SCM are both continually expanding, and there is a remarkable increase in the application of MCDM practices in SCM literature over the last six years, which is predicted to continue. Cruz (2008, 2009) has found the MCDM methodology to be applied extensively in the SCM literature. Decision makers’ behaviours, such as profit maximization, emission minimization and risk minimization, have been evaluated by several MCDM techniques. On the other hand, Seuring (2013) and Segura and Maroto (2017) suggest integrating the social and environmental dimensions of SSCM by using multi-objective optimization or AHP (Cruz, 2008; Cruz, 2009; Beck and Hofmann, 2012; Seuring, 2013; Segura and Maroto, 2017).

This study aims to provide contribution to the SSCM literature and decision making literature first by making a research on social, environmental and economic dimensions of SSCM. Secondly, the interrelation of these three dimensions will be determined, and finally the factors affecting these dimensions will be prioritized to build an MCDM framework in prospect.

2 - A Decision Support Model for the Assessment of Consumer Preferences: A Case Study on Coffee House Companies

Gözde Kadioglu, Istanbul Technical University, Turkey
kadioglug@itu.edu.tr
Ilker Topçu, Istanbul Technical University, Turkey
ilker.topcu@itu.edu.tr

Coffee cultivation and trade began on the Arabian Peninsula and spread in Persia, Egypt, Syria, and Turkey by the 16th century. In addition, European people travelled to Near East and coffee reached
Europe as a popular drinking. Turkish people met coffee in 1555. They discovered a new method of drinking coffee: the beans were being roasted over a fire and then slowly cooked with water on the ashes of a charcoal fire. Accordingly, Turkish coffee became popular and regarded as a vital part of Turkish traditional cuisine.

Over the last 20 years, the habits, the priorities, and the diet of consumers have changed dramatically because of the modern life. Accordingly, these changes affected the preferences of consumers at food and beverage industry. Today, coffee is a new market for both national and international brands. Different types of coffee, e.g. instant coffee, have entered in Turkish daily life. Afterwards, international big coffee house companies launched in the market: Gloria Jeans in 1999, Starbucks in 2003, Tchibo in 2006, and Caffè Nero in 2007. In the meantime, a local brand, Kahve Dunyasi, entered into the market in 2004. Nowadays there are many local and global coffee house companies at the market. They have different marketing strategies: take-out existence; traditional tasting; offering beverages, snacks, and desserts; using renewable materials and energy.

Understanding the economic and social factors as well as brand related issues related with these effects will sustain a competitive advantage for the brands in the industry. Therefore coffee house companies should understand the preferences of consumers as well. Assessment of preferences necessitates a multi criteria decision making (MCDM) approach as there are several, conflicting, weighted, and incommensurable factors affecting consumer preferences.

In this study, the assessment of consumer preferences for coffee house companies in Turkey are taken into consideration. As the decision model can be represented as a hierarchy, to analyze it, Analytic Hierarchy Process, one of the most widely used multi-criteria decision method, is utilized.

To determine the most appropriate coffee house company for the customers, first, evaluation criteria affecting customer preferences are identified based on a detailed literature review and expert opinions. The authors come up with a set of main criteria that includes financial aspects, product specifications, service characteristics, coffee shop characteristics, and brand image.

The criteria of the financial aspects are determined as price affordability, availability of customer loyalty programs, and existence of sales promotion. Product variety, having its own products, deliciousness, freshness, and healthiness of the products, and finally the presentation of the products are the criteria that are considered as the product specifications. The attitude of employees toward customers, the type of service (i.e. self-service, service at a single point, specialized service), speed and accuracy of the service, and offering extra food or beverages without charging are the criteria related to the service characteristics. Among the coffee shop characteristics, there exist cleanliness, coffee shop design, relaxing and pleasant music, suitable illumination, beautiful and charming fragrance. Finally, as brand image criteria, brand awareness, fair trade, eco-friendly image, and being desirable among customers are taken into account.

In accordance with iterative steps of AHP, after constructing the hierarchy, the authors pose the customers of coffee house companies pairwise comparison questions to assess the relative priorities of evaluation criteria as well as coffee house companies. Quota sampling is used and graduate students are taken as the target group of the survey. Sixteen students participate the survey.

According to the results, the product specifications is found as the most important main criterion. Besides, the most preferred criterion for the participants of the survey is revealed as healthiness of the products (12.92%), followed by the attitude of employees toward customers (12.34%). On the other hand, the least preferred criterion for the participants is brand image (7.44%). Among alternatives, the most preferred coffee house is found as Caffè Nero (29.57%), followed by Starbucks (28.30%).

The survey results can be generalized by expanding the participant group and interacting with other customer groups of the coffee house companies. As a further study, sensitivity analysis can be conducted and the impact of importance of criteria on alternatives can be explored as a managerial insight. Another research avenue may be comparing and discussing priorities of different groups.

3 - How to Write a Contract with the AHP

Luis Vargas, University of Pittsburgh, USA
lgvargas@pitt.edu
Conflict resolution methodologies have gone through a transformation over the past decades since (a) the economist Kenneth Boulding of the University of Michigan along with the mathematician-biologist Anatol Rapoport, the social psychologist Herbert Kelman and the sociologist Robert Cooley Angell created the Journal of Conflict Resolution in 1957 and the Center for Research in Conflict Resolution in 1959; (b) Johan Galtung, the founder of Peace Research, created a unit within the Institute of Social Research at the University of Oslo in 1960, that later became the International Peace Research Institute Oslo, and he started the Journal of Peace Research in 1964; and (c) John Burton developed a new way of studying conflicts based on problem-solving methodologies such as game theory and organizational behavior. This constituted a paradigm shift in thinking about behavior and conflict in general.

In 1981 the book Getting to YES (Fisher and Ury 1981, Fisher, Ury et al. 1991) revolutionized the way conflicts were looked at. Fisher and Ury introduced the concept of principled negotiation in which the participants are problem solvers. The approach is based on four principles: (1) Separate the people from the problem, (2) Focus on interests not positions, (3) Invent options for mutual gain, and (4) Insist on using objective criteria. However, the approach does not measure the gains and losses of the parties for different options, and hence they may not be able to perceive how fair the proposed solution is to both parties.

In this paper we propose an approach based on the AHP that could be considered an extension of principled negotiation. Principled negotiation looks for fair and equitable solutions to conflicts rather than finding solutions in an environment in which each party considers the other party an adversary. To find fair and equitable solutions one needs to use measurement to determine which options are: (1) best for both parties, and (2) as close as possible to each other in the value provided to the parties.

In the last decade, several studies about ERP systems and softwares have been realized for the purpose of system evaluation and selection, risk assessment, performance analysis, measurement of success and system implementation by using several statistical analysis and multicriteria decision making methodologies. However, there are a limited number of studies concerning user satisfaction for an ERP system or software. The purpose of this study is to develop a novel integrated user satisfaction model for an ERP software. In the first stage, factors affecting user satisfaction were determined by carrying out a survey study. Then these factors were analysed by multivariate statistical analysis for the purpose of determining the dependency. In the second stage, considering the findings of the first stage, Analytic Network Process (ANP) was used in order to evaluate and prioritize the factors affecting user satisfaction. The results showed that the proposed model can effectively be applied for measuring level of satisfaction of the end-users and for getting feedback for the future development of the software.

4 - An Integrated Approach for Developing a User Satisfaction Model for an Enterprise Resource Planning (ERP) Software
Birsen Karpak, Youngstown State University, USA
bkarpak@ysu.edu
Seyhan Nisel, School of Business Administration, Istanbul University, Turkey

Today, many companies and organizations have been investing in Enterprise Resource Planning (ERP) systems and softwares in order to stand out among business competitors and to keep up to date with the changes in the industry. ERP programs, which are capable to manage all the business processes in an integrated structure, provide companies competitive advantage, and also enhance their corporate capabilities and productivity.

TUE-4-INV-DMS4130
Invited Session: Constructive Preference Learning in MCDA II (Kadzinski, Slowinski)
Tuesday 15:40 - 17:20 - Room DMS4130
Chair: Roman Slowinski

1 - Using Dominance-based Rough Set Approach in Interactive Evolutionary Multiobjective Optimization
Salvatore Corrente, University of Catania, Italy
We present a new interactive procedure for evolutionary multiobjective optimization involving decision rule preference model in the search of the best compromise solution. During the decision phase of the procedure, the Decision Maker (DM) is periodically asked to select in the current population of solutions those ones that she considers relatively good. Using the Dominance-based Rough Set Approach (DRSA) this information is represented in terms of “if ..., then ...” decision rules which represent DM’s preferences. They are used within an Evolutionary Multiobjective Optimization (EMO) with the aim of converging towards the part of the Pareto front containing the best compromise solution. Beside guiding the search process, the decision rules can be read as arguments explaining the DM’s choices. An experimental analysis demonstrates the effectiveness of the proposed procedure.

2 - Multiobjective Reinforcement Learning Considering Preference of a Decision Maker
Tomohiro Hayashida, Hiroshima University, Japan
hayashida@hiroshima-u.ac.jp
Ichiro Nishizaki, Hiroshima University, Japan
nishizaki@hiroshima-u.ac.jp
Shinya Sekizaki, Hiroshima University, Japan
seki@hiroshima-u.ac.jp
Hiroyuki Yamamoto, Hiroshima University, Japan
b133649@hiroshima-u.ac.jp

Reinforcement learning is a machine learning method suitable for acquiring optimal measures in a sequential environment, that is, it can be said that it is a machine learning system that can obtain if-then rule corresponding to a continuously changing environment that interacts with a decision making entity such as an artificial agent. An agent using reinforcement learning can choose the appropriate actions based on the value function of the states or the actions. Scalarization such that predetermined weights are assigned to these objectives is a popular process for multiobjective optimization problems. However, it is difficult to determine appropriate weights. Drugan (2015) has proposed decision method for multiobjective optimization using the hypervolume which is calculated based on Pareto frontier, and he has indicated the computability and usability of the decision method. However, in a multiobjective environment, the states or the actions are evaluated in multidimensional, thus, a set of appropriate actions on the Pareto frontier can be obtained, though a single action cannot be reasonably selected, because the weight determination method of hypervolume is not always appropriate. This study suggests a multiobjective reinforcement learning considering the preference of a decision maker based on the multiobjective optimization method using hypervolume for the sequential environments. The weights of the objectives are evaluated by human-computer interactive technique.

3 - New Machine Learning Algorithms for Multiple Criteria Classification Method PROAFTN
Nabil Belacel, National Research Council, Canada
nabil.belacel@nrc.gc.ca

The main objective of this presentation is to give an overview of new approaches for learning multicriteria classification methods. I will show how the integration of two major techniques from machine learning and multicriteria decision analysis can solve the classification problems. I will focus on the application of machine learning and metaheuristics for outranking PROAFTN method. PROAFTN method belongs to the class of supervised learning algorithms and enables to determine the fuzzy resemblance relations from pessimistic and optimistic intervals. Some of the applications of the developed method to different areas including bioinformatics, intrusion detection and telecommunication will be also presented.

4 - Qualitative Multiple Criteria Models with Cycles: A Preliminary Study with Method DEX
Marko Bohanec, Jožef Stefan Institute, Slovenia
marko.bohanec@ijs.si
Multiple criteria models, which are aimed at the evaluation of alternatives, usually employ a simple input-output structure: they consist of multiple input criteria (or attributes) that represent some quality measures of the evaluated alternatives, and have one, or rarely more, output attributes that represent the overall assessments of these alternatives. In addition, some methods, such as the AHP (Analytic Hierarch Process), DEX (Decision EXPert), and MCHP (Multi-Criteria Hierarchical Process), internally organize model variables into a tree or hierarchy. In both cases, such a structure corresponds to a directed graph without cycles. Consequently, the evaluation of alternatives boils down to a simple step-by-step aggregation of input values into the overall assessments of these alternatives; there are no loops or cycles involved in the process. However, there is a notable exception to this principle among MCDM methods: the ANP (Analytic Network Process). The ANP is a more general form of the AHP which explicitly addresses the inter-dependence among the criteria and the alternatives. In general, the ANP model has a network structure and does contain cycles. Cycles are also very common in areas other than MCDM and can be found in all kinds of dynamic models, where they represent various aspects of inter-relations and feedback loops between elements of the modelled system.

In this study, we investigate possible ways of introducing cycles into DEX models. DEX is a qualitative multi-criteria method, in which all criteria are represented by qualitative (symbolic, verbal) attributes. The attributes are structured into a hierarchy, and the evaluation of alternatives is governed by decision rules. The method DEX is implemented in the software DEXi (http://kt.ijs.si/MarkoBohanec/dexi.html). The introduction of cycles to DEX models, and thus turning DEX models into some kind of dynamic models, has been motivated by practical needs observed in some problem areas. For instance, in agriculture, an evaluation of cropping systems may contain strong cyclic elements in cases where some future outcome (e.g., soil quality, weed quantity) depends on today’s decisions and today’s state of that same quality or quantity. Similar cyclic relationships also occur whenever two or more attributes mutually influence each other, requiring a network rather than hierarchical structure. Having a possibility to explicitly model network relationships in DEX would considerably extend the applicability of the method. Furthermore, as we will show in the presentation, DEX models with cycles would be strong enough to simulate the Conway’s Game of Life (CGL), which is in turn known to be Turing complete, i.e., theoretically as powerful as any computer with unlimited memory and no time constraints. In other words, the introduction of cycles to DEX models would substantially boost their computational power.

So far, we have conducted a preliminary study aimed at showing that an introduction of cycles to DEX is indeed possible. In the presentation, we will first justify the need to introduce cycles in DEX models. As this introduction comes with a price, for instance, disrupting the natural distinction between inputs and outputs in MCDA models and considerably affecting the evaluation procedure, we will also highlight some problems and obstacles associated with the approach. The theoretical potential of the approach will be demonstrated on the case of CGL, and its practical applicability will be shown on a selected realistic example: evaluation of employees. The DEX and DEX with Cycles’ models will be compared with corresponding models developed by the AHP and ANP, respectively.
Mariana Nagy, Faculty of Exact Sciences, "Aurel Vlaicu" University of Arad, Romania
mariana.nagy@uav.ro
Miguel Casquilho, Instituto Superior Técnico, CERENA
mcasquilho@tecnico.ulisboa.pt

The landscape and the factors affecting the operations of the Pharmaceutical Supply Chains (Pharm-SC) with specific concern on medicines manufacturing disruptions are described, so as the main topics on Medicines Shortages within the homonymous COST Action (CA1505) are introduced. The paper deals with MCDM tools to address the Suppliers Selection Problem and curb shortages, by applying robust optimization models for the Pharm-SC design and planning, dealing with uncertainty and risk, and coping with computational issues. Definitions and goals are updated, adjusting the Pharm-SC approaches and models, in a way to enlighten the costing and performance indexes of shortages. Relevant topics are also integrated, namely: the provisions and procurement disruptions, the clinical-pharmacological needs; and the shortages impact. Thereafter, a real situation for deciding on the supplier bid within a pharmaceutical SC is addressed. On considering the referred criteria set, the decisional matrix is built and three different methods with the associated software are applied: i) the simple additive model; ii) the ELECTRE model; iii) the "e" Fuzzy model; and iv) the TOPSIS model. A hierarchic process directed to the top of alternatives is built, and the decisional process ends by assigning one of the bidder supplier companies. As the resulting hierarchies are only slightly different, a comparative analysis that addresses the deviations amplitude, the best alternative, and the least preferred alternative is performed.

2 - Selecting Local Public Transport what with Universal Design Principles
Fatma Ateş, Necmettin Erbakan University, Turkey
fatma.ates@konya.edu.tr
Metin Dağdeviren, Gazi University, Turkey
mdagdeviren@gazi.edu.tr

People are in need of transportation to reach individual requirements such as sheltering, nourishment, education and occupation. It is not ignored that transportation provides access to social life and its amenities. The idea of universal design (UD) in local public transport expresses the accessibility of as many passengers as possible. UD also called real life or lifespan design makes things usable for all ages and abilities including not only people with physical disabilities or child-elder but also people with cognitive disabilities and having physical characteristic such as tall-short, obese-frail, pregnant, left-handled without the need for rearrangement. This study proposes an integrated criterion to utilize local public transport by allowing for UD principles and technical elements. Fuzzy VIKOR method overcomes the problem of differentiation and conflict in opinion and preferences in case of multiple decision makers is employed to evaluate alternatives. Alternatives are tried and evaluated using 7-point Likert scale by public transport passengers are 10-68 aged, all sex and abilities. Inherently conflicting criteria are evaluated and weighted by experts have at least 5 years relevant work experience and conflicting idea each other. The study findings ranking alternatives remark problem of public transport passengers and provide awareness for improving the quality of public transport.

3 - Some methods and algorithms for constructing smart city rankings
Marisa Luisa Martinez-Cespedes, Computer Science School, Universidad Politecnica de Madrid, Spain
marisa.martinez@philips.com
Esther Dopazo, Computer Science School, Universidad Politecnica de Madrid, Spain
edopazo@fi.upm.es

The problem of rank a set of cities according to their smart city nature can be classified as a multi-criteria decision making problem, due to the multidimensional character of the smart city concept. It involves to aggregate data from several ranked lists according to multiple criteria in order to produce a synthetic ranking which compares city performance. There is a growing interest about city-rankings since they are recognized as instruments for assessing attractiveness of urban regions, policy evaluation, benchmarking, management decision-making, etc. We address the rank aggregation problem and present some methods and algorithms to be applied in the smart city context.
Methods are based on deriving priority vectors of cities from outranking matrices that collect relevance information from input data. Furthermore, fuzzy preference relation properties and procedures similar to Google’s PageRank algorithm are considered. Using data provided by the IESE Cities in motion index 2016 (CIMI 2016) study, the application of the proposed methods is illustrated and contrasted.

4 - SISTI: a methodological approach to reduce uncertainty and to structure a complex and new decision problem in a “good” model

Maria Franca Norese, DIGEP - Politecnico di Torino, Italy
mariafranca.norese@polito.it

A decision aid process should be the result of an interaction between analysts, decision makers and stakeholders, but decision aiding is sometimes required when the problem situation is new and a formal decision system does not exist. Its role becomes that of facilitating the Intelligence phase of a decision process, even when interaction with the actors of the decision process is from necessity very limited. In some situations, a decision problem is perceived, recognized and/or proposed by people (or organisations) that are only marginally connected to the problem, when a decision process has not yet been activated and a formal decision system does not exist. Its role becomes that of facilitating the Intelligence phase of a decision process, even when interaction with the actors of the decision process is from necessity very limited. In some situations, a decision problem is perceived, recognized and/or proposed by people (or organisations) that are only marginally connected to the problem, when a decision process has not yet been activated and a formal decision system, with well-defined rules, clear constraints, roles and relations, does not exist. In these situations, formal and informal documents may be present, and they could be used to understand the organizational context and define the decision problem.

When structured data are not available, the need for some actions, in relation to the new and not sufficiently defined problem, generates a request for investigation, data acquisition and elaboration. These activities are often not clearly defined and not aimed at a specific goal, because of a total lack of knowledge and specific competences, and their developments and results cannot be oriented and controlled because decision authority and accountability have not yet been foreseen. When data and possible indicators are easily accessible in institutional databases their use in active policy making processes is often characterized by a very high multiplicity of items/indicators, as a result of the general belief that only a large amount of data can produce information. An integration of these data becomes difficult for at least two reasons: because a logical structure of the problem and its information needs had not been generated before, and a synthesis of so different and “incomparable” elements, from different sources, is not so easy.

Multicriteria decision aid (MCDA) adopts a constructivist approach in which model, concepts and procedures are not envisaged to reflect a well-defined reality, existing independently of the actors, but as a communication and reflection tool. A constructivist approach cannot be applied easily in situations in which only some actors perceive the nature and importance of the decision problem, and in which there are not sufficient conditions to activate a process and decision system. An MCDA process can also be developed in these situations, and oriented towards facilitating a pre-decisional analysis and understanding phase. Effective interaction with the few potentially involved actors and a preliminary study, which should include multicriteria (MC) modelling, application of MC methods and result analysis and validation, become useful to clarify a complex new situation, reduce uncertainty, structure the relevant complexity elements in a “good” model of the problem situation and propose a consistent approach for the later phases of a decision process. This kind of study may be described as a simulated decision aid approach, because the decision process and the system are in a pre-decisional phase, and may also be described as a stimulating approach, because the study is developed together with the few actors that perceive the need to understand and propose structured elements for later phases of a still not activated decision process.

This SImulated and STImulating (SISTI) approach integrates modelling and validation of each modelling result as the study is developed. The main results are: a conceptual model, which includes all the main aspects, requirements and uncertainties associated with the problem situation in a structured form; a formal model, specifically oriented towards the method that has to be adopted; the result of the method application to a formal model, and the application of this result to a real or virtual component of a specific problem situation. All the used data and each of these results have to be validated in order to demonstrate the consistency of each step in SISTI, and the quality of
each answer to the problem difficulties, or to underline the need to re-act and improve the modelling process results.

The points of view of the potential actors have to be gathered when SISTI is adopted. A set of possible decisions have to be identified, or elaborated, and an MC model has to be structured and formalized in analytical terms, to evaluate each alternative decision in relation to the actors’ points of view. The different level of importance of each criterion can be set, without decision makers, in relation to some specific scenarios.

If there is time to carry out SISTI, the study needs great and full attention to the specific incremental nature of the associated learning process. A cyclic application of a method and an analysis of its results, at each iteration, can facilitate and control the development of this process. Each temporary result, in the various steps of the process, produces new knowledge and may include elements that stimulate a marginal or structural change to the model, or a problem formulation improvement or reformulation. Each method application implies a clear definition of all the inputs, and a critical analysis of each result, in order to use this knowledge to converge towards a final model, or to formulate new treatment hypotheses for the problem situation.

SISTI has been applied to some problem situations (in relation to flood management and resilience activation) which suffered from an innovative and difficult modeling process and to aid some decision makers in Public Administrations, in contexts of law implementation monitoring, pharmacological trial and airport services innovation. Elements from some of these applications will be proposed to describe this methodological approach.

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**SISTI**

Contributed Session
Tuesday 15:40 - 17:20 - Room DMS4170
Session: Industry and Business Applications
Chair: Lorraine Gardiner

**1 - Occupational health and safety of seafarers: exploring the network between the constituents of ISM Code and OHSAS 18001: 2007**

Sait Gül, Beykent University, Turkey
saitgul@beykent.edu.tr

Özgür Kabak, Istanbul Technical University, Turkey
kabak@itu.edu.tr

Ilker Topcu, Istanbul Technical University, Turkey
ilker.topcu@itu.edu.tr

International business environment enforces all the companies from different industries to implement a bundle of management systems about quality, safety or environment. Besides, the global authorities establish regulations that the companies should comply with. In the shipping industry, competition and legislation create a pressure on shipping companies and they reflect it to their seafarers. Many companies prefer downsizing on equipment and crewing levels to cope with this enforcement. Therefore, seafarers have to overcome the shorter turnarounds, sleep withdrawal, hard physical workloads, longer working hours, etc. The psychological features of seafaring such as separation from families, loneliness, living with multinational fellows can create an additional stress on them. The possible undesirable results of this stressfulness at sea are not only about the individual health and job performance, but concerning the general safety and well-being of others.

One of the most important management systems is about occupational health and safety (OHS). An OHS management system (OHSMS) is a set of people, resources and policies interacting in an organized way to reduce damage and losses generated in processes in the workplace. Although there are many OHSMS in shipping industry such as International Convention for the Safety of Life at Sea (SOLAS), International Maritime Dangerous Goods (IMDG) Code and Maritime Labour Convention, the fundamental international standard for OHS at sea is International Safety Management (ISM) Code which was published by International Maritime Organization (IMO).

ISM Code is mandatory for all type of ships. It basically establishes an international standard for OHS management in ships and pollution prevention. Furthermore, this Code enforced the shipping companies to redesign their management systems and their daily routines for achieving its requirements. The first part of ISM Code consists of implementation concerns while the second part includes certification and verification procedures. There are 12 clauses in the “implementation” part: general, safety and environmental protection policy, company
responsibilities and authority, designated person(s), master’s responsibility and authority, resources and personnel, development of plans for shipboard operations, emergency preparedness, reports and analysis of nonconformities and accidents, maintenance of the ship and equipment, documentation, company verification and evaluation. “Certification” part has 4 clauses: certification and periodical verification, interim certification, verification and forms of certificates.

According to the literature, the current implementation of ISM Code cannot appropriately provide the expected enhancement in OHS management outcomes because actual implementation of the Code generates a larger bureaucracy within the shipping industry, and inclines reduction of implementation activities at the operational level. Occupational Health and Safety Management System (OHSAS 18001: 2007) is a good alternative to strengthen the implementation performance of ISM Code. For all the industries, OHSAS is the general and dominant OHSMS that specifies requirements for building the safety at workplaces. It aims to promote a systematic and structured management understanding to provide sustainable safety for workers. It has 6 main requirements: general, OHS policy, planning, implementation and operation, checking and management review. The planning section has 3 subsections: hazard identification, risk assessment and determining factors; legal and other requirements and objectives and programs. The fourth section (implementation and operation) includes 6 constituents: resources, roles, responsibilities, accountability and authority; competence, training and awareness; communication, participation and consultation; documentation; control of documents; operational control and emergency preparedness and response. Finally, there are five subsections in checking requirements: performance measurement and monitoring; evaluation of compliance; incident investigation, nonconformity, corrective and preventive action; control of records and internal audit.

An integrated ISM-OHSAS system can potentially establish a more powerful and practical OHS management system for shipping industry by redesigning safety procedures in the workplace of ships. While the deficiencies of ISM Code are remedied by this integration, the constituents of OHSAS can be specialized for the shipping companies. The clauses of ISM Code and the requirements of OHSAS can be integrated by Multiple Criteria Decision Making techniques.

The aim of this study is the exploration of the linkages between above mentioned two OHSMSs, namely ISM and OHSAS. The relations between their elements will be determined by DEMATEL (Decision Making Trial and Evaluation Laboratory) method, which is a decision making approach based on the evaluations of expert judgments. It utilizes the experts’ pairwise comparisons of the elements in terms of the impact level of the relations. The comparison scale consists of four levels: 3 for strong, 2 for moderate, 1 for weak and 0 for no relation. Considering the comparisons, direct-relation, normalized direct-relation and total relation matrixes are built, respectively. The method’s “Prominence” and “Relation” computations give the causal map of the elements which can be accepted as the network linking the constituents of ISM and OHSAS.

This study is prepared as a first step of a more general decision support model for evaluating a ship’s OHS performance level. The network built in this study will be used as the criteria of a ship’s OHS qualification. Further researches will propose a weighting method for these criteria and an MCDM method to evaluate the ship’s OHS management preparedness and qualification level.

2 - Designing an Optimal Hydrostatic Transmission System between the Conflicting Objectives of Minimal Effort and Maximum Availability

Lena C. Altherr, Chair of Fluid Systems, TU Darmstadt, Germany
lena.altherr@fst.tu-darmstadt.de

Peter F. Pelz, Chair of Fluid Systems, TU Darmstadt, Germany
peter.pelz@fst.tu-darmstadt.de

We are a chair at the mechanical engineering faculty of the Technical University of Darmstadt. We use Mixed Integer Programming for the optimal design of technical systems, like pump or ventilation systems. In this work, we design a hydrostatic transmission system which consists of a piston, that is operated via a system
of different valves. The system designer's task is to choose the type and the amount of valves and how to connect them.

In times of planned obsolescence the demand for sustainability keeps growing. Ideally, a technical system is highly reliable, without failures and down times due to fast wear out of single components. Dispersion of load between multiple components can increase a system’s reliability and thus its availability. However, this also results in higher investment costs and additional efforts due to higher complexity. Given a load profile and the resulting wear of the components, it is often unclear which system structure is the best trade off. For the engineering application example of the hydrostatic transmission system, we balance effort and availability and calculate the pareto front.”

3 - Agricultural Supply Chains Prioritization for Development of Affected Areas by the Colombian Conflict

Eduar Fernando Aguirre Gonzalez, UNIVERSIDAD DEL VALLE, Colombia
eduar.f.aguirre@correounivalle.edu.co

Pablo Cesar Manyoma Velasquez, UNIVERSIDAD DEL VALLE, Colombia
pablo.manyoma@correounivalle.edu.co

Colombia has been immersed in an armed conflict for more than six decades, leaving fatal consequences for the country's development, especially in rural areas. Nowadays, the Colombian government has been working to reestablish state control through a strategic approach that integrates security, fight against drug trafficking, and economic and social development [1]. For this research, Cauca department’s northern zone is our study object since it has become one of the most affected by this armed conflict [2]. This zone is an area of great importance with approximately 400,000 inhabitants distributed in 13 small towns. Due to their strategic location, there is abundant natural resources, a great cultural richness represented in the ethnic diversity, peasant communities, religious traditions, urban zones but a low human development index [1]. The sub region has more than 356,164 hectares of arable land in different thermal floors, which allows planting of different products throughout the year. Among identified products that can be converted into production chains are Cassava, Mango, Pineapple, Gulupa, Avocado, Cocoa, Banana, Mandarin, and Lulo, among others.

To restore control in the most affected areas by the conflict, the Colombian government has been working through various institutions, such as Ministry of Agriculture and Rural Development, and Socio-Entrepreneurial Strengthening for Competitiveness, promoting the agro industrial development of small producers.

Likewise, there are international initiatives such as prioritization municipalities by the United Nations, where it considers that nine of these municipalities are key to working post-conflict in Colombia [7]. In addition, the United States Government, through USAID (United States Agency International Development), supports different efforts to promote economic prosperity and improve the living conditions of the most vulnerable populations [8].

The use of schemes that linkage producers and agribusinesses are necessaries to evolution of agro-food chains and suppose a greater vertical and horizontal coordination. This action implies to go from "market push" schemes to “market-pulled” strategies to driven aimed at meeting the needs of demand, in order to increase the producers capacity that it is adapt continuous changes [4].

In this perspective, productive agro-business approach is a support tool that allows actors from different agro-commercial chains in developing countries to insert or expand their participation in the market in a sustainable and competitive way. The concept of productive agribusiness refers to the set of actors involved in the whole process of production, transformation, marketing and distribution of similar goods. The stages and activities presents an agro-chain, developed in an environment of institutional and private services that directly influence its operation and competitiveness [4].

Decision problems are increasingly complex and usually involve several criteria. Precisely, main force of the multi-criteria analysis is its ability to treat issues that have different situations in conflict, allowing an integrated evaluation of problem in question [5].

In this research, Analytical Hierarchical Process (AHP) is used to weight decision criteria and obtain their relative weight. Then, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is
developed to define a ranking of agro-alimentary chains that may represent the geographical area previously defined. Dimensions Technical, Economic, Social and Environmental are most used in this type of decisions. Table 1 shows the relationship of the dimension with a selected criterion, through the measurement of the performance of that criterion.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Selected criterion</th>
<th>Measurement unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td>Output</td>
<td>ton/ ha</td>
</tr>
<tr>
<td>Economic</td>
<td>Price</td>
<td>US$ /k</td>
</tr>
<tr>
<td>Social</td>
<td>Affiliations</td>
<td>Number/ agrochains</td>
</tr>
<tr>
<td>Environmental</td>
<td>Impact</td>
<td>Expert opinion</td>
</tr>
</tbody>
</table>

**TABLE 1. Dimensions and criteria proposed**

- Output (C1): Shows relationship between production and harvested area. It must be maximized.
- Affiliations (C3): Organizations formally identified and operating around the product. It is maximization. It must be maximized.
- Environmental impact (C4): It is rated from 1 to 5, depending on the negative impact. It must be minimized.

<table>
<thead>
<tr>
<th>Relative Importance</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18.53%</td>
<td>35.49%</td>
<td>38.84%</td>
<td>7.14%</td>
</tr>
</tbody>
</table>

Table 2. Relative importance of the criteria

Through different reports and questions made to experts (Cauca Chamber of Commerce, USAID, Agronet, Asohofruco, among others), it was possible to establish that the most promising products for the establishment of a food chain are: Lulo (A1), Cocoa (A2), Plantain (A3), Pineapple (A4), Avocado (A5) When developing the TOPSIS, initial matrix presents the following data:

<table>
<thead>
<tr>
<th>Alternative</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lulo</td>
<td>10.00</td>
<td>0.62</td>
<td>6.00</td>
<td>3.00</td>
</tr>
<tr>
<td>Cocoa</td>
<td>0.50</td>
<td>1.44</td>
<td>4.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Plantain</td>
<td>7.00</td>
<td>0.31</td>
<td>6.00</td>
<td>3.00</td>
</tr>
<tr>
<td>Pineapple</td>
<td>45.00</td>
<td>0.30</td>
<td>4.00</td>
<td>5.00</td>
</tr>
</tbody>
</table>

Table 3. Decisional matrix

After performing all steps proposed by TOPSIS, from the normalization of decision matrix, to finding distances to ideal and anti-ideal solution, we obtain the relative proximity and ranking of possible alternatives (see table 4).

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Ri</th>
<th>Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.556</td>
<td>Cocoa</td>
</tr>
<tr>
<td>2</td>
<td>0.423</td>
<td>Pineapple</td>
</tr>
<tr>
<td>3</td>
<td>0.379</td>
<td>Lulo</td>
</tr>
<tr>
<td>4</td>
<td>0.291</td>
<td>Plantain</td>
</tr>
<tr>
<td>5</td>
<td>0.238</td>
<td>Avocado</td>
</tr>
</tbody>
</table>

Table 4. Ranking alternatives evaluated.

Alternative 2 corresponds to the option of Cocoa as a viable product to start development of a basic agricultural supply chain. The main purpose of this work is to assign scarce public and international cooperation resources according with the needs of the region. This instance is a first approximation of work that must be done in near future to obtain that prioritization.

4 - Multiple Criteria Decision Making Methods in Practice

Lorraine Gardiner, Dalton State College, USA
lgardiner@daltonstate.edu

The paper provides a bibliography survey of documented applications of multiple criteria decision making (MCDM) methods over the last decade. The survey includes peer-reviewed articles that describe the actual use of one or more MCDM methods by decision makers in an organization. The author summarizes results by general problem area, organizational type, decision level and MCDM method category. Additionally, possible trends in MCDM method usage over the time period are examined.

Tuesday, 17:20-18:50

TUE-5-POS-DMSLOBBY

Poster Session:
Due to increasing environmental regulation and customers demanding environmentally friendly products, organizations are forced to adopt sustainable manufacturing practices by implementing clean technology (cleantec) in order to produce green products. By producing environmentally friendly products, organizations can also get qualitative and quantitative benefits such as lowering energy and material cost, remain competitive in market and meeting governmental environmental policies effectively and efficiently. Significant amount of articles addressing sustainability perspective in manufacturing has been published in the past few years shows the importance of the topic. Therefore, the purpose of this paper is to conduct a systematic literature review in the application of multi-criteria decision making (MCDM) methods in sustainable manufacturing. Our review methodology is based on both qualitative and quantitative content analysis and consists of four (4) steps which are i) Material Collection, ii) Descriptive Analysis, iii) Category Selection, and iv) Material Evaluation. This paper is an attempt to answer research questions which are a) Which MCDM methods have frequently been applied in sustainable manufacturing? b) What was the purpose of study that frequently applied MCDM methods in sustainable manufacturing? c) Which sector frequently applied MCDM methods and considered sustainable manufacturing perspective? d) Which decision making technique have been used frequently? A total of 110 articles, published between 2009 to 2016, met the criteria sets in research methodology, and in line with research questions has been selected and reviewed. These articles are then analyzed and categorized in terms of (a) MCDM Methods application in sustainable manufacturing perspective (social, environmental, and economical), b) MCDM methods application and purpose of study, c) MCDM methods application in different sectors, and d) MCDM methods based on DM techniques (AHP, Fuzzy, TOPSIS, etc.) The review serves as a guide to decision makers, managers, and those interested in how to use a particular MCDM method in sustainable manufacturing at different perspective and in which sector / application area used which method specifically. At the end, some recent trends and future research directions are also highlighted.

Despite the importance that sustainability has acquired in recent decades, there is a serious lack of objective tools to assess the level of environmental care taken by organizations. This is especially important in Health Care Organizations due to the consumption of resources, a result of continuity in provision of service and the number of patients, care and non-care staff, and other visitors, who are present daily. They are also the only organizations which generate all the classes of waste, from waste without risk to radioactive waste. Most Spanish hospitals are undergoing a process of reduction in resources such as water and energy. It would, then, be very useful to have an objective, easy to use tool to control the level of environmental responsibility of a Health Care Organization over time. This research describes a system of multicriteria assessment designed by the Fuzzy Technique for Order Preference by Similarity to Ideal Situation (FTOPSIS) to assess environmental responsibility in a Health Care Organization over time. The following criteria were used: annual water consumption, annual energy consumption, environmental accidents and incidents, biodiversity, activities which promote and distribute environmental issues, training and cooperation on environmental matters, noise inside and outside the building, waste production, and green...
purchasing. All the criteria and/or subcriteria were assessed according to the number of admissions or annual services provided by the Health Care Organization. In this way, the results can be compared over time for an Organization, and are also comparable between different Health Care Organizations. The model has been applied to a Spanish Health Care Organization over three consecutive years.

3 - Optimization of maintenance strategy in critical systems

*Professor Carnero, University of Castilla-La Mancha, Spain*

carmen.carnero@uclm.es

*Andrés Gómez, University of Castilla-La Mancha, Spain*

andres.gomez@uclm.es

The choice of a maintenance strategy for use in systems on which other care systems depend, such as medical equipment in contact with the patient, plays an essential role in achieving availability, quality and safety in the care services of a Health Care Organization. All of this will, in turn, affect the quality of care experienced by patients. Despite its importance, however, there is a lack of suitable models providing tools for optimizing maintenance decisions in critical hospital systems. This research describes a multicriteria model created with the Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH) approach, which optimizes decisions about the maintenance strategy to be used in electrical and lighting systems in the operating theatres of a Health Care Organization. These systems are considered critical due to the impact on hospital activity, because of the critical subsystems dependent on them, and the potential risk to the patient of a fault. Among the decision criteria considered for the electrical supply system in theatres are costs in use, investment costs, level of acceptance by staff, and quality of care. Among the alternatives considered are corrective and preventive maintenance, corrective and preventive maintenance with availability of spare bulbs, and corrective and preventive maintenance with spare bulbs and a spare control panel. The criteria used in the lighting systems for operating theatres are investment costs, maintenance costs, level of acceptance by staff, safety of workers and impact on hospital activity. The alternatives considered are corrective and preventive maintenance, corrective and preventive maintenance plus an uninterruptible power supply (UPS) in active reserve, corrective and preventive maintenance plus an immediately available spare panel, and corrective and preventive maintenance plus a UPS in active reserve, plus an immediately available spare panel. To assess the criteria quality of care and impact on hospital activity, both systems were modelled using continuous time Markov chains. This required information about the failure and repair rates over the life cycle of these systems in a Health Care Organization. These models were created with the assistance of a multi-disciplinary decision group comprising managers responsible for maintenance of facilities, maintenance of medical equipment, safety, environment, admissions programming, clinical services and the supervisors of medical areas of the Hospital. The model described, therefore, as well as choosing the best combination of maintenance policies, also considered the possibility of including different typologies of spares, contributing to an improvement in the availability of the systems. This would, in turn, lead to improvements in quality of care as experienced by the client, by reducing the cancellation of theatre activity and the serious risks to the patient in the case of a fault in the system while the care service is being carried out. Finally, the real implications that applying the best alternative found by the model would have for availability and quality of care are set out.

4 - Parallelisation for biobjective minimum cost network flow problems

*Andrea Raith, The University of Auckland, New Zealand*

a.raith@auckland.ac.nz

Minimum cost network flow (MCF) problems are widely applied in network optimization. Here we consider MCF problems with two objective functions: Biobjective minimum cost network flow (BMCF) problems. BMCF problems with continuous variables can be solved by identifying all efficient extreme supported solutions. To solve integer versions of BMCF often a Two Phase approach is applied where in Phase 1, again extreme supported solutions must be found. Phase 2 is dedicated to identifying a complete
Phase 2 is solved using ranking of k-best flows until it can be guaranteed that a complete set of the remaining (non-extreme and non-supported) efficient solutions is found. This can be achieved by ranking flows in search areas that are defined by two neighbouring extreme supported non-dominated points in Phase 1. Therefore search areas are independent and the search in Phase 2 can be conducted in parallel.

The effects of the parallelisation are tested on a variety of different BMCF test problem instances.

5 - Does the MCDM process attempt to reflect reality or is just a simplification which produces questionable results?

Nolberto Munier, Valencia Polytechnic University, Spain
nolmunier@yahoo.com
Eloy Hontoria, Cartagena University, Spain
eloy.hontoria@upct.es
Fernando Jimenez, INGENIO - Universidad Politecnica de Valencia, Spain
fjimenez@ingenio.upv.es

Nowadays MCDM problems are “solved” using a myriad of different models standing alone or in combination with other models; only advances, and some debatable, have been made in new tools regarding uncertainty data. Amongst the plethora of models based on different assumptions the most usual are AHP, ANP, ELECTRE, PROMETHEE, TOPSIS and VIKOR, and that accounts for thousands of projects, especially AHP and ANP, which are by far the most popular.

In general, the mathematical foundation of these models is unobjectionable, however, many researchers are concerned about why two different models, applied to the same problem using the same data give different result. In addition it is really amazing to read expressions from some practitioners in the sense that model xxx was successfully applied to solve a problem, without taking in consideration that said assertion has no basis whatsoever due to the simple fact that nobody knows which the authentic and true result is. Once we asked a defender of a model why he could affirm that it was successful, his response was that because the procedure followed; however, it is precisely the procedure that is under suspicion, not the mathematics.

An examination of the literature shows that for a couple of decades no important new contributions has been made, and practically all models resort to the same old procedure of writing a decision matrix, using weights to quantify criteria importance and use those criteria to evaluate alternatives.

In our opinion, we MCDM practitioners and researchers are working on a false and oscillating platform, and placidly accepting it, although we know that the actual MCDM process is far from being reliable. Most researchers are aware that the MCDM as done at present is flawed, that results are debatable because the process does not considered reality, however they continue using it, and what is worse, no solutions are proposed.

For this reason we believe that our obligation as researchers involves trying to change the paradigm followed by actual models, whatever they can be. We have to revamp the system, because as docents, we are lecturing our students with methods that some of us believe are not correct.

We are not defending or supporting any particular model as well as not criticising any of them. In my opinion, those of us that are interested in this endeavour must be free to propose a new model or improve an existing one.

As researchers we believe that we have the obligation to start looking for ways to improve the process. For starters we think that we should be able to point out the deficiencies of the process or the aspects of reality that we think must be taken into account. It follows our modest contribution by a list of aspects that we deem should be considered. Its purpose is to be used as a guide, which of course can be modified, added, reduced, amended, improved, or flatly rejected in part or in its totality.
Strategic multi-agent adversarial non-cooperative decision making conflicts have ill-structured decision making situations. Agents, individually and collectively, have conflicting goals and constraints. Alternatives are not predetermined, and the conflicts’ states dynamically change over time. Agents’ preferences are usually not clear, hard to quantify and validate. This makes these conflicts’ outcomes, and their agents’ options/moves, rely heavily on rich contextual knowledge of the involved agents’ goals, constraints, emotions, attitudes, external realities and the interrelationships among all.

Constrained Rationality is a formal qualitative value-driven enterprise knowledge management modelling framework, with a robust multi-agent decision support methodological approach. The framework provides a systemic process to model and analyze strategic multi-agent adversarial competitive decision making conflicts. It offers mechanisms to model the agents’ individual goals and constraints and the relationships among these goals and constraints, including the level of importance the agents put on each goal, the level of constraining power each constraint have on each goal, and how the goals and constraints interrelationships affect each other. It also offers a process by which alternatives are elicited to operationalize these goals, and the conflict’s states are defined. The framework’s robust fuzzy reasoning mechanisms are utilized to calculate the agents’ cardinal and ordinal preferences over their alternatives, and the conflict’s states, using the amount of achievement the agents’ strategic goals can harness from each alternative/state, given the collective goals, constraints, priorities, emotions and attitudes, the agents have.

We discuss the theory of moves and counter-moves of decision making agents that Constrained Rationality proposes for strategic multi-agent non-cooperative conflicts and define four different stability and equilibrium solution concepts to analyze such conflicts. These concepts will guide the stability analysis of each of the conflict’s states, for each of the conflict’s players. Then, we define the stability strength for each solution concept, the strength of the equilibrium that could result from it, and how to calculate each.

To demonstrate the effectiveness of the framework, and its proposed modelling and reasoning mechanisms, we model and analyze the Cuban Missile Crisis. The crisis stands as one of the most important strategic political conflicts in the history of mankind. History offers no parallel to the thirteen days (16-28) of October 1962, when the two rivalry post-second-world-war superpowers, the United States and the Soviet Union, were at the verge of starting the first nuclear war in history. We present the Constrained Rationality’s goals and constraints models for both players, and how the framework helps generate the players’ alternatives, define the conflict’s states, and elicit the players’ preferences over these states. We show how the players’ unilateral moves and counter-moves are defined, and how the stabilities’ strengths for all the conflict’s states are calculated. At the end, we conclude by showing how the Constrained Rationality models and analysis, including the calculated strength of the equilibrium states, provide a clear cut answer to: why each move the players took in reality, during the conflict, was the most rational step to take; and why the sequence of events observed in reality was the most rational sequence of events for the conflict to take.
or approach which allows to distinguish appropriate and inappropriate polypharmacy (Patterson et al., 2012).

This research work proposes an original approach for classifying polypharmacy using multi-criteria sorting methods. The approach is applied on a clinical case reflecting a very common situation in the management of a polymedicated elderly patients. The clinical case is a 73-year-old man with type 2 diabetes, heart failure and chronic obstructive pulmonary disease.

The assessment of the quality of the polypharmacy is carried out in four steps. Step 1 focuses on collecting data and information on the risk, benefit and impact on the quality of life for a list of drugs potentially involved in the treatment of the clinical case. An e-Delphi method will allow experts/clinicians to express their opinions on drugs. Clinicians will evaluate drugs on a 5-point Likert scale and may hesitate between two or more responses while evaluating their risks, benefits and impacts on quality of life. Step 2 consists of aggregating these evaluations to obtain, for each drug, a multi-criteria evaluation vector representing the collective opinion of the consulted clinicians. Step 3 focuses on the interactions, especially major ones, between the drugs, and on evaluating each polypharmacy considering these interactions. Finally in step 4, the ELECTRE Tri-C and ELECTRE Tri methods are used for the evaluation of the polypharmacy and its assignment to one of the three categories: inappropriate, more or less appropriate or appropriate.

References

8 - A note on the detection of outliers in a binary outranking relation

Jean Rosenfeld, ULB, Belgium
Jean.Rosenfeld@ulb.ac.be
Yves De Smet, ulb, Belgium
yves.de.smet@ulb.ac.be
Jean-Philippe Hubinont, ulb, Belgium
jhubinon@ulb.ac.be

Outliers is a concept widely studied in statistics (i). It is defined as an element rare and dissimilar to the majority of the other elements of a dataset (ii). However, the concept of outlier in a multi-criteria context has not been defined yet in the literature. Due to the asymmetrical relations between alternatives, its definition should differ from the classical one. For instance, rank reversal (iii) is a phenomenon appearing with outranking methods. It consists of withdrawing or adding an alternative to the dataset that results in a slightly or totally different ranking. It appears that an alternative might not be dissimilar to the others regarding the evaluations but might involve a higher amount of rank reversal than the other alternatives. Therefore, the definition has to be refined. In this study we first attempt to provide a proper definition of the multi-criteria outliers. Second, we address the problem of outliers detection in a binary outranking relation. We propose a model based on the distance introduced by De Smet and Montano (iv) and extend it to different samplings of the set of alternatives (which are used as a comparison basis). This leads to study the distribution of distance values. The presence of outliers is detected by the identification of bi-modal distributions. We focus on the ELECTRE I method (v) and illustrate this on examples based on the Human Development Index, the Environmental Performance Index (where artificial outliers are added) and the Shanghai Ranking of World Universities.

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8 - A note on the detection of outliers in a binary outranking relation

Jean Rosenfeld, ULB, Belgium
Jean.Rosenfeld@ulb.ac.be
Yves De Smet, ulb, Belgium
yves.de.smet@ulb.ac.be
Jean-Philippe Hubinont, ulb, Belgium
jhubinon@ulb.ac.be
9 - Using Big Data Predictive Analytics to Improve Inside Sales Performance
Alhassan Ohiomah, Telfer School of Management, University of Ottawa, Canada
aohio100@uottawa.ca
Morad Benyoucef, Telfer School of Management, University of Ottawa, Canada
benyoucef@Telfer.uOttawa.ca
Pavel Andreev, Telfer School of Management, University of Ottawa, Canada
andreev@Telfer.uOttawa.ca
David Hood, VanillaSoft, Canada
david@vanillasoft.com

Organizations are investing in predictive analytics to help unravel insights from their big data for better decision-making, future predictions, and to gain competitive advantage. However, little research to date has explored the implications for inside sales of the rise of predictive analytics. In this research, we collect transactional data from 53 inside sales organizations, consisting of over 50 million records and 50 variables. Our preliminary analyses provide data-driven insights for inside sales that can help optimize lead management calling activities. Our findings also suggest that inside sales transactional data alone do not offer enough data-driven insights for inside sales. Therefore, we suggest that direct information about target prospects is needed to improve prediction for inside sales.

10 - Emergency Preparedness and Response Planning: A Value-Based Indicators Approach
Alexander Chung, University of Ottawa, Canada
alexander.chung@uottawa.ca
Colleen Mercer Clarke, University of Waterloo, Canada
mercerclarke@rogers.com
Daniel E. Lane, University of Ottawa, Canada
dlane@uottawa.ca

Coastal communities are adversely affected by the changing climate, as evidenced by the increasing frequency and severity of storms. The need to be proactive, to adapt, and to reduce disaster impacts, is evident. Five characteristics of emergency preparedness and response are defined: (1) the existence of emergency plans, (2) awareness of procedures and training in emergency assistance, (3) resources and emergency services, (4) community engagement, communication and collaboration, and (5) monitoring and forecasting of the emergency events. This paper presents an indexed score of coastal community preparedness based on a framework of quantitative indicators that address the characteristics of preparedness and response to emergency events. The indicators are arranged in a weighted hierarchy of characteristics and their attributes to evaluate the preparedness and response capabilities of coastal communities. Scoring metrics and weights are assigned to each indicator using utility functions and pair-wise comparison methods from the analytic hierarchy process (AHP) respectively. The framework is applied to the coastal communities associated with the C-Change International Community University Research Alliance (ICURA) and the results compared. The preparedness index forms the foundation for a gap and sensitivity analysis of community preparedness that coastal communities can use for seeking and directing adaptation strategic planning and funding requests toward preparing and responding to the inevitable next big storm.
During the last 25 years, design science research (DSR) has evolved into one of the accepted ways of conducting research and developing theories within information systems (IS) research community in addition to the quantitative and qualitative research approaches. The foundations of the DSR movement are in the history of the IS discipline itself, which builds on operations management and research, management science, computer science, and engineering studies. The rationale for the movement was to go back to the information technology artifact, constructs, instantiations, methods, and models, and to study them and to develop theories with them versus aspiring to be social scientists. These ideas and methods have later been adopted by others fields like operations management and service research communities among others. This talk will give an overview of design science research, its principal concepts and contemporary research methods used by DSR researchers, but also how the IS community have conceptualized DSR theories and theory development. These concepts and methods are illustrated with examples from my own studies in the area of method development for IS and service design. I hope that the DSR ideas provide a possible theory foundation for modelling research conducted within Management Science in general, and within MCDM in particular.

Wednesday, 10:30-12:10

WED-2-INV-DMS4120
Invited Session: Innovation for Sustainable Development (Schillo, Lopez)
Wednesday 10:30 - 12:10 - Room DMS4120
Chair: Sandra Schillo

1 - Giving future generations a voice: constructing a sustainability viewpoint in transport appraisal
Yannick Cornet, Department of Management Engineering, Technical University of Denmark, Denmark
yancor@transport.dtu.dk
Merrill Jones Barradale, Renewable and Sustainable Energy Institute, University of Colorado, USA
Merrill.J.Barradale@Colorado.EDU
Michael Bruhn Barfod, Department of Management Engineering, Technical University of Denmark, Denmark
mbba@dtu.dk
Robin Hickman, Bartlett School of Planning, University College London, United Kingdom
r.hickman@ucl.ac.uk

Despite the clear need for methods of analysing and comparing transport strategies and measures against a wide range of competing goals, there currently exists no standardized process for appraising transport projects against long-term sustainability objectives, with practices varying widely across countries. Conventional transport appraisal methods, such as cost-benefit analysis (CBA) whereby future impacts are discounted to a fraction of their value, fail to adequately represent the interests of future generations.

In order to give future generations a voice in decisions that will impact them, this paper proposes a dual-approach method for constructing a “sustainability viewpoint” in transport appraisal. To demonstrate our proposed method, the appraisal of HS2 Phase I in the UK is used as a case study. High-speed rail in general and HS2 Phase I in particular provide an excellent opportunity to examine sustainability in the context of transport appraisal, not least because of the uncertainties and long-term effects of such mega-projects. HS2 Phase I is compared with two alternative projects: a high-speed rail alignment following an existing transport corridor; and an extensive upgrade to an existing conventional rail line. The assessment criteria used in this case consist of a comprehensive list of 28 criteria covering direct project impacts (10), indirect societal impacts (9), and environmental impacts (9).

Multi-actor multi-criteria analysis (MAMCA) emphasizes the inclusion of multiple viewpoints, not just through the incorporation of multiple criteria but also through the involvement of multiple actors, and thereby opens up the possibility of incorporating sustainability viewpoints into transport appraisal. A sustainability viewpoint (SV) weights criteria with sustainability in mind.

Our dual-approach method for using MAMCA to construct the SV juxtaposes an expert-based SV with a principle-based SV. The former is a bottom-up approach in which sustainability experts (identified on the basis of environment and sustainability-related training and experience) are asked to prioritize criteria
for project assessment. The latter, a top-down approach in which criteria weights are calculated based on sustainability theory, has two variants: one representing “strong sustainability” and the other representing “weak sustainability”.

The two approaches complement each other, providing additional context and robustness through triangulation. Together, these sustainability viewpoints are intended to inform decision-making. For this specific case, we find that all three variants of the sustainability viewpoint - though not identical in their prioritizations of criteria - nonetheless result in similar project preferences (an upgrade of the existing rail network over construction of a new high-speed rail line). It has also been noted that HS2 performs best if considered from the perspective of the official project goals only, and it is found that these goals match the criteria prioritized by government transport professionals.

We also compare the viewpoint of sustainability experts with that of other transport professionals. An important result of this paper is that training and experience matter. Those transport professionals whose education or work included environmental analysis prioritized project impacts differently from those who did not.

We conclude by arguing for the explicit inclusion of a sustainability viewpoint within transport appraisal, on a multi-actor basis. We also recommend hiring more transport planners with sustainability experience into government planning agencies. Finally, we suggest that additional testing of different approaches is needed, along with further research on how sustainability viewpoints should be incorporated into transport planning and decision-making.

2 - MUPOM: A multi-criteria multi-period outranking method for decision-making

Anissa Frini, Université du Québec à Rimouski, Canada
anissa_frink@uqar.ca

Bruno Urli, Université du Québec à Rimouski, Canada
Bruno_Urli@uqar.ca

Sarah Ben Amor, Telfer School of management, Canada
BenAmor@telfer.uottawa.ca

Making decisions in sustainable development context is a complex decision-making problem, for which government departments and agencies are seeking to develop best approaches and innovative methods. This article tries specifically to answer the following request: how can we make sustainable decisions which guarantee a balance between environmental integrity, social equality and economic efficiency and which take into account evaluations of options over the short, medium and long-term in a context of uncertainty. For selecting a best compromise decision in SD context, we should first be aware of the complexity of the decision-making problem. In fact, the decision problem is complex because:

- Economic, social and environmental impacts of alternatives must be considered concurrently in the decision-making process [1]. Each alternative is evaluated according to several conflicting criteria (economic, social and environmental), that could be quantitative or qualitative (e.g. expressed with linguistic variables).

- Each alternative has to be evaluated over short, medium and long-term planning horizons.

- Many players (stakeholders), with different and ultimately conflicting viewpoints, would intervene in the decision.

- Evaluations of each alternative are uncertain and possibly flawed (inaccurate, ambiguous, or incomplete).

- Unforeseen events can occur over time and affect future impacts of the alternatives.

Although sustainable development consists of achieving a balance between the short and the long-term, only a few of the reviewed articles on MCDA use for sustainability (3%) tackles the temporal impact of decisions [2, 3, 4]. The way these papers consider this issue remains limited since they either consider the long-term effects as one criterion among others or they use scenario planning and uncertainty prediction. Long-term consequences are roughly and only qualitatively evaluated.

This article proposes a novel MUlti-criteria multi-Period Outranking Method (MUPOM) which takes into account not only the immediate but also the future consequences of alternatives in order to not compromise future generations. This method will demonstrate how the paradigm behind outranking methods, can be of use in processing the multi-period
aspect of decisions. This new method is then applied in both deterministic and uncertainty contexts to select the best compromise sustainable forest management option, while considering the environmental impacts, the economic benefits and decision-maker preferences.

MUPOM is structured in three steps: multi-criteria aggregation, temporal aggregation and exploitation. First step is multi-criteria aggregation, which consists of aggregating, at each period of the horizon, the criteria based on pairwise comparisons, and concordance-discordance principles. In this paper, the method is illustrated with both outranking methods ELECTRE and PROMETHEE and uncertainty on the data is managed with Monte Carlo simulations.

Second step is temporal aggregation, which consists of aggregating, for each pair of alternatives, the binary relations obtained at each period using the measure of distance between preorders proposed in [5]. Third step is exploitation, which consists of computing the performance of each alternative a_i based on the number of alternatives that are preferred (strictly or weakly) to a_i and those that a_i are preferred (strictly or weakly) to them. Based on this performance, the subset of “best compromise” alternatives is constructed.

References

3 - Innovation for sustainable development: a review of recent tools and indicators for the assessment of environmental impacts in (clean) innovation policy

Fernando J. Díaz Lopez, Netherlands Organisation for Applied Scientific Research TNO, Aruba
fernando.diazlopez@tno.nl
Will McDowall, UCL Institute for Sustainable Resources, United Kingdom
w.mcddowall@ucl.ac.uk
Massimiliano Mazzanti, University of Ferrara, Italy
mzzmsm@unife.it
Roberto Zoboli, Catholic University of the Sacred Heart, Italy
roberto.zoboli@unicatt.it
Carlos Montalvo, Netherlands Organisation for Applied Scientific Research TNO, Netherlands
carlos.montalvo@tno.nl
Michal Miedzinski, UCL Institute for Sustainable Resources, United Kingdom
m.miedzinski@ucl.ac.uk

Clean innovation holds the promise of facilitating the achievement of environmental goals while also supporting economic growth and social welfare. Clean innovation policies aim to stimulate the development and deployment of innovations that reduce environmental pressures compared to a relevant alternative. Such believe if fueled by a naïve belief that more green products and services and by judgements on how and when the diffusion of all sorts of clean innovations will lead to better environmental outcomes. However, the relationship between the policy objective of decoupling economic growth and environmental degradation is not always straightforward (McDowall, Diaz Lopez, et al 2016). Available tools, indicators and methods of innovation and environmental policy hardly ever consider the intrinsic, complex nature, and plausible cause-effect relationship, between clean technology and negative environmental consequences. As a result, the definition of issues (or agenda setting), policy formulation and assessment, decision-making and policy implementation often rely on the assumption
that it is possible to identify, ex ante, innovations which are “good” for the environment and the economy. More critically, monitoring and evaluation of past and future impacts pose difficulties to address unintended consequences which are a real risk for technology-specific policies. Hence, judgements about whether any given technology will actually generate environmental savings may not be reliable without detailed assessment.

Innovation for sustainable development policy studies call for the use of pluralistic and eclectic approaches vis-à-vis the use of both qualitative and quantitative methods to conduct theoretically informed empirical analysis. A large number of clean innovation (policy) studies have focused on firm-centered approaches using input, throughput and output innovation performance indicators (Del Rio, et. al. 2016). Consequently, such indicators are used as proxies for innovation/technology/product generation, diffusion and use linked to competitiveness and economic growth (c.f. Markard & Truffer, 2008). Micro-level approaches face the challenge of data availability the quality of data collected about real economic impacts (e.g. those using innovation surveys such as the European Community innovation survey) whereas macro-level approaches fail short in characterize the environmental impact of innovation processes (e.g. those using environmentally-extended input-output analyses).

The approaches above introduced fall short in predicting displacement effects of eco-innovation diffusion and/or providing guidance on how to avoid mid and long term environmental and economic rebound effects of specific innovations (McDowall, Diaz Lopez, et. al. 2016). Put it simply, the use of mainstream tools (e.g. EU guidelines for policy assessment) prove difficult to anticipate a-priory, time lag between environmental benefits and innovation diffusion - e.g. when a technology brings about negative environmental impact the first few years after introduction, but achieving long term economic and environmental benefits in a longer time span.

Notwithstanding, a new generation of tools and indicators are available to perform detailed assessments of the indirect effects of specific innovations, across the life-cycle and incorporating various economic feedback effects, which can help avoid unintended consequences of clean innovation.

Following a standard approach to indicators in the (environmental) policy cycle this paper provides a review of tools, indicators and methods for measuring the environmental impacts of clean innovation. Specifically, this paper provides an account of new(er) insights on indicators and tools developed by European scholars for the ex-ante and ex post evaluation and monitoring of environmental consequences of innovation policy. Such account is primarily based on on-going work/selected outcomes of the projects “Global European Network of Eco-innovation, Green Economy and Sustainable Development (green.eu)” and “Environmental Marco Indicators of Innovation (EmInInn)”, respectively. Such indicators can help policy monitoring answering pressing question such as (i) under what conditions innovation leads to environmental improvements at the macro-level and (ii) how can the environmental pressures of innovations be assessed at the macro-level.

4 - Multi-Criteria Decision Making and Innovation Policy in the Literature
Sandra Schillo, Telfer School of Management, Canada
schillo@telfer.uottawa.ca

Like S&T policies, innovation policies are typically designed with a mix of economic, social and environmental outcomes in mind (Bozeman & Sarewitz, 2012). This suggests that multi-criteria decision making methods would be most appropriate in determining the effectiveness of such policies. However, such methods have only very rarely been applied to this context. Searches in academic literature databases provide only extremely few articles combining “innovation policy” with “multi-criteria” decision making (or “multiple-criteria” decision making). For example, Scopus provides 6 references, ABI/INFORM 50, and Web of Science only 1.

Instead, the academic literature has applied simpler methods - in many cases regression analyses focusing on a single dependent variable at a time - with some relatively small set outcome variables. Of particular importance in the literature are publications, patents and patent citations, invention disclosures, licences or licensing revenues, number of commercialized products, company formation, revenue growth, employment growth, and regional economic impacts.
Typically, innovation research and practice contends that data for other measures are far too difficult to obtain, and that it is not possible to appropriately aggregate outcomes on different dimensions. In this paper, the argument is made that multi-criteria decision making has successfully addressed some of the issue relating to the integration of diverse dimensions. A review of the existing literature on multi-criteria decision making and innovation policy provides some examples and the limitations of current approaches are discussed. A subset of the identified multi-criteria innovation policy literature addresses sustainability concerns, and this paper provides a discussion of this specific application. The paper concludes with suggestions for future research and innovation policy practice.

**WED-2-INV-DMS4130**
Invited Session: Building MCDM/A Models: Practical And Methodological Issues I (Mota, de Almeida)
Wednesday 10:30 - 12:10 - Room DMS4130
Chair: Rodrigo José Pires Ferreira

**1 - ELECTRE TRI-nB: A new multiple criteria ordinal classification method**
José Rui Figueira, CEG-IST, Instituto Superior Técnico, Portugal
figueira@ist.utl.pt
Eduardo Fernandez, Universidad Autónoma de Sinaloa, Mexico
eddyf@uas.edu.mx
Jorge Navarro, Universidad Autónoma de Sinaloa, Mexico
jnavarro@uas.edu.mx
Bernard Roy, Université Paris-Dauphine, France
roy@lamsade.dauphine.fr

This paper presents a new method for multiple criteria ordinal classification (sorting) problems. This type of problem requires that the different classes or categories be pre-defined and ordered, from the best to the worst or from the worst to the best. A set of actions (not necessarily known a priori) is assigned to the different and ordered classes. Several ELECTRE type methods were designed to deal with such a problem. However, no one proposes to characterize the categories through a set of limiting profiles. This is the novelty of the current method, which may be considered as an extension of ELECTRE TRI-B. It fulfills a set of structural requirements: uniqueness of the assignments, independence, monotonicity, homogeneity, conformity, and stability with respect to merging and splitting operations. All these features will be presented in the current paper as well as two illustrative examples.

**2 - Less effort or higher accuracy? A study on applying UTA* vs. UTADIS and ELECTRE TRI methods to build the negotiation offer scoring systems**
Tomasz Wachowicz, University of Economics in Katowice, Poland
tomasz.wachowicz@ue.katowice.pl
Ewa Roszkowska, University of Białystok, Faculty of Economic and Management, Poland, Poland
erosz@o2.pl

The negotiation theory considers the prenegotiation phase as a strategic stage in the negotiation process. From the viewpoint of decision support in negotiation, the prenegotiation requires of the negotiators to build the negotiation template and the negotiation offer scoring system. The former describes in details the structure of the negotiation problem, i.e. the list of issues, the sets of feasible resolution levels (options) or the salient options. The latter, in turn, describes quantitatively the negotiators’ preferences for various elements of the template [4]. Based on such a scoring system the wide range of support may be offered to the negotiators, beginning with the offers evaluation, measuring the scale of concessions and visualizing the negotiation progress, and ending with the arbitration possibilities or contract improvements. For multi-issue negotiations the effective preference elicitation requires applying selected multiple criteria decision aiding (MCDA) techniques [1]. Out of many potential support methods the most popular are the ones based on the direct rating (e.g. SAW, SMARTS), which are applied in the negotiation many support systems. Despite the direct rating approach seems technically easy, they may be troublesome to some negotiators of low cognitive capabilities, decision-making skills and number sense.

In our previous studies we found that some decision makers prefer to express their preferences verbally, not operating with numbers but using rather some kind
of visualization (e.g. marking the stars in a five- or seven-star quality banner) Yet, they expect to obtain the scoring systems with a certain level of quantitative precision [5]. Therefore, in our ongoing laboratory tests we used the UTA* algorithm to determine the negotiation offer scoring systems and found that their accuracy (i.e. the concordance with DM’s system of preferences) does not differ significantly from the systems determined by means of direct rating. In UTA* the negotiators provide their preferential information in a form of rank order of some reference offers, which does not require operating with numbers. On the other hand, ranking alternatives may be tiresome and problematic especially when the set of reference alternatives is relatively big so as to assure a certain level of scoring system accuracy [3].

In this paper we try to find if it is possible to reduce further the amount of preferential information provided by the negotiators without significant damage to scoring system accuracy. We compare the scoring systems obtained by means of UTA* method with those determined by means of UTADIS and ELECTRE TRI. In the latter ones, instead of rank ordering the reference alternatives, the decision makers need only to classify them into some categories. This seems to be cognitively less demanding than building the complete (or partial) order of alternatives. In case of ELECTRE TRI, originally designed to support the sorting problems, a modified algorithm is used that allows calibrating the alternatives within the categories and hence build an equivalent of rating system for all offers within the template. To analyze the potential differences in the accuracy of UTA*-, UTADIS- and ELECTRE TRI-based scoring systems we use the dataset of online business negotiation experiment conducted by means of Inspire negotiation support system [2]. First, we study the potential applicability of these three methods for determining the accurate scoring systems in laboratory, using various theoretical configurations of references sets but based on the preferences defined by the negotiators in this experiment (in which the hybrid conjoint measurement approach was used). Then we discuss the results of the in-class survey, in which the negotiators could define the reference sets themselves, according to their cognitive capabilities and skills. The effect of reducing the scoring system accuracy depending on the amount of preferential information provided by the negotiators is studied, as well as the issue of identifying the minimal reliable reference set, which would allow determining the scoring system of the assumed accuracy level.

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References

3 - Supplier selection in a food industry: an application with FITradeoff method
Eduarda Frej, Federal University of Pernambuco, Brazil
eafrej@gmail.com
Adiel Teixeira de Almeida, Federal University of Pernambuco, Brazil
almeida@cdsid.org.br

1 Introduction
Selection of supply sources is a strategic decision for organizations, because it enables companies to reduce their costs and improve profits (Parathiban, Zubar & Katakar, 2013). Besides that, appropriate decisions can reduce purchasing costs, decrease production lead
time, increase costumers’ satisfaction and strengthen competitiveness of organizations (Kara, 2011). Decision models for supplier selection problems are strongly present in the literature, as one can see in the works of Ho et al. (2010) and Chai et al. (2013). Due to the significant importance of this kind of decision for organizations, it is not appropriate to consider only the lowest price when selecting a supplier. Several other objectives can be involved in this kind of decision, so that supplier selection is a multiple criteria decision making problem, including qualitative and quantitative objectives (Xia & Wu, 2007).

This paper aims to solve a supplier selection problem in a food industry in Pernambuco (Brazil), by considering different and conflicting objectives. FITradeoff (de Almeida et al., 2016) is a flexible and interactive method for elicitation of criteria weights in additive models, and it is applied here in order to collect the decision maker’s preferences and find the best compromise solution.

2 Supplier Selection problem
This study concerns the selection of a packaging material supplier of a food industry located in Vitória de Santo Antão, Pernambuco, Brazil. The alternatives are five vendors pre-approved by the company. According to de Almeida et al. (2015), decision problems usually have different objectives that should be dealt simultaneously. Hence, seven criteria are going to be considered: price of the material; quality of the material; reliability of the freight; accuracy of the deliveries; lead time; promptness of the deliveries and flexibility of the supplier. These are all important aspects expected from good suppliers.

The decision maker is the manager of the purchasing department of the company, but other actors such as analysts of planning and quality department can also help the decision maker with factual information and data.

3 FITradeoff method
The multicriteria method selected to solve the healthcare supplier selection problem addressed here was FITradeoff method. The flexible and interactive tradeoff (de Almeida et al., 2016) is a new method for elicitation of scale constants in additive models, in which the decision maker considers tradeoffs by comparing consequences, similar to what happens in the traditional tradeoff procedure (Keeney & Raiffa, 1976).

The main contribution of FITradeoff is that this method overcomes some shortcomings of the traditional tradeoff procedure, such as the high inconsistency rate (Weber & Borcherding, 1993). Besides that, FITradeoff requires partial information about the decision maker’s preferences, which makes the elicitation process easier for the DM, requiring a reduced cognitive effort compared to traditional methods.

During the elicitation process, the DM answers questions judging tradeoffs between consequences. After each statement, linear programming problems are solved in order to build a pairwise dominance relation matrix, from which is possible to have a partial ranking of the alternatives. The elicitation process finishes when a complete order is found. But the decision maker can also choose to stop the elicitation before that if he is not willing to give additional information, or if the partial ranking obtained is already enough for his problem.

The FITradeoff DSS is available for download on request at www.fitradeoff.org/download.

Acknowledgments. The authors would like to acknowledge CNPq for the financial support for this research.

References
4. Ho, W., Xu, X., Dey, P. K.: Multi-criteria decision making approaches for supplier evaluation and
Decisions in supplier selection problems are an important task for managers, once they need to consider many aspects in order to achieve the objectives set by their companies. Solving this multicriteria problem through a pertinent MCDM/A process will influence the strategic success of an organization (de Almeida et al., 2015; Figueira, Greco, & Ehrgott, 2005). In this paper we model a supplier selection problem set in a Colombian agricultural research company–Company A–and use partial information on preferences to assist the selection of the most suitable laboratory equipment supplier from a set of potential ones.

A satisfactory multicriteria analysis should start from a well framed problem which is able to represent the context of the decision (Belton and Stewart, 2002). Some authors have suggested procedures to be followed during a MCDM/A process. De Almeida et al. (2015) present a dynamic procedure consisting of twelve steps organized into three main phases following a flexible sequence that promotes learning through a successive refinement. We used this procedure in our study in order to assist the identification of problem’s relevant information, decide the method to be employed, and implementing the decision in Company A.

The first phase of the procedure is called preliminary phase. At this stage the problem’s fundamental information need to be defined and structured. For Company A’s supplier selection problem, we defined the decision maker and other actors, i.e., analyst, specialists and stakeholders, as well as the role of each of them in the decision-making process. Aided by the analyst, the objectives and criteria set were defined based on judgments of the company’s specialists, considering both technical and purchasing aspects. Seven criteria were established: price, payment conditions, lead time, technical capability, training, maintenance and warranty, and technical service. Finally, a discrete set composed by seven potential suppliers was established according with the local market, and specialists assigned performance values for each of them in each criterion.

In the preference modeling and method choice phase, the method to be applied to the decision-making problem is chosen (de Almeida et al., 2016). Many authors have proposed models to solve supplier selection problems in a multicriteria context (de Almeida et al., 2016). One of such models is the well-known additive aggregation model consisting of weighted sums, which accommodates the compensatory rationality of the decision maker. The major challenge of this approach, nonetheless, is eliciting the scaling constants used to assign an overall value to each potential supplier.

The tradeoff procedure (Keeney & Raiffa, 1976) has been proposed to eliciting scaling constants in a MAVT context using complete information. In this procedure, the decision maker needs to answer questions about his preferences in order to establish all points of indifference between hypothetical consequences profiles. Despite the tradeoff procedure has a strong axiomatic foundation (Weber &
Borcherding, 1993), it is not widely applied because the decision maker finds it difficult to use, presenting many inconsistencies in his answers. FITradeoff (Flexible and Interactive Tradeoff) elicitation method proposed by de Almeida et al. (2016) uses partial information from the decision maker to eliciting the scaling constants in MAVT. It makes use of the axiomatic foundation and properties of classical tradeoff, with the advantage of requiring less cognitive effort from the decision maker in answering questions. FITradeoff refines the subset of potential solutions in order to reduce the number of questions necessary to find a recommendation. When using the method, the decision maker can access the current potential solutions based on the information so far available, being allowed to stop the process at any time. In this study, we applied FITradeoff method to solve the supplier selection problem in Company A. The third and last phase of the MCDM/A process proposed by de Almeida et al. (2015) is the finalization, in which the choice of the supplier and the implementation of the decision are conducted. Applying FITradeoff method to the problem, a final score was obtained for each potential supplier based on partial information given by the decision maker, aiding the selection of the most suitable equipment supplier for Company A.

Thus, we modeled a supplier selection problem of an agricultural research company and applied the FITradeoff method to support the decision-making process, assisting managers to make a better choice according to their preferences, requiring less information and cognitive effort from them. The FITradeoff Decision Support System is available for download on request at www.fitradeoff.org.

References
decision. Criteria space, on the other hand, contains possible vectors of criteria values, and this is where the decision maker’s preferences are defined. In the example of investment portfolio selection, the simplest criteria space (based on the Modern Portfolio Theory) would consist of possible two-dimensional vectors, where a vector shows the expected value and variance of the return generated by a specific portfolio of assets. Criteria mapping assigns to every feasible decision in the decision space the corresponding vector of criteria evaluations, so that the decision maker can use them to find preferred solution(s). For the above model to work, we need a clear understanding of each of its three components, and a major challenge comes from determining criteria and their values. This is the area which presents the most arguments and disagreements among both researchers and practitioners in multiple criteria optimization.

In the current work, we will first discuss major challenges in forming criteria set and supplying each criterion with a mechanism for evaluating alternative decisions against it. Most difficulties stem from situations where definitions are ambiguous and allow for different interpretations. Even so, we can distinguish two possible scenarios. For example, in the case of an investment portfolio risk can be defined as the variance of the return value or as the probability of a total loss, depending on the view of an investor; nevertheless, once the decision maker chooses a definition of risk, it is possible to measure it. Another common characteristic of an investment portfolio, diversification level, represents a different challenge because there is no exact, universally accepted way to define it as a measurable characteristic. The distinction between risk and diversification is the distinction between tangible and intangible, measurable and not measurable. How often do we participate in “evaluating” unmeasurable things on the scale from 1 to 5? Or from 0 to 10? Each option and each scale may yield a different image of the feasible set in the criteria space and a different optimal solution, even if we agree on the optimization model. There is no efficient way of combining tangible and intangible criteria in a single criteria space, unless one tries to squeeze qualitative, intangible criteria into their quantified versions. When one does this, it inevitably distorts the model as a reflection of reality and might cause failure in finding truly optimal solutions. Furthermore, attempts of creating more tractable optimization models such as value/utility functions become even more open to questions and doubts about realistic character and adequacy of such models. In the current work, we are proposing several possible ways to handle a combination of tangibles and intangibles during multiple criteria decision-making.

Suppose a decision analyst determines that the decision-maker wants to base his/her decision on several criteria while a subset of the criteria set consists of qualitative, hard to measure goals and objectives. Then we may consider two major cases. In case one, a qualitative criterion is very important in the sense that its value must satisfy a minimum requirement. For example, in a hiring problem, best candidates must first satisfy such minimum requirements as academic degree and quality of previous work experience, which would exemplify case one. In case two, a qualitative criterion is important but less so than other, measurable objectives. For instance, in the hiring problem the overall fit with the organization would probably represent case two.

After distinguishing what role qualitative/intangible objectives play in determining decision-maker’s preferences, it becomes possible to offer entirely different approaches to incorporating them in the decision-making process without forcing either side (the decision maker and the decision analyst) to create a biased model which goes beyond actual approximation of preferences.

2 - Group decision functions studied as extensions of simple games

Josep Freixas, Universitat Politècnica de Catalunya, Spain
josep.freixas@upc.edu
Montserrat Pons, Universitat Politècnica de Catalunya, Spain
montserrat.pons@upc.edu

Boolean functions assign an aggregate binary output to any vector of binary components. We study (j,k)-functions, which assign an aggregate output, among k choices, to any vector with j choices for each index or component. The binary case, achieved for j=2 and k=2, reduces to the Boolean context. Simple games are
particular examples of Boolean functions, and (j,k)-functions can be seen as extensions of simple games. We consider distinguished subclasses of monotonic (j,k)-functions: regular, threshold and anonymous and establish some relations among them. The case of anonymous (j,k)-functions deserves special attention: we get a closed formula to count them for \( j=2 \) and any value of \( k \), and for \( k=3 \) and any value of \( j \) we prove an extension of May’s theorem.

3 - Extracting decision-making related information from big data using text mining techniques
Sajid Siraj, University of Leeds, United Kingdom
sajidsiraj@gmail.com
Nitin Jain, University of Leeds, United Kingdom
nitin13293@gmail.com

This research focuses on the use of text mining for extracting multi-criteria decision-making (MCDM) related information from unstructured textual data, such as social media blogs and tweets. For this purpose, a corpus of textual documents have been processed using natural language processing techniques and then categorized using statistical machine learning algorithms. A vocabulary of terms has been compiled and investigated that are commonly used in different phases of the MCDM process. We consider this a novel area of research with a number of useful applications in prescriptive and descriptive research related to decision making.

4 - Structuring Problems for Multicriteria Decision Analysis
Valerie Belton, University of Strathclyde Business School, United Kingdom
val.belton@strath.ac.uk
Mika Martunnen, SYKE, Finland
Judit Leinert, EAWAG, Switzerland

"The importance of problem structuring for MCDA has long been acknowledged and there is a growing literature offering advice and describing practice across a range of application areas. At the same time, increasing interest in behavioural aspects of OR has highlighted the potential motivational and cognitive biases that can influence the structuring of multicriteria problems and the analyses that follow. This presentation will describe and report the findings to date of programme of work which sought to:

(i) better understand and learn from reported practice in problem structuring for MCDA, in particular the extent and benefits of use of a range of problem structuring approaches (from OR and more widely)
(ii) explore the extent to which previously identified objectives hierarchy related biases occur in practice
(iii) develop a framework for building concise objectives hierarchies

The first part of this research is based on a literature review of papers published between 2000 and 2015 describing the combined use of a PSM and MCDA and the second part draws on a meta-analysis of 60 published case studies describing the use of MCDA in practice in environmental and energy applications. The third component builds on this research and the authors’ experiences to propose a framework and associated methods to support the building of concise objectives hierarchies for MCDA.

WED-2-CON-DMS4170
Contributed Session
Wednesday 10:30 - 12:10 - Room DMS4170
Session: AHP/ANP II
Chair: Robin Rivest

1 - Computing the principal eigenvector of positive matrices by the method of cyclic coordinates
Kristóf Ábele-Nagy, Hungarian Academy of Sciences - Institute for Computer Science and Control, Hungary
kriszo_5@yahoo.de
János Fülöp, Hungarian Academy of Sciences - Institute for Computer Science and Control, Hungary
fulop.janos@sztaki.mta.hu

Pairwise comparison matrices are fundamental building blocks of the Analytic Hierarchy Process. In the process, one has to obtain a weight vectors from pairwise comparison matrices. One of the most common methods to obtain a weight vector is the Eigenvector Method, which gives the weight vector as the principal right eigenvector of a pairwise comparison matrix.

We are proposing a simple method to calculate the principal eigenvalue and corresponding eigenvector of positive matrices based on the Collatz–Wielandt formula. The minimax property of the principal eigenvalue makes it possible to formulate a multivariate optimization problem where the elements
of the principal eigenvector are variables. This problem can be solved in an iterative way with the cyclic coordinate method. The algorithm is customized for large matrices. Although the method is quite universal, our intended field of application is obtaining the principal eigenvector of pairwise comparison matrices.

An extension of this method deals with missing elements in the matrix. In this case the missing elements are additional variables. An application of this method is computing the principal eigenvalue and optimal completion of incomplete pairwise comparison matrices.

2 - Spanning trees and logarithmic least squares optimality for complete and incomplete pairwise comparison matrices

Sándor Bozóki, Institute for Computer Science and Control, Hungarian Academy of Sciences (MTA SZTAKI), Hungary
bozoki.sandor@sztaki.mta.hu
Vitaliy Tsyganok, Laboratory for Decision Support Systems, The Institute for Information Recording of National Academy of Sciences of Ukraine, Ukraine
tsyganok@ipri.kiev.ua

"Pairwise comparison matrices provide a user-friendly way of cardinal preference modeling. Decision makers compare the importance of criteria, or the performance of alternatives with respect to a given criterion. Numerical answers are arranged into a square matrix, which is elementwise reciprocal of its own transpose. A pairwise comparison matrix can be completely filled in (complete) or incomplete. Incomplete pairwise comparison matrices offer a wider range of applicability, not only in multi-criteria decision making, but in ranking problems as well.

The objective is to determine weights that express the importance of criteria, or the scores of the alternatives with respect to a criterion, by numbers, such that the pairwise ratios of the weights are as close as possible to the matrix elements, given by the decision maker. Several distance minimizing methods have been proposed, as well as other methods without the specification of the metric. The spanning tree approach belongs to the second group by definition. However, Lundy, Siraj and Greco proved in a recent EJOR paper (DOI 10.1016/j.ejor.2016.07.042) that the geometric mean of the weight vectors, calculated from all spanning trees of a complete pairwise comparison matrix’s graph, is in fact the optimal solution of the logarithmic least squares problem. We generalize this result for the class of incomplete pairwise comparison matrices. The detailed proof can be found at https://arxiv.org/abs/1701.04265

Lecture slides can be downloaded from http://www.sztaki.mta.hu/%7Ebozoki/slides"

3 - Green Hotel Evaluation and Selection:A Study for Turkey

Erdem Aksakal, Atatürk University, Turkey
erdem.aksakal@atauni.edu.tr
Merve Kayacı Çodur, Atatürk University, Turkey
mkayaci@atauni.edu.tr
Mustafa Yılmaz, Atatürk University, Turkey
mustafay@atauni.edu.tr

With the rising sense and concern for environment, travelers begin to look for hotels and resorts to be environmentally friendly/responsible. In this sense being environmentally friendly/responsible is named as green in recent years. The green concept is becoming very popular because it is innovative and valuable and this makes it a much more important demand concept. For this reason, green concept begins to have a greater role in all part of our lives. As well as being everywhere, the green concept is also integrated in the tourism sector. At the same time, like all over the world, the hotels and resorts in Turkey begin to implement the green concept with the guidance of the government. In this study an evaluation model is designed to select a suitable green hotel selection for a traveler in Turkey. The model uses Entropy method and VIKOR method. Entropy method is used for determining the weights of the criteria determined for selection and VIKOR method is used for selection process.

4 - A Numerical Experiment on the Possibility of Getting the AHP Solution with Much Less Pairwise Comparisons

Robin Rivest, HEC, Canada
robin.rivest@videotron.ca

The number of comparisons required to complete an AHP matrix increases rapidly when the number of
alternatives expands. However, priority vectors can be derived even if some entries are missing. This study revisits the key findings of the last thirty years on this subject. It aims to determine which entries can systematically be omitted without significantly affecting the overall solution to the AHP model. Such omissions will be guided by simple heuristics which will be verified empirically through numerical simulations. These simulations will compare the vectors obtained with complete versus incomplete matrices. Several elements will be investigated, most importantly: proximity measures, accuracy thresholds, spectrum of inconsistency and scale dependencies as well as a reality check on simulation data.

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Wednesday, 13:30-15:10

WED-3-CON-DMS4120
Contributed Session
Wednesday 13:30 - 15:10 - Room DMS4120
Session: Uncertainty, Stochastic II
Chair: Mert Sahinkoc

1 - An Interactive Approach for Product and Process Design Parameter Optimization under Model Uncertainty
Melis Özateş Gürbüz, Middle East Technical University, Turkey
mozates@metu.edu.tr
Gülser Köksal, Middle East Technical University, Turkey
koksal@metu.edu.tr
Murat Köksalan, Middle East Technical University, Turkey
koksalan@metu.edu.tr

In recent years, there has been an increasing interest in improving products and processes through design. Several factors affecting quality of a product have to be considered to determine settings of controllable design parameters that yield high quality with minimal variation. Furthermore, the quality of a product is typically defined by multiple responses (or performance measures) of a product or process where optimal design solution for a response is typically not optimal for another response due to the conflicting nature of the responses. These problems can be referred to as Multi Response surface Optimization (MRO) problems. In order to find meaningful solutions, multiple responses should be considered simultaneously. Several approaches have been developed to address these problems. Most of these approaches consist of three main solution stages. First, experiments are designed to gather data. Then, the relationships between responses (or performance measures) of interest and several controllable design parameters are modeled as empirical relationship functions. Finally, these functions are treated as objectives or constraints in an optimization model. The majority of the existing MRO approaches in the literature assume that the preferences of the decision maker (DM) are known exactly prior to the solution procedure. This is a strong assumption that is hard to justify in practice. Such approaches typically combine multiple responses into a single function and optimize the resulting function. They assume that all DMs evaluate with the same type of a function. Although the parameters of these functions are determined according to the DM’s preferences, process economics and statistics, finding them is difficult, even when the general structure of the function matches with the DM’s preferences. There also exist several studies employing interactive multi objective optimization (MOO) approaches. None of these consider model uncertainty in the predictions. Ignoring uncertainty inherent in the structure and/or parameters of the response surface models may result in undesirable solutions.

In this study, to overcome many of those deficiencies, we develop an interactive approach for the two-response product and process design optimization problem, considering DM’s preferences under model uncertainty associated with the parameters of response surface models. We use several controllable properties of the responses, such as the distance of the estimated response means from their respective target values and the estimated response variances, to control the performance of the solutions in our models. In order to provide relevant information on the consequences of solutions to the DM, we produce visual aids on performance measures such as joint response confidence and prediction regions of selected solutions together with lower and upper specification limits and target values of the responses. The performance measures facilitate the communication
with the DM. Although the effects of changing the controllable properties on the performance measures are roughly known, the exact magnitudes of those effects are not known since they are related to the problem characteristics. Capturing these relations may be hard for a DM. Therefore, we involve the problem analyst (PA) in the searching procedure to help the DM converge to his/her preferred solutions quickly. At each iteration, the PA converts DM’s verbal preferences into mathematical expressions and searches the solution space to identify and present solutions that are in line with the DM’s expressed preferences. The PA systematically searches the relevant solution space at each iteration. The procedure continues until the DM finds a desirable solution.

We illustrate the developed approach on a two-response problem widely used in the literature. We also discuss the issues for covering more than two responses and handling further problems on modeling and estimation.

2 - A novel stochastic nonlinear multi-objective decision model to aggregate production planning under uncertainty

Aboozar Jamalnia, Alliance Manchester Business School, United Kingdom
aboozar.jamalnia@postgrad.mbs.ac.uk
Jian-Bo Yang, Alliance Manchester Business School, United Kingdom
jian-bo.yang@manchester.ac.uk
Dong-Ling Xu, Alliance Manchester Business School, United Kingdom
Ling.Xu@manchester.ac.uk

The present study proposes a novel, comprehensive, stochastic, nonlinear, multi-stage, multi-objective optimisation approach to model aggregate production planning (APP) decision making problem based on mixed chase and level strategy under uncertainty where the market demand acts as the main source of uncertainty. The model involves multiple objectives such as total revenue, total production costs, total labour productivity costs, optimum utilisation of production resources and capacity, etc., and is implemented on the basis of real world data from beverage manufacturing industry. Applying the recourse approach leads to empty feasible space and, therefore, the wait and see approach is used instead. The WWW-NIMBUS software is utilised to run the large scale, nonlinear, non-smooth, non-convex, non-differentiable multi-objective optimisation problem. Finally, the sensitivity analysis is conducted by trade-off analysis and by changing different parameters/coefficients of the constructed model.

3 - Preferred paths under uncertainty

Katarzyna Krupińska, Wrocław University of Economics, Poland
katarzyna.krupinska@ue.wroc.pl

"We consider the problem of determining preferred paths in a directed graph under uncertainty. Preferred paths are defined as minimal elements of an order relation which is defined on the power set of the set of arcs, whereas uncertainty is related to infinitely (finitely) many values for arc weights which form intervals (finite sets). Preferred paths thus obtained may be perceived as robust solutions. We work with the concept of interval order and its variants, and also use a measure to further refine the set of preferred paths. We also try to give an operational description of obtaining preferred paths."

4 - Many-objective Evolutionary Approaches to Optimization Under Scenario-based Uncertainty

Mert Sahinkoc, Bogazici University, Turkey
hmertsahinkoc@gmail.com
Umit Bilge, Bogazici University, Turkey
bilge@boun.edu.tr

Optimization problems involving uncertain parameters occur in almost all fields of science and engineering, from power generation to telecommunication and medicine, thus approaches concerning with uncertainty come into a great importance. One way of modeling uncertainty is the scenario-based approach in which only a finite number of sampled instances of uncertainty is considered. Scenario-based uncertainty is studied under the fields of stochastic programming and robust optimization. In stochastic programming, uncertain parameters are governed by probability distributions that are known in advance by the decision maker and usually the goal is to optimize the expected behavior. In robust optimization, on the other hand, these probability distributions are not necessarily required or in some
cases not available, and the common approach is to optimize the worst-case performance of the system. Choosing an appropriate performance measure to deal with the uncertainty in a particular problem is a critical issue since the definition for good performance under the set of all possible scenarios depends on the decision maker as well as the application. The techniques driven from both stochastic programming and robust optimization methodologies offer different ways of converting the distinct objective values given by a feasible solution under each scenario realization into a single performance measure. Any stochastic or robust performance measure is a particular preset function of scenario objectives that leads into a compromising decision. This approach is analogous to the a priori preference articulation paradigm in multi-objective optimization. A priori approaches require the decision maker to define importance and preference relationships among multiple objectives in advance and the search is guided accordingly to find a solution that obeys these preferences, whereas in a posteriori approach, the emphasis is on generating as many as possible efficient solutions in the Pareto front and the decision making takes place after the decision maker sees all these solutions.

From another point of view, noting that robust optimization is indifferent towards non worst-case scenarios, it can be argued that the classical robust optimization framework need not produce solutions that possess the Pareto optimality property, and therefore can lead to inefficiencies and sub-optimal performance in practice. Also, a theoretical characterization of Pareto robustly optimal (PRO) solutions can be derived based on the fact that one of the robust optimal solutions should also be a Pareto optimal solution. The relationship of robust optimization and stochastic programming with multi-objective optimization is already pointed out in a few researches introducing the concept for transforming an uncertain optimization problem into a deterministic multi-objective optimization problem where the objectives correspond to uncertainty scenarios. However, as far as we are aware, none of these studies explore the viability of this approach by explicitly investigating it on well-known optimization problems. Namely, the aim of this study is characterizing the scenario-based optimization problems that lend themselves to multi-objective optimization approach, thereby allowing a posteriori approach for analyzing the performance of different decisions. More specifically, if a solution results in different objective values under each scenario, the corresponding uncertain optimization problem can be transformed into a multi-objective optimization problem by treating each scenario as a different objective. Then, a posteriori multi-objective optimization techniques can be applied to obtain the efficient set. All robust optimal solutions as well as solutions corresponding to weighed linear aggregations (i.e. expected value) of the scenario objectives happen to exist in this efficient solution set. By obtaining the Pareto optimal set, or at least exploiting the necessary and satisfactory portion of it, the optimal solutions for many metrics covered in stochastic and robust approaches are found simultaneously in a single step. In this way, after the optimization process, the decision maker will end up with efficient solutions that cover a wide range of different performance metrics and has a chance to choose a solution that pleases his preferences. On the other hand, the number of scenarios in the optimization problem can be a challenge in this approach. When the number of uncertainty scenarios gets larger than three, due to scalability issues existing in available multi-objective optimization techniques, approaches from an emerging research area named many-objective optimization are required. The issues debated above, will be demonstrated and validated in this study through some well-known combinatorial optimization problems such as 0-1 Knapsack problem and the quadratic assignment problem (QAP). The many-objective evolutionary algorithm developed in this study uses elitist non-dominated sorting based on reference points that are mapped onto a “fixed hyperplane” integrated with path relinking recombination scheme and complementing selection mechanisms. Numerical experiments yield promising results in terms of approximating the Pareto set in comparison to a set of existing multi-objective evolutionary algorithms. Our approach brings a new and natural application area for multi-objective optimization into attention and offers contribution to both stochastic/robust optimization and multi-objective optimization research streams.
1 - Prioritization of Business Processes associated with the Textile Pole of the Agreste of Pernambuco: a multicriteria approach.

Edinalva Carvalho, ufpe/caa, Brazil
edinalvaproducao@gmail.com
Lucio Silva, ufpe / caa, Brazil
lucio_camara@hotmail.com

The efficient management of the supply chain has provided organizations with a more effective control on production processes, being recognized as key to organizational performance. Effective management has been accomplished through the aid of modern procedures, especially the Business Process Management (BPM). However, managing processes, according to strategies considered relevant for organizations, is still considered a critical procedure. Thus, this research aims at applying the PROMETHEE II method in prioritizing business processes associated with supply chain management as a means of contribution to better management practices and, consequently, competitive acquisition of advantages. A survey was carried out on the major business processes, both internal and external to organizations, associated with the organizational context of the Textile Pole of the Agreste of Pernambuco, according to the following dimensions: strategic alignment, governance, information technology, method, people and culture. In this study, a methodology for structuring the problem of decision, the Value Focused Thinking-VFT, was also used in order to identify the manager’s values. The survey results demonstrate that the alternatives "perform fabric washing", "define the process improvement plan", along with "customer relationship management" and "supplier relationship management", which correspond to structuring all the company's business processes, were considered the most critical. It was also observed that out of the five most critical processes, three are associated with the strategic alignment dimension.

2 - Group Decision Making based on Multi-Attribute Utility Theory using Baysien Estimation Method

Tomohiro Hayashida, Hiroshima University, Japan
hayashida@hiroshima-u.ac.jp
Ichiro Nishizaki, Hiroshima University, Japan
nisizaki@hiroshima-u.ac.jp
Shinya Sekizaki, Hiroshima University, Japan
sekizaki@hiroshima-u.ac.jp

This study considers group decision making based on the multi-attribute utility theory (MAUT) using the Baysien estimation method. Multi-attribute utility analysis deals with the preferences of decision makers to multicriteria decision making problems including uncertainty, and the preferences are elicited through interactive processes with the decision makers. In group decision making, although consideration of the preferences of stakeholders in the decision problems is also necessary, they do not always have similar preferences for all attributes related to the decision making problems. Related researches propose several methods identifying or approximately defining a multi-attribute utility function by uniquely defined scale constants which represent the trade-off relationships between the corresponding attributes and selecting the most preferred alternative based on such evaluation processes. This study treats differences in the preferences of stakeholders in the group multicriteria decision making problem as probability distributions of the scale constants, and proposes a method for selecting the most preferred alternative from the feasible set of the alternatives based on the probability distributions of the scale constants identified by the Bayesian estimation method using several preference relations obtained from the stakeholders.

3 - WCM projects prioritization using the FITradeoff method

Dr. Ana Paula Gusmão, Universidade Federal de Pernambuco, Brazil
anapaulahg@hotmail.com
Wladson Silva, Acumuladores Moura, Brazil
wladsonsilva@hotmail.com

The current environment of competitiveness and limited resources has motivated companies to improve
the performance of their processes more and more. Thus, the WCM (World Class Manufacturing) approach appears as an alternative.

Most decisions, through the WCM implementation process, are taken considering the impact that a particular action or area presents in relation to reducing losses, waste, defects and inventories. Thus, the main focus is on reducing costs, which, although characterized as one of the eleven pillars of the WCM, acts in a transversal way, since it is responsible for identifying the losses and wastes to be tackled and the areas where both of these occur.

Issues that go beyond reducing costs, however, must be taken into account, since such decisions have a strategic impact within organizations and directly influence their competitive position. The decision to invest in improvement projects, within the WCM approach, is therefore a multicriteria problem. In fact, the application of multicriteria modeling in the context of prioritizing and selecting improvement projects, by taking an approach that aims to increase efficiency and competitive advantage, has the advantage of addressing different criteria (operational, strategic, among others) and allows the decision maker (DM) to clarify other relevant aspects in this type of decision.

This paper presents the application of the FITradeoff (Flexible and Interactive Tradeoff) multicriteria method to support the decision to prioritize improvement projects in a large, automotive parts factory, using the WCM system. Regarding the choice of method, the context of the problem and the fact that the DM prefers to work with balanced alternatives were first considered. Thus, we started to identify the additive method, where the choice of FITradeoff is justified by the greater flexibility that this method presents for defining weights when compared to the traditional tradeoff procedure. The FITradeoff Decision Support System is available upon request at www.fitradeoff.org/download.

4 - Identifying vulnerable areas to homicide with spatial multi-criteria approach
Caroline Mota, UFPE, Brazil
carol3m@gmail.com
Debora Pereira, Universidade Federal de Pernambuco, CDSID, Brazil
deboravianapereira@gmail.com

Ciro Figueiredo, Universidade Federal de Pernambuco, CDSID, Brazil
figueiredocj@yahoo.com.br

Violent deaths in developing countries is a known and old problem. In Brazil, for decades many efforts have been done to try to reduce crime. However, the number of homicides is steadily growing, even if we consider that Brazil is a country that does not have conflicts of religion, ethnicity, race, or territory. Therefore, something more effective must be done to control this phenomenon, such as to identify where actions to reduce violence must be allocated. In this sense, this study has the objective of suggesting a multi-criteria model associated with local spatial analysis to identify the most vulnerable areas to homicide and, consequently, needier of public intervention. We made an application in a Brazilian neighborhood, called Boa Viagem, considering factors as education, inequality, income, and infrastructure. Through this approach, we were able to identify clusters and outliers of vulnerability. The use of local spatial analysis was important because it allows to consider the surroundings, then we could analyze the effect of the neighbors. Therefore, the areas were classified and the public effort can be allocated more efficiently, according to the specific needs of each group. We may affirm that our proposal made a satisfactory prioritization of the neighborhood, since the critical areas have a similar pattern when compared to the homicide density map. Moreover, this analysis contributes to public security planning in different aspects: the preferences of a decision maker are considered, many criteria are taken into account; the spatial component is considered, and the vulnerability of the surroundings is contemplated.

WED-3-INV-DMS4140
Invited Session: AS3: Innovative Decision Aiding for Industries (Ben Amor, Miranda, Aktas)
Wednesday 13:30 - 15:10 - Room DMS4140
Session:
Chair: Farzaneh Ahmadzadeh

1 - Optimization of time-of-use electricity pricing with demand response - a semivectorial bilevel programming approach
The electricity sector has been open to retail competition, including to residential customers, in several countries. Retail companies procure electricity in wholesale markets and offer flat or slightly variable time-of-use tariffs to their residential customers, thus managing the risk involved. These tariffs are, in general, defined for long periods (e.g., one year) and therefore do not convey to customers price signals reflecting generation costs and grid situation. Therefore, consumers do not have sufficient incentives to adopt consumption patterns different from habitual behaviors, which could be also beneficial from the perspective of grid management. The flexibility consumers generally have regarding the feasible time of operation of some end-use loads is a valuable asset, the exploitation of which can contribute to improving the system overall efficiency, lowering peak generation costs, facilitating the penetration of renewable sources, reducing network losses, while offering them economic benefits. Time-differentiated retail tariffs reflecting the power systems conditions (generation availability, network congestion, etc.), i.e. energy prices displaying possible significant variations in short periods of time, are expected to become a common tariff scheme in the realm of smart grids. This trend will be facilitated by the deployment of smart meters, supporting the empowerment of consumers, who assume a more active role regarding energy decisions (which may also involve microgeneration and electric vehicle operation).

Dynamic time-of-use tariffs will motivate consumers to engage in different consumption patterns, making the most of the flexibility in the operation of some appliances through demand response actions affecting the provision of energy services (hot water, laundry, electric vehicle charging, etc.). In this setting, after receiving tariff information some time in advance (e.g. one day) the consumer responds by scheduling load operation. This involves trading-off the minimization of the electricity bill (to profit from periods of low energy prices) and the minimization of dissatisfaction (a proxy for the possible loss of comfort associated with postponing or anticipating appliance operation according to his preferences and requirements). Load operation scheduling is performed by a home energy management system parameterized with the customer’s energy usage profile, with communication capabilities to receive grid information (prices and other signals) and address appliances.

In this setting, the retailer company problem consists of determining the optimal time-of-use tariffs to be offered to consumers along the day to maximize its profits, considering the variable energy acquisition costs in wholesale markets and anticipating the consumers’ response in scheduling demand when faced with dynamic prices. This problem was tackled developing a semivectorial bilevel optimization model with a single objective function at the upper decision making level (the retailer company) and multiple objective functions at the lower decision making level (the consumer). The retailer is the leader aiming to determine the tariffs that maximize its profit and the consumer is the follower reacting to those time-differentiated prices to minimize the electricity bill and the dissatisfaction associated with rescheduling load operation. The follower’s decision, which represents a compromise between its objective functions, affects the maximum leader’s profit, as the leader does not know which optimal solution the follower will choose from the set of its nondominated solutions for each price setting established by the leader. The lower level optimization problem is formulated as a multi-objective mixed-integer linear programming (MOMILP) model. The semivectorial bilevel optimization model is dealt with a hybrid approach consisting of a genetic algorithm for the upper level problem and an exact solver to solve surrogate scalar MILP problems (i.e. combining both objective functions) at the lower level. Four “extreme” solutions are computed: the optimistic solution offering the leader the best objective function value when the follower’s decision for each setting of upper level variables is the best for the leader; the deceiving solution when leader adopts an optimistic approach but the follower’s reaction is the worst for the leader (i.e., the optimistic approach “failed” leading to the worst result); the pessimistic solution offering the best objective function value for the leader when the follower’s decision for each setting of upper level variables is the worst for the leader; and the rewarding
solution when the leader adopts a pessimistic approach but the follower’s reaction is the most favorable to the leader (i.e., the best outcome that may result of the most conservative decision). These solutions capture not just the optimistic vs. pessimistic leader’s attitude but also the possible follower’s reactions, which may be more or less favorable to the leader within the lower level nondominated solution set.

A case study is used to illustrate these concepts, in which the consumer controls a set of shiftable appliances, the operation cycle of which can be set within acceptable time slots according to his preferences and comfort requirements in face of the electricity prices established by the retailer.

2 - An Integrated Decision Support Model to Calculate the Risk Scores of Workstations in Assembly Lines

Berna Unver, Istanbul Technical University, Turkey
unverbe@itu.edu.tr

Mine Işık, Bogazici University, Turkey
mineisik@boun.edu.tr

Özgür Kabak, Istanbul Technical University, Turkey
kabak@itu.edu.tr

Ilker Topcu, Istanbul Technical University, Turkey
ilker.topcu@itu.edu.tr

Today, one of the serious problems in production systems is rapid increase in process complexities. Process complexities in production systems directly affect quality, performance, and efficiency of the system. Companies that can manage their own complexities in production systems will have great advantages in terms of productivity, quality, profitability, and competitiveness as well as cost and time savings.

Rapidly evolving and changing customer requests in the automotive sector have recently directed businesses to make more customer-focused designs. A large number of workstations and operations in automobile assembly lines have a significant effect on complexities. Moreover, customer orientation, total quality, design process, and cost constraints increase the complexity of the systems that result with failures in the overall process. Therefore, innovative, open to improvement, customer-focused, continuous improvement, and process development in the automotive industry will help businesses to keep their own position in the future and gain competitive advantages.

The aim of this study is to develop a multi-criteria decision support system for the prediction and quantification of the risk of failures on the workstations in an automobile manufacturing company. A generic decision support system is developed to be used in all workstations of the assembly lines. By the help of such a decision support tool, risk of failure levels of work stations can be measured during the production and workforce planning before the failures occur. By this way, precautions such as Poka Yoke (Hard/Soft), warning system, Raccolta Ticket, visual control can be applied to work station or the workers are assigned to the stations according to their abilities.

The decision support system is developed in four main stages. First, the factors causing failures on the workstations of the assembly lines in the automotive industry are determined. Literature review is conducted and an initial list of factors is composed. The factors in the initial list are then reviewed by the managers of the company using the Delphi method, a structured and systematic communication technique, to find out the final list of factors.

Second, the relations among the factors are revealed. For this, initially, the existence of the relations among the factors are discovered using a cognitive mapping approach. Then, since the relations are in a network structure instead of a hierarchical one, Analytic Network Process (ANP) is used to prioritize the factors in the system.

Third, in order to measure the levels of each factor in a given work station, the rating scales are designed. Possible levels of the factors are analyzed by the help of the managers to define the rating scales.

Finally, in the fourth stage, the risk of failure scores of work stations are calculated based on the factor priorities and the evaluation of work stations with respect to factors. It is also possible to re calculate scores when a precaution is applied or a different worker is assigned.

In the further steps of the study, pilot studies will be conducted in several production cells and sensitivity analysis will be performed to explore managerial insights."
Information Technology (IT) can be described as a collection of instruments and methods such as; programming, data transmission, transformation, storage & recovery, analysis & design control of systems and consolidated tools in order to collect, process, and exposure information. In this sense, integration of a number of different information technologies applications is crucial for the organizations. “Digital Hospitals” as the lattermost IT that has been applied to many hospitals enables the distribution of e-health systems providing online information, disease management, and the ability to monitor information remotely and also telemedicine services that can be widen for the access of rare medical sources. It is clear that succeeding a successful implementation of integrated healthcare information systems is one of the most common target for many countries in order to pursuit of obtaining coordinated and comprehensive healthcare services. This study proposes a multi-criteria decision making model incorporating IT integration project selection framework in healthcare sector. The final objective is to determine the implementation sequence of IT integration projects with following a systematic approach. The proposed model is applied to a real life problem in one of the leading ready - Bursa state hospitals in Turkey. The selected hospital currently is in the last phase of “Digital Hospital” concept and it has three IT integration projects waiting to be implemented. However, no systematic approach has been defined in determining priority of IT integration projects’ implementation even this is a very important business decision that should be optimized with a systematic approach. It is considered that the hospital needs the use of a model to make an efficient decision in order to determine the sequence of projects considering efficiency, interoperability and maximum global profitability.

The proposed model is defined as a multi attribute value theory based intuitionistic fuzzy multi-criteria decision making (IFMCDM) model reinforced with using three different Multi Criteria Decision Making algorithms in order to establish IT integration project sequence attending to terms of efficiency, interoperability and maximum global profitability. In the proposed model (1) the weights of decision makers as well as the criteria are gathered using intuitionistic fuzzy sets (IFS). Performance rates for alternatives are also evaluated using IFS. (2) The aggregation of weight vectors and performance rates are conducted. (3) IFS TOPSIS, SAW and VIKOR methods are applied to the aggregated group evaluation and individual evaluations. (4) Spearman’s rank correlation coefficient between group and individual outcomes by each corresponding method are calculated. (5) The MCDM method that has the highest averaged correlation coefficient is selected, and the results of this method is suggested as the final solution.

The model supports the selection of the IFMCDM model providing the most preferred group ranking result for a problem. Such approach extracts the group ranking result of a IFMCDM method having the highest consistency rate according to its corresponding ranking results of individual decision makers.

Although the model proposed has been developed for healthcare sector, it can be also applied to many other ones just adapting the criteria to the particular sector specifics, either adding, removing or changing criteria elements where are advisable to do or when the ones used for healthcare sector are not directly applicable.

4 - Identification and measurement of features that enable practice-based innovation

Farzaneh Ahmadzadeh, Mälardalen University, Sweden
farzaneh.ahmadzadeh@mdh.se
Tomas Backström, Mälardalen University, Sweden
tomas.backstrom@mdh.se
Peter Johansson, Mälardalen University, Sweden
peter.e.johansson@mdh.se
Jennie Schaeffer, Mälardalen University, Sweden
jennie.schaeffer@mdh.se
Helena Karlsson, Mälardalen University, Sweden
helena.karlsson@mdh.se
Innovation has been placed at the top of many organizations' strategic agendas because the demand on skills, tools and work procedures that support innovative work in practice has grown exponentially. To meet many organizations' needs and to strengthen their innovation capabilities, a pilot study called Innowatch was conducted. Innowatch's focus was how research-based innovation management tools can be designed. It was developed and evaluated over a period of 9 months during 2014-2015. Innowatch contains two types of digital-based innovation management tools: An online survey tool (Prindit) assessing the climate for creativity on a weekly basis. A digital photo-elicitation tool (PET) is used to research how new media allows a temporary artefact to be used to stimulate group discussions on innovation. Innowatch's process included a series of four externally facilitated workshops, which each of the Innowatch teams participated in. The objective of the workshops was to link the two digital-based tools (PET and Prindit) and facilitate learning on innovation.

The aim of current research is to explore which features and to what extent the use of Innowatch innovation management tools turns it into a pedagogical tool and enable practice-based innovation. To explore if different Innowatch workshops as pedagogical tools could enable practice-based innovation, and to get some understanding about which features and to what extent those features could be used for enabling practice-based innovation, a questionnaire is distributed in different occasions before and after each workshop among three different Innowatch teams. Variation of the results would be some evidence that those Innowatch innovation management tools are useful for turning it into a pedagogical tool. To measure the variation, Evidential Reasoning (ER) approach has been applied. ER advocates a general, multi-level evaluation process for dealing with multi-criteria decision making (MCDM) problems. An important advantage of ER is the possibility of handling qualitative and quantitative uncertain information of any kind: lacking data, missing data, incomplete information. ER is developed on the basis of Dempster-Shafer evidence theory and evaluation analysis model and decision theory. Result shows all three companies are about the same level of innovation capabilities without any practice and experience of any workshop. To understand which features would be more sensitive as enabling practice-based innovation each workshop would focus on some specific features and then after each workshop the respondent would answer the questionnaire. The expected outcome is that after each workshop as enabling practice-based innovation there are some deviation on different features level especially on level of those features which are the main focus of each workshop. By applying ER the level of deviation (decrease or increase in different features) would be plotted and it will visualize if those features could be used for enabling practice-based innovation.

**WED-3-CON-DMS4170**
Contributed Session
Wednesday 13:30 - 15:10 - Room DMS4170
Session: Multi Objective Optimization
Chair: Kaisa Miettinen

1 - Easy to say they’re Hard, but Hard to see they’re Easy Ñ Towards a Categorization of Tractable Multiobjective Combinatorial Optimization Problems
Michael Stiglmayr, University of Wuppertal, Germany
stiglmayr@math.uni-wuppertal.de

It is a well-known fact that multiobjective combinatorial optimization problems are not efficiently solvable in general. This is true for two reasons. First, from an asymptotic worst case perspective, the number of non-dominated points may grow exponentially with the input size. Second, the computation of non-supported efficient solutions may be significantly more demanding than the solution of the single objective analogon. Linear scalarization methods capable of yielding non-supported efficient solutions introduce new (knapsack-type) constraints to the combinatorial structure. Thus, these scalarized problems lead to resource constrained versions of combinatorial problems with the consequence that these scalarized single objective combinatorial optimization problems turn out to be NP-hard.
Apart from this general observation, are there also variants or cases of multiobjective combinatorial optimization problems which are easy and, if so, what causes them to be easy? In this talk, these two questions will be addressed and a systematic description of reasons for easiness is given. Particularly, combinatorial problems on the boundary between easy and hard are investigated. For some of these problems (like the biobjective assignment problem) it is still unclear if there exist polynomial solvable special cases.

This talk is based on results archived in collaborations with Cristina Bazgan, Fritz Bökler, JosŽ Rui Figueira, Carlos Fonseca, Lucie Galand, Pascal Haußmann, Kathrin Klamroth, Lu’s Paquete, Stefan Ruzika, Britta Schulze, Daniel Vanderpooten, and David Willems.

2 - A new generic algorithm for enumerating the set of nondominated points in multiobjective discrete optimization problems
Satya Tamby, Université Paris-Dauphine, France
satya.tamby@lamsade.dauphine.fr
Daniel Vanderpooten, Université Paris-Dauphine, France
daniel.vanderpooten@lamsade.dauphine.fr
Hassene Aissi, Université Paris-Dauphine, France
aissi@lamsade.dauphine.fr

Real world problems often involve several conflicting objectives. Thus, solution of interests are efficient solutions which have the property that an improvement on one objective leads to a decay on another one. The image of such solutions are referred to as nondominated points. We consider here the standard problem of computing the set of nondominated points, and providing a corresponding efficient solution for each point.

In order to be applicable for a large variety of problems, including multiobjective combinatorial optimization problems, generic algorithms usually rely on integer programming since most of the problems can be represented using integer variables. Such algorithms iteratively solve single objective programs over the search region, which corresponds to the part of the objective space which contains the remaining non dominated points. When a new point is found, the part dominated by this point is removed from the search region before repeating the procedure until the search region becomes empty. Thus, the challenging part consists of reducing the number and the difficulty of the integer programs to be solved, and finding a way to compute easily the search region associated to the set of already enumerated points.

Most recent approaches involve budget constrained programs, i.e. programs exploring a zone of the objective space delimited by a local upper bound on the objectives (assuming that objectives are to be minimized). If the zone is non empty, then using a suitable aggregation function, e.g. a weighted sum of the objectives with positive weights or a lexicographic aggregation, a nondominated point is generated. Otherwise, the problem is infeasible. In the latter case, it has been observed that the corresponding problem is practically longer to solve than a problem admitting feasible solutions. The reason is that integer solvers cut the search space as soon as a feasible solution is found.

The algorithm we propose maintains an explicit list of local upper bounds, delimiting search zones whose union corresponds exactly to the search region. Any search zone which does not contain any feasible point is simply discarded. When a new point is found, the update of the search region can be performed easily by considering each zone to which this point belongs and splitting each of these into subzones by removing the part dominated by this point.

To reduce the number of programs solved, we propose some rules to detect empty zones without having to explore them. Since computation time is mostly spent on the resolution of the programs, discarding entire parts of the search region, and therefore avoiding to solve the associated programs, significantly improves the efficiency of the algorithm. Moreover, without additional effort, we are also able to provide a feasible starting solution at each exploration, which also speeds up the solving process. The resulting algorithm is highly competitive compared to other state of the art algorithms, as shown by the computational experiments we have performed on the multiobjective knapsack and assignment problems.

3 - Helping Android Users to Find the Most Efficient Apps.
Rubén Saborido Infantes, Polytechnique Montreal, Canada
ruben.saborido-infantes@polymtl.ca
Google Play Store App is the official marketplace of Android which offers more than a million applications (apps) belonging to different categories. Due to the constraints in hardware, compared to other platforms like desktop computers and workstations, Android users and developers have to meticulously manage the limited resources available in mobile devices. Although for each application (app) the repository offers a description and the rating given by users, information concerning their performance is not usually available although it is well known that there are apps more efficient than others.

Recently, we presented ADAGO, a recommendation system aimed at helping Android users and developers alike. It helps users to choose optimal sets of apps belonging to different categories (e.g. browsers, e-mails, cameras) while minimizing energy consumption, transmitted data, and maximizing app rating. It also helps developers by showing the relative placement of their app's efficiency with respect to selected others. When the optimal set of apps is computed, it is leveraged to position a given app with respect to the optimal, median and worst app in its category (e.g. browsers).

Out of eight categories in Google Play Store App we selected 144 apps, manually defined typical execution scenarios, collected performance metrics, and computed the Pareto optimal front solving a multiobjective optimization problem. From the user perspective, we show that choosing optimal sets of apps, power consumption and network usage can be reduced by 16.61% and 40.17%, respectively, in comparison to choosing the set of apps that maximizes only the rating. From the developer perspective, we show that it is possible to help developers understanding how far is a new Android app power consumption and network usage with respect to optimal apps in the same category.

Even if ADAGO is able to find optimal sets of apps, thousands of different optimal solutions could exist. This fact is even worse if we consider all the existing apps on the official Android marketplace, which contains more than a million apps. Even if our recommendation tool is able to find optimal combinations of apps, a huge cognitive effort is required by the user to choose one of the optimal solutions. At this point Multiple Criteria Decision Making (MCDM) could be applied to select the most preferred solution regarding user's preferences. In this research we extend ADAGO to include more performance metrics, but also to consider user's preferences in the optimization process.

4 - Supporting Inventory Management with Interactive Multiobjective Optimization

Kaisa Miettinen, University of Jyväskylä, Finland
kaisa.miettinen@jyu.fi
Vesa Ojalehto, University of Jyväskylä, Finland
vesa.ojalehto@jyu.fi
Risto Heikkinnen, University of Jyväskylä, Finland
risto.heikkinnen@statisti.fi
Juha Sipila, JAMK University of Applied Sciences, Finland
juha.sipila@jamk.fi

Lot sizing is important in production planning and inventory management. Typical approaches are limited to considering e.g. only inventory costs or they assume a constant demand. However, such assumptions are not viable in practice. Lot sizing is an example of problems where one can apply data-driven optimization approaches. Actually, there are multiple objectives to be simultaneously considered. A decision maker needs support in lot sizing in particular when the demand is stochastic. Thus, stochastic modelling and multiobjective optimization are needed.

We propose an inventory planning problem formulation for simultaneously optimizing inventory costs, fill rate and inventory turnover. The problem formulation involves Bayesian models to capture the stochastic behaviour of the demand.

In a previous study, we applied an a posteriori method to a similar problem and the need of an interactive approach became evident. In interactive methods, the decision maker typically directs the search for the most preferred solution by providing preference information to move from a Pareto optimal solution to a more interesting one. In this way, the decision maker can learn about what kind
of solutions are available for the problem and also learn about the feasibility of one's own preferences and even change one's mind if needed.

Typically in the literature, one interactive method is applied throughout the solution process. Opposed to this, we propose to apply interactive methods Nonconvex Pareto Navigator and NIMBUS to solve the lot sizing problem and give the decision maker a possibility to switch the method during the solution process. In this way, one can utilize the strengths of different methods. Naturally, this necessitates an environment where switching is convenient.

For example, the decision maker can first learn about the problem and the interdependencies involved and after having gained sufficient insight, then focus on a desired part of the Pareto optimal set. We consider the lot sizing problem of a Finnish production company and utilize their data from the past.

Even though the demand behaviour is challenging, we demonstrate with real decision makers how they can be supported in lot sizing with demand predictions and the support provided by interactive methods in finding the most preferred Pareto optimal lot sizes.

Based on the comments of the decision makers, the possibility of considering all the relevant objectives simultaneously is very helpful and beats the prevailing practice. Furthermore, the interactive solution process has enabled them to lean a valuable lesson about the potential of appropriate lot sizing.

This case is an example of the ever-increasing need of decision support in considering problems where there is data available and one should make the most of the data. The results of data-driven interactive multiobjective optimization are encouraging.

Thursday, 10:30-12:10

THU-2-INV-DMS4120
Invited Session: Optimal Design of Formularies (Reinhardt)
Thursday 10:30 - 12:10 - Room DMS4120
Chair: Gilles Reinhardt

1 - Ranking of Countries Based on Indicators of Innovation by the Method of Multi-Attribute Utility Theory
Rauf Nisel, Faculty of Business Administration, Marmara University, Turkey
rnisel@marmara.edu.tr
Seyhan Nisel, School of Business Administration, Istanbul University, Turkey
sipahi@istanbul.edu.tr

Innovation has always been an important factor in the economic and social development of the countries. Innovation is the main stimulus of economic growth and it helps to improve productivity and welfare. Innovation also provides a crucial commercial advantage in a global competition. That is why it is important for countries to determine their positions in the global market by assessing the contribution of innovation to achieving economic and social objectives.

The purpose of study is to determine ranking of the World’s most innovative countries. Ranking is based on OECD indicators of innovation. In this study OECD indicators are considered by classifying them into two groups as “global positioning indicators” and “thematic indicators”. Global positioning of indicators traditionally used to monitor innovation, and complements them with indicators from other domains that describe the broader context in which innovation occurs. And thematic indicators provide more refined version of positioning indicators and present five key areas of action as empowering people to innovate, unleashing innovation in firms, investing in innovation, reaping the returns from innovation and innovation for global challenges.

The method of our choice is MCDA ranking method of Multi-Attribute Utility Theory due to the structure and size of indicators where its output provides complete ranking with scores without pairwise comparisons.
Intuition has always been a fundamental part of police work. Knowledge in the field by experienced managers of Public Security has proven to be a useful weapon against crime. In most police departments, this experience-based system remains unchanged. However, police intuition may not be taking into account all the factors influencing the evolution of crime. Historically, criminology has shown great interest in the identification of areas with a higher rate of criminal activity. It has been proved that studying historical data allows identifying places where crime tends to agglomerate. Therefore, making use of historical information is fundamental for decreasing crime, as we know that crime has greater chances of happening when there are no security measures and a motivated criminal encounters an appropriate objective. Consequently, in the last decade, predictive policing measures have been developed, with different levels of sophistication, with the aim of providing an analysis of the evolution of crime in a territory. More recently, both academics and practitioners, such as the RAND corporation and the National Institute of Justice of the United States (NIJ), have recognized the need for taking a step forward and developing explicit DSS to provide help to decision makers in law enforcement agencies.

In Spain, the security of towns is the responsibility of the Spanish National Police Corps (SNPC), usually sharing a territory with other local security forces. The SNPC is an armed institution of a civil nature, dependent on the Spanish Ministry of Home Affairs. Among its duties are keeping and restoring order and public safety and preventing the commission of criminal acts. The SNPC is one of the country's most valued institutions, and is at the global forefront of the fight against crime, with the aim of constant innovation. Under the current system, the distribution of agents is determined by the inspectors that coordinate the service during a particular shift. Their experience, accompanied by preliminary information, such as a summary of the criminal activity of the last days, leads them to decide on the allocation of policemen in a whole district.

The socio-economic context in recent years in Spain is that of a severe crisis that has reduced the number of police officers available to the SNPC. Therefore, designing the distribution of agents in a territory has become a complex task, and the lack of personnel can result in a lowered level of security and, as a consequence, in an increased level of crime. The Police Districting Problem concerns the definition of sound patrolling sectors in a police district. In this talk we present the Multi-Criteria Police Districting Problem (MC-PDP), a Police Districting Problem formulated in collaboration with the SNPC. The objective of the MC-PDP is to define a partition on a graph describing the territory under the jurisdiction of a Police District in such a way that the workload of the patrol sectors is homogeneous. The novelty of the MC-PDP model stands in that it evaluates the workload associated to a specific patrol sector according to multiple criteria, such as area, crime risk, diameter and isolation, and that it finds a balance between global efficiency and workload distribution among the agents, according to the preferences of a decision maker (i.e., the service coordinator in charge of the patrolling operations in a police district). Also, the resulting patrol sector are required to be convex, to ensure efficiency. Given the complexity of the model, we solve it by means of a multi-start tabu search. The proposed approach is tested on real crime data from the Central District of Madrid. The results show that the MC-PDP is capable of rapidly generating patrolling configurations that are more efficient than those adopted by the SNPC.
The supply chain of prescription drugs should be designed to meet critical criteria in allowing their consumers access to products through intermediaries who aggregate demand from their participants, extract volume discounts from manufacturers and make available and affordable products that are essential to the health and well-being of the population. Formulary tiering is a mechanism that can make the supply chain of prescription drugs perform better. We discuss analytic designs and multi-criteria decision methods for a coordinated and equitable supply chain, particularly for its upstream segment (manufacturer-insurer, who have conflicting objectives and action sets) and downstream one (plan-consumer, where we model drug-to-tier allocations).

4 - Are provincial formularies optimal?
Vusal Babashov, University of Ottawa, Canada
vbaba051@uottawa.ca
Gilles Reinhardt, University of Ottawa, Canada
Gilles.Reinhardt@telfer.uottawa.ca

We focus on the downstream relationships between benefit management and consumers. In this phase, we assume that the set of products and the formulary structure (number of tiers and copay schedule) are fixed. We develop drug-to-tier allocation models that uses multi-criteria methods to maximize the expected return of the plan, its coverage, and other objective criteria that take into account operational factors (demand, capacity, inventory, and service level), clinical factors (drug effectiveness, interactions, and indications), and economic factors (cost, utility, and preference).

THU-2-INV-DMS4130
Invited Session: Finding a Set of Nondominated Points in Multi-objective Combinatorial Optimization (MOCO)
(Koksalan)
Thursday 10:30 - 12:10 - Room DMS4130
Chair: Murat Koksalan

1 - A Preference-Based Evolutionary Algorithm and Implementation on UAV Route Planning in Continuous Space
Erdi Dasdemir, Hacettepe University, Turkey
edasdemir@hacettepe.edu.tr
Diclehan Tezcaner Öztürk, TED University, Ankara, Turkey
diclehan.ozturk@tedu.edu.tr
Murat Köksalan, Middle East Technical University, Turkey
koksalan@metu.edu.tr

We develop a multiobjective evolutionary algorithm that uses reference point(s) provided by the decision maker (DM) to converge to the preferred regions of the Pareto-optimal frontier. We develop a mechanism that helps the algorithm perform well independent of the shape of Pareto-optimal frontier and the whether or not the reference point is dominated. We test our algorithm on several problems including those having discontinuous Pareto-optimal frontiers. The algorithm allows the DM to change his reference point(s) and continue the search in different regions of the Pareto-optimal frontier. This allows the DM to search different parts of the solution space as he/she gains information on the solution space. Once the DM changes his/her reference point(s), our algorithm quickly converges to the neighborhood of the new point(s).

We implemented the algorithm for multiobjective route planning of unmanned air vehicles (UAVs) that move in a continuous terrain. The aim in this problem is to determine both the visiting order of the targets and the specific trajectories to be used between consecutive target pairs under multiple objectives. The continuous terrain and conflicting objectives lead to infinitely many efficient solutions. It is neither practical, nor meaningful to generate all Pareto-optimal solutions for such a complex problem. In our problem, there are infinitely many trajectory options for each visiting order to the targets. Hence, each individual (solution) in the population corresponding to a tour has a continuous Pareto-optimal frontier, except for special cases. To evaluate the performance of a tour, we develop a special scheme. We demonstrate that the algorithm finds solutions close to the reference point(s) on a number of example problems. We also show that the algorithm converges to new regions quickly when the reference point is changed.
2 - Representing the Nondominated Set for Multi-objective Integer Programs
Ilgin Doğan, Middle East Technical University (METU), Turkey
ilgin.dogan@metu.edu.tr
Sami Serkan Özarık, ASELSAN, Turkey
ssozarik@hotmail.com
Banu Lokman, Middle East Technical University (METU), Turkey
lbnu@metu.edu.tr
Murat Köksalan, Middle East Technical University, Turkey
koksalan@metu.edu.tr

Multi-objective Integer Programs (MOIPs) have a wide variety of application areas. Finding a representative set of nondominated points is an important research area for MOIPs. The representative set could contain as few as several points or as large as all nondominated points. Therefore, finding a representative set can be considered as a generalized version of characterizing the nondominated set. There are approaches that aim to generate all nondominated points, as well as approaches that aim to generate a small set of representative points. Since the number of nondominated points grows exponentially with the problem size and finding each nondominated points is typically hard in MOIPs, generating a subset having “desired properties” is an important problem. The desired properties could naturally differ from application to application. We observe that the distribution of nondominated points may be critical in defining the desired properties of the representative subset to be generated. In this study, we search for common properties of the distributions of nondominated points in various MOIPs. We introduce a density measure and analyze typical distributions of nondominated points for different MOIPs. Once the distribution of nondominated points is known, one may want to generate more points from densely populated regions. Alternatively, one may wish to positively discriminate less dense regions in order to capture the properties of rare solutions in addition to typical solutions.

More specifically, we categorize the nondominated set into regions based on their estimated densities. We then demonstrate different approaches of generating distribution-based representative sets for different MOIPs. We also consider generating points that are not necessarily nondominated but approximate the nondominated set of MOIPs with a desired level of accuracy.

3 - A web-based solution platform for Multi-objective Integer Programs
Banu Lokman, Middle East Technical University (METU), Turkey
lbnu@metu.edu.tr
Gökhan Ceyhan, Middle East Technical University, Turkey
e162742@metu.edu.tr
Murat Köksalan, Middle East Technical University, Turkey
koksalan@metu.edu.tr

In multi-objective integer programs (MOIPs), finding nondominated points is typically hard. There are recent approaches that try to generate all or a representative subset of nondominated points. To the best of our knowledge, there is no publicly-available software to generate such points for any general MOIP. Recognizing the general need for generating nondominated points, we develop a web-based solution platform that generates a set of nondominated points with a desired level of accuracy for MOIPs. The algorithms iteratively generate nondominated points using a decomposition and search method. Based on the desired quality level, the search region is partitioned and reduced progressively by removing the regions that are dominated by previously found nondominated points. We implement these algorithms as an online tool that allows the users not only to generate a representative set satisfying a desired level of accuracy but also to generate all nondominated points. The tool provides the output in terms of the objective function values of the generated nondominated points as well as in terms of the decision variables corresponding to the desired nondominated points. We also maintain a digital library that contains a collection of MOIPs and make their inputs and outputs available to researchers. We demonstrate the platform together with its input and output structures, as well as various other features.
4 - Estimating Weights of Criteria in a Utility Function using a Bayesian Approach
Ceren Tünece Şakar, Hacettepe University, Turkey
cerents@hacettepe.edu.tr
Barbaros Yet, Hacettepe University, Turkey
barbaros.yet@hacettepe.edu.tr

The preferences of decision makers (DMs) in multiple criteria decision making problems can be expressed in the form of weights for the criteria considered. There have been studies that directly assess criteria with respect to each other to estimate these weights; and other indirect approaches used for this estimation. In this study, we assume that the DM evaluates multicriteria alternatives with respect to a weighted additive utility function, and we estimate the weights using a Bayesian approach. The DM is presented with sets of alternatives in consecutive iterations and asked either to choose the most preferred one or to provide a ranking. The proposed Bayesian approach uses the responses of the DM to compute the posterior probability distributions of the weights. These distributions provide more useful information than point estimates of weights as they show both the expected value and uncertainty regarding the weights. The Bayesian approach can also incorporate DM’s judgements about the absolute and relative value of weights by using prior distributions and variable constraints respectively. We make tests with two datasets. Firstly, we consider a portfolio optimization problem with two criteria of expected return and Conditional Value at Risk. We make tests with stocks from NASDAQ. Next, we apply our approach to a university ranking problem with five criteria. We make tests with universities ranked in Times Higher Education.

THU-2-INV-DMS4140
Invited Session: AS4: Decision Support for Services Systems and Companies (Ben Amor, Miranda,Aktas)
Thursday 10:30 - 12:10 - Room DMS4140
Chair: Ahmet Kandakoglu

1 - A Multi-Criteria Selection Approach for a Multi-Strategy to Deal with Drug Shortage
Tarek Abu Zwaida, ETS, Canada
tariq.lutfi@gmail.com
Yvan Beauregard, ETS, Canada
yvan.beauregard@etsmtl.ca
Sarah Ben Amor, University of Ottawa, Canada
benamor@telfer.uottawa.ca

Drug shortage (DS) is the supply of drugs that does not meet the demand, thus compromising the health of patients. Shortage in drug supply affects the preparation of medications, the method of medication administration, and even denial of medication to patients. Medical facilities need to be proactive in their approach in dealing with drug shortage as some of the causes are not within their control. Drug shortage can be caused by voluntary recalls, non-compliance with regulatory standards, lack of raw materials, restricted distribution, manufacturer discontinuation, manufacturer rationing, market shifts, and supply issues. Due to the myriad issues, a multi-strategy approach is required to deal with all the relevant causes of a drug shortage.

The various ways of dealing with drug shortage include the use of Canadian drug shortage database, structured communications with manufacturers/distributors, Just-In-Time delivery, stockpiling, Information and Networking, Gray market, priority-driven dispensing, and alternative therapies. All these strategies are not usable as some can be integrated with each other while others are opposites of each other e.g. Just-In-Time delivery and stockpiling. A Multi-Criteria Decision Making (MCDM) appears as an appropriate approach in determining the best multi-strategy to employ in dealing with a drug shortage. The relevant stakeholders in determining the best strategy are a group of physicians, pharmacist, and purchasing agents as they are the critical parties with regards to effectiveness and procurement activities of drugs. The primary criterion for choosing the best multi-strategy is the quality of patient care. The supportive sub-criteria for the primary criterion include a value for money, legitimacy, compliance, availability, location, reputation, and other relevant variables that may arise.

2 - Classification of consumer complaints in mobile telecommunications using the evidential reasoning rule
Ying Yang, hefei university of technology, China
hfyyonline@126.com
Companies are facing an increasing amount of complaints due to consumers’ high expectations for products or services. Previous research indicates that the majority of complaining consumers continue to buy the same products or services from the same companies compared to those who are unsatisfied but do not bother to complain. Therefore, it is essential for companies to handle consumer complaints in an appropriate, timely and effective manner. The most important step in handling complaints is to categorize them according to their causes. The cause categories of complaints should be clearly defined and exclusive of one another so that the complaints can be assigned to appropriate persons for resolution. Compared with consumer complaints in traditional service industry, those in mobile telecommunications are more immeasurable, complex and often with uncertain information in customers’ feedback. Some complaints are caused by mobile telecommunication network quality while others may be triggered by customers’ mobile phones. The former must be assigned to technical support departments for resolution while the latter can be quickly resolved by receptionists.

Many researchers have developed various techniques to solve this kind of classification problem. However, few studies address the particular case of mobile telecommunications consumers. How to classify these consumer complaints efficiently and effectively for improvement of customer satisfaction is a challenge that is routinely faced by mobile telecommunication companies. This research presents a classification method using the evidential reasoning rule to classify the causes of all complaints into two categories, Mobile Telecommunication Network Quality Class (MTNQC) and Customer Terminal Class (CTC). Firstly, the service attributes related to a complaint are identified. They include: (1) whether the complaint is from an area with weak signal strength; (2) whether there is a compatibility issue between the mobile telecommunication network and the terminal used by the complaint consumer. The values of these service attributes can be obtained from telecommunication systems according to the information associated with consumer complaint records, such as the time stamps of the records and the sites where complaints are triggered. Then each service attribute is turned into the probabilities of MTNQC and CTC by using historical data, which is named a piece of evidence. Each piece of evidence is assigned a weight to reflect the relative importance in comparison with other evidence and a reliability to indicate its ability in recognizing complaint categories. Both the weight and the reliability can be obtained from expert knowledge or self-learning from data. Lastly, the evidential reasoning rule is applied to combine the evidence activated by a certain consumer complaint and to categorize the complaint into the two categories with probabilities. The proposed approach is validated by conducting experiment on the consumer complaint data collected from 410 mobile phone users in a Chinese telecommunication company. While the proposed method is equipped with the inherent features for handling missing data without deletion or imputation and for being independent of the prior classification of consumer complaints, the experimental results also show its high classification accuracy that is competitive with other classical and well-known classifiers, such as Bayesian networks, logistic regression and decision trees. The solution offers telecommunications companies an informative and knowledge-based methodology for handling consumer complaints systematically and automatically.

3 - An overview on decision making methods in obsolescence management

Imen Zaabar, École de Technologie Supérieure, Canada
zaabar.imen@gmail.com
Yvan Beauregard, École de technologie supérieure, Canada
Yvan.Beauregard@etsmtl.ca
Marc Paquet, École de technologie supérieure, Canada
Marc.Paquet@etsmtl.ca
This paper aims to collect, study, analyze, and criticize different works, methods, or tools of decision support in obsolescence management via a literature review. Actually, parts obsolescence has become a big issue especially for long-lifecycle sectors like defense, aerospace, and nuclear where systems need to be maintained for decades. It forbids the maintenance of systems, affects not only their security and readiness, but also disrupts the production line. It is for that reason that obsolescence management now becomes a crucial part of the system design, maintenance, and support activities in long-lifecycle products. The management of obsolescence risk, necessary to ensure industrial competitiveness, is done on 3 levels: proactive, reactive, and strategic. The proactive and strategic levels have been well studied in the literature, the first with prediction tools and the second with the establishment of design refresh planning or the components risk exposure. While in reactive management, most studies have just stated and enumerated the possible solutions. This is not enough for a very complex process with such importance for the profitability and competitiveness of the company and which involves several factors. Choosing the optimal solution that maximizes profit and minimizes impact is not always easy and requires a lot of study and analysis. The result of this work is an overview of different decision making tools that have been used or developed in obsolescence management to allow decision makers to choose the optimal solution responding to their objectives. This work will open up prospects and encourage researchers to develop a general framework for multicriteria obsolescence management based decision making. Collaboration with concerned industries is very important to improve their obsolescence management processes, a risk that increases rapidly in terms of frequency and impact.

4 - SMAA-Based Approach for Course of Action Comparison with Uncertain and Incomplete Information
Ahmet Kandakoglu, Telfer School of Management, University of Ottawa, Canada
kandak@gmail.com

Course of Action (COA) comparison is a critical step of operation planning process whereby COAs are considered independently and evaluated/compared against a set of criteria that are established by the staff and commander. The goal is to support the commander’s decision-making process by identifying and recommending the COA that best accomplishes the mission. However, the uncertainty associated with the results of the COAs and incomplete preference information on the evaluation criteria make the decision process more complicated in practical applications.

Hence, this study proposes a Stochastic Multicriteria Acceptability Analysis (SMAA) based approach for course of action comparison. SMAA is a suitable method that allows the representation of a mixture of different kinds of uncertain, imprecise, and partially missing information in a consistent way. It applies Monte Carlo simulation to provide the ranking of the alternative COAs to find out the best one. Furthermore, SMAA method has the ability to articulate to the commander why one COA is preferred over another. Through an example case study, it has been observed that this approach provides an effective solution for this kind of military problems.

THU-2-CON-DMS4170
Contributed Session
Thursday 10:30 - 12:10 - Room DMS4170
Session: Interactive Methods
Chair: Jussi Hakanen

1 - A sorting and ranking multi-criteria approach based on Delphi and ELECTRE TRI to assess technological innovation policies
Luis Dias, University of Coimbra, Portugal
lmdias@fe.uc.pt
Carlos Henggeler Antunes, University of Coimbra, Portugal
ch@deec.uc.pt
Guilherme Dantas, Universidade Federal do Rio de Janeiro, Brazil
guilhermcvrg@yahoo.com.br
Nivalde de Castro, Universidade Federal do Rio de Janeiro, Brazil
nivalde@yahoo.com
Lucca Zamboni, Universidade Federal do Rio de Janeiro, Brazil
lucca.zamboni@edpbr.com.br
The assessment of public policies to decide which ones should be implemented brings several difficulties. Often, such decisions entail significant economic, social and environmental consequences, which can be costly to reverse, and consequences last for a long period of time. Furthermore, these decisions potentially affect many stakeholders. Although stakeholders may have different views on the problem, their support is important for the implementation of the policies. Finally, committing to or discarding a policy is often a decision made at a stage when the policies have not yet been designed in detail, since the detailed specification of a policy can be costly and time consuming. Multi-Criteria Decision Analysis (or Multi-Criteria Decision Aiding, MCDA) methods are particularly well-suited to address policy assessment problems. MCDA provides a transparent way to encompass multiple and potentially conflicting objectives, facilitating the incorporation of different stakeholder perspectives. This communication presents an MCDA methodology and an application to assess policies based on qualitative assessments from multiple experts or stakeholders. The application aimed at assessing policies to foster technological innovations in the Brazilian electricity sector.

In the structuring stage, a set of policies was identified and a hierarchy of objectives was developed using a structured approach to elicit and organize information gathered in literature, interviews and workshops. Using Soft Systems Methodology (Steps 1-3) the electricity system was analysed under different perspectives, suggesting a large number of issues to be taken into account in an evaluation process. A bottom-up approach was followed to define a set of fundamental objectives associated with fundamental purposes for technological innovation in the electricity sector. Afterwards, a top-down approach ensured no relevant aspects were missing.

The elicitation stage was based on qualitative assessments from 28 experts using a Delphi process. The experts were geographically dispersed and represented different stakeholder perspectives (government, business and knowledge workers). The questionnaire was prepared considering ELECTRE TRI as the MCDA aggregation model that would be used, but it did not assume respondents were familiar with this method. Respondents used qualitative scales to assess the impact of different policies on the fundamental objectives, and to assess the importance of the objectives and the possibility of veto.

The aggregation stage consisted in using ELECTRE TRI to sort the policies into categories related with the implementation priority, from “Uninteresting” to “Implement with maximum priority”. This method evaluates each policy on its merits (independently of other policies) being able to deal with qualitative assessments of performance and not assuming full compensability among the criteria. It was also considered of interest to obtain a ranking of the alternatives that would be consistent with the ELECTRE TRI results. The approach developed in this work translated Delphi qualitative assessments about the importance of the criteria into constraints on the weights. These were the input for a robustness analysis and a stochastic multi-criteria analysis varying some of the model’s parameters (weights and cutting level), suggesting a precise classification for each policy or an interval of possible classifications. A reference-based ranking approach was also developed in this work to derive a ranking of the policies compatible with sorting results, based on a robustness analysis of outranking credibility indices. Results were obtained considering the entire set of experts and considering subsets of experts representing different perspectives.

2 - Using DANP-mV Model to Modify SWOT Analysis for Improving Competitiveness of Private Colleges

Bo-Wei Zhu, Macau University of Science and Technology, China
zhubowei301@gmail.com
Ya-Nan Xing, Harbin Institute of Technology, China
xyn9202@126.com
Lei Xiong, Asia University, China
kmt20005@yahoo.com
Gwo-Hshiung Tzeng, National Taipei University, Taiwan
ghtzeng@gm.ntpu.edu.tw
Shan-Lin Huang, National Taipei University, Taiwan
samlin0668@gmail.com

As a powerful tool for making the structured planning and strategies, SWOT analysis is applied to identify the main internal factors (strengths and weaknesses) and external factors (opportunities and threats) for the
objects. For generating strategies, as a strategy-oriented analysis implementation, conventional SWOT analysis involves the identification of internal and external factors (using the popular 2x2 matrix) only, the selection and evaluation of the most important factors, and the identification of the relationship existing between internal and external features, such as the relationship between strengths and opportunities (S-O), strengths and threats (S-T), weaknesses and opportunities (W-O), and weaknesses and threats (W-T). From a practical point of view, it is an intelligible and usable way to get the strategies. However, the main limitation of this technique is that the evaluation criteria are independent of the assumptions, while in real-life the relationship between them is often characterized by a certain degree of interaction, interdependence and feedback effects. Whereas, the advantage of DANP-MV (DEMTEL-based ANP with modified VIKOR) model is how to reduce the performance gap toward closing zero in all criteria of the four SWOT factors by taking into account the influential relationship between these criteria. Therefore, from a comprehensive and systematic point of view, developing the strengths and avoiding the weaknesses under the influences of the external factors (S-W-O, S-W-T or S-W-O-T) should be taken into consideration at the same time in order to improve towards achieving the aspiration level. Thus, for releasing previous assumption and making strategies more effectively, this paper adopts DANP-MV model to modify the conventional SWOT analysis. Then, an empirical case of the modified SWOT method is presented how enhancing the competitiveness on marketing operations of private colleges in Taiwan, where is facing the demographic dilemma of fewer children. Under this trend of demographic change, the number of existing private colleges seem to be excessive, which results in more heated competition among existing private colleges. Therefore, this paper uses the new model to apply to the real case, and then discuss how to create strategies for improving competitiveness of private colleges towards the best private college under the influence of the external factors.

3 - Interactive K-RVEA: interactive evolutionary multiobjective optimization algorithm for computationally expensive problems

Jussi Hakanen, University of Jyväskylä, Finland
jussi.hakanen@jyu.fi
Tinkle Chugh, University of Jyväskylä, Finland
tinkle.t.chugh@jyu.fi
Karthik Sindhya, University of Jyväskylä, Finland
karthik.sindhya@jyu.fi
Yaochu Jin, University of Surrey, United Kingdom
yaochu.jin@surrey.ac.uk
Kaisa Miettinen, University of Jyväskylä, Finland
kaisa.miettinen@jyu.fi

We introduce an interactive evolutionary multiobjective optimization method for computationally expensive problems, called interactive K-RVEA. By computationally expensive problems we here refer to problems where the evaluation of objective function values is time consuming (e.g., computationally expensive simulation based problems). As an interactive method, where a decision maker is continuously involved in the solution process, the developed method is aimed at nonlinear problems with more than three objective functions. The contribution is to introduce an algorithm that combines an interactive solution process, different ways for the decision maker to express preferences, an efficient evolutionary approach for solving problems with more than three objectives, and surrogates for handling computationally expensive functions. As far as we know, no currently available algorithm contains all the features mentioned above.

Interactive K-RVEA is based on the surrogate-assisted reference vector guided evolutionary algorithm for computationally expensive many-objective optimization (K-RVEA). K-RVEA trains a Kriging model to each computationally expensive objective function separately and the underlying mechanism is based on reference vectors. At each generation, parent and offspring populations are combined and their member individuals are associated to the closest reference vectors. Then, the individuals for the next generation are selected by using an angle penalized distance so that one individual corresponding to each reference vector is selected (note that the number of reference vectors is equal to the population size). After a fixed number of generations utilizing the Kriging models, a pre-defined number of individuals is selected to be evaluated with the original functions in
order to update the Kriging models based on both uncertainty and diversity.
The steps of the interactive K-RVEA algorithm are the following. First, the (Latin hypercube) sampling is used to generate the initial training data in the whole search space. Then, a Kriging model is trained for each objective function and K-RVEA with a uniformly distributed set of reference vectors is run for a fixed number of generations by using the Kriging models. The obtained non-dominated solutions are then shown to the decision maker for evaluation. If there are more solutions than the decision maker wants to see at a time, the set is reduced accordingly, e.g. by clustering, and only the resulting solutions are shown. After evaluating the solutions, the decision maker expresses preferences on which part of the Pareto optimal front to guide the search. By using the preferences, the set of reference vectors is then modified accordingly and K-RVEA is again run for a fixed number of generations to obtain improved solutions. This iterative solution process is continued until the decision maker is satisfied with the obtained solutions or until the budget of expensive function evaluations is exhausted. The output of the algorithm is a most preferred non-dominated solution with respect to the latest preferences.

At any interaction of the interactive K-RVEA, the decision maker is able to express preferences in different ways: 1) selecting preferred solutions, 2) specifying non-preferred solutions, 3) specifying a reference point, or 4) specifying preferred ranges for the objectives. It is also possible to express different types of preference information to different objectives. The preference information provided by the decision maker is then used to modify the set of reference vectors which is further used for guiding the evolutionary search within K-RVEA. Note, that the number of reference vectors used (and, thus, the population size) with the decision maker’s preferences is typically much smaller than when an approximation for the whole Pareto front is targeted. The ability to express preferences in different ways in different phases of the solution process provides the decision maker with a flexibility to guide the search as well as a possibility to express preferences in a way that suits the decision maker best. The new method has been tested by using both benchmark and real-world problems and promising results have been obtained. We also propose a user interface for the method enabling visual interaction for the decision maker to analyze the existing solutions and to express new preferences to improve them. The versatile ways of interaction allow the decision maker to flexibly analyze the solutions available and to express preferences in a way that is suitable for the current decision making phase and the desires of the decision maker. Thanks to the surrogates, the decision maker does not need to wait for solutions to be generated based on the preferences specified. Thus, the underlying mechanisms based on surrogates enable an efficient search of the objective space with respect to the limited amount evaluations with the real computationally expensive functions.

Thursday, 13:30-14:50
THU-3-INV-DMS4130
Invited Session: AHP/ANP Theory and Applications in Supply Chain Management and Industrial Engineering II (Karpak, Buyukozkan, Guleryuz)
Thursday 13:30 - 14:50 - Room DMS4130
Chair: Birsen Karpak

1 - Using the Analytic Hierarchy Process Decision Making Model for International Expansion: Analyzing Germany, India, The United Kingdom and Brazil
Crystal Thomas, Youngstown State University, USA cmthomas03@ysu.edu
Erin Whitehouse, Youngstown State University, USA emwhitehouse@student.ysu.edu
Matthew Yourstowsky, Youngstown State University, USA mryourstowsky@student.ysu.edu
Robert Woolley, Youngstown State University, USA rgwoolley@student.ysu.edu
Birsen Karpak, Youngstown State University, USA bkarpak@ysu.edu

In 2016, the United States exported $2.2 trillion of products and services around the world, promoting business growth and stability. In this study, the authors utilized the analytic hierarchy process (AHP) decision making model to select the optimal market for international expansion for the company. The benefits of exporting to four different countries:
Germany, India, The United Kingdom and Brazil were analyzed. Research included multiple factors about these four countries. Market size, market growth rate, market consumption capacity, market intensity, market receptivity, commercial infrastructure and country risk were the statistical criteria specifically considered. Importance of each criteria and subcriteria were determined with export market experts and company decision makers. Authors guided the process with Expert Choice 11.5, decision-making software to elicit the most accurate yet easy to use elicitation method. The software enabled the authors to determine the best possible export market for the company by comparing and contrasting the data from Germany, India, United Kingdom and Brazil. The results were tested for robustness using the sensitivity analysis features of the program. Sensitivity analysis results were then discussed with the decision makers. The best market was selected and alternative markets were presented with degrees of preference. Managerial implications of the study and future research directions will be discussed.

2 - Inconsistency in the ordinal pairwise comparisons method with and without ties
Konrad Kulakowski, AGH University of Science and Technology, Poland
kkulak@agh.edu.pl

Comparing alternatives in pairs well-known method of ranking creation. In this approach the experts are asked to perform a series of binary comparisons. As experts do the individual assessments, they may not always be consistent. The level of inconsistency among individual assessments is widely accepted as a measure of the ranking quality. The higher the ranking quality, the greater its credibility. One way to determine the level of inconsistency among the paired comparisons is to calculate the value of inconsistency index. One of the earliest and most widespread inconsistency indexes is consistency coefficient defined by Kendall and Babington Smith. In their work, the authors consider binary pairwise comparisons, i.e., those where the result of an individual comparison can only be: better or worse. The presented work extends the Kendall and Babington Smith index to the set of paired comparison with ties. Hence, this extension allows the decision makers to determine the inconsistency for sets of paired comparisons that can result “worse,” “better” or “equal” To capture the quantitative relationship between the consistent and inconsistent triads of pairwise comparisons new absolute inconsistency index is introduced. The paper contains definition and analysis of the most inconsistent set of pairwise comparisons with and without ties. In particular, for the first time, the number of inconsistent triads in the ordinal pairwise comparisons matrix with ties is given. It is also shown that the most inconsistent set of pairwise comparisons with ties is also a solution of a particular case of a set cover problem.

3 - A Fuzzy Framework to Evaluate Service Quality in Turkish Public Hospitals
Sezin Güleryüz, Bartın University, Turkey
sezinguleryuz@gmail.com

This study presents an effective new evaluation model with Group Decision Making (GDM) based Multi Criteria Decision Making (MCDM) framework for evaluating the performances of Turkish public hospitals. Since service industry contains intangibility, inseparability and heterogeneity, it makes people more difficult to measure service quality. As the evaluation is resulted from Decision Makers’ (DMs) view of linguistic variables, it must be conducted in an uncertain, fuzzy environment. In order to overcome the issue, fuzzy set theory is invited into the measurement of performance. The proposed models’ structure is a network hierarchy and able to evaluate various alternatives, Analytic Network Process (ANP) is utilized, which can successfully handle dependencies among decision criteria. The ANP approach has major advantages: Firstly, by using ANP, the criteria priorities can be determined based on pair wise comparisons by DMs evaluation, rather than arbitrary scales; secondly, DMs can consider both tangible and intangible factors; thirdly, ANP can transform qualitative values into numerical values for comparative analysis; the fourth one is being simple and intuitive approach that DMs can easily understand and apply it without specialized knowledge; the fifth one is to allows participation of all DMs in the decision making process. The Decision Making Trial and Evaluation Laboratory (DEMATEL) technique have the ability to pinpoint
the mutual relationships and the magnitude of the dependencies among the decision criteria. It can also be applied to establish causal diagrams that are able to visualize the causal relationship of sub-systems. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is utilized to rank the alternatives. TOPSIS is one of the best known MCDM methods based on the concept that the chosen alternative should have the shortest distance from the positive-ideal solution, and the longest distance from the negative ideal solution. The positive ideal solution is the solution which maximizes the benefit criteria as well as minimizes the cost criteria, also the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria. These MCDM methods require DMs to handle complicated situations by appraising many criteria simultaneously but differently to offer the most appropriate result.

In many practical situations, particularly in the process of GDM, the DMs may come from different research areas and thus have different ways of thinking and levels of knowledge, skills, experience, and personality. When DMs may not have enough expertise or possess a sufficient level of knowledge to precisely express their preferences over the criteria, these challenges can be solved with the use of GDM considering a common interest to reach collective decision. It should be pointed out that applying only one of these techniques would already have been satisfactory in an MCDM problem. However, by integrating these three techniques in combination, the procedure is improved in terms of efficiency and effectiveness. According to surveyed literature, DEMATEL, ANP and TOPSIS techniques are applied in different areas (logistics, education, supply chain etc.). In recent years, there are some studies that use DEMATEL, ANP, TOPSIS methods together but it is believed that there has been no studies that consider DEMATEL, ANP and TOPSIS integrated methodologies in healthcare sector and this is the contribution of the study.

4 - Evaluation of Transportation Modes Using an Integrated Dematel-ANP Approach

Gulcin Buyukozkan, Galatasaray University, Turkey
gulcin.buyukozkan@gmail.com
Ugur Karadag, Galatasaray University, Turkey
karadag_ugur@yahoo.com

For a global logistics company, decision-making processes constitute a prioritized business component due to their complex and sophisticated nature. It is not just about being in the right place at the right time but also about the flexible of managing the whole process. Several studies have focused on transportation modes evaluation by means of various MCDM models. Based on a detailed literature survey and discussions with experts, an MCDM approach is applied in this study using the Decision Making Trial and Evaluation Laboratory Model (DEMATEL) technique, integrated with Analytic Network Process (ANP) for the evaluation of transportation modes in Turkey. This integrated DEMATEL-ANP structure comes in handy for identifying and exploring the influential weights of attributes of policy implementation. DEMATEL is used for extracting the mutual relationships and strength of interdependencies among criteria. ANP is used for successfully handling dependencies among decision criteria, providing a valuable evaluation tool. The paper contributes to the development of an evaluation model that is able to deal with real business situations. As a case study, the proposed method is applied on the mode selection problem of an international logistics company based in Turkey, a country where a plethora of intermodal logistics improvements have been exerted and still some policies and improvements are ahead. The results are analyzed over the cause-effect relationship. Managerial recommendations are provided, which may enhance the flexible precision of the logistics decision-making and support decision makers to plan their strategic logistics improvements

THU-3-INV-DMS4140
Invited Session: AS5: Prospects and Future Challenges on MCDA/M (Ben Amor, Miranda, Aktas)
Thursday 13:30 - 14:50 - Room DMS4140
Chair: Joao Luis de Miranda

I - Computational analysis for the design of bias mitigation methods in preference elicitation

Raimo Hämäläinen, Aalto University, Finland
raimo.hamalainen@aalto.fi
Tuomas Lahtinen, Aalto University, Finland
In the practice of decision analysis the need to consider biases originating from various cognitive, motivational and social phenomena has been recognized for long (see, e.g. von Winterfeldt and Edwards 1986). We show how computational analysis can help at finding new ways of reducing biases, i.e. debiasing (see, e.g. Montibeller and von Winterfeldt 2015, Lahtinen and Hämäläinen 2016), in preference elicitation. The earlier related studies have considered the design of preference assessment tasks with reduced bias, adjusting the responses, averaging the responses, and training decision makers.

Computational analysis is a potentially useful approach to evaluate the effectiveness of debiasing techniques and methods before incorporating them in real processes. Testing debiasing approaches in practice with people can be time consuming and difficult. A behavioral experiment typically focuses on the effect of a single bias in an isolated step. Computational support can help in particular in assessing the overall effects of multiple biases that occur at different steps along the preference elicitation process. Naturally, a prerequisite for a computational analysis is that we have a model of the effects of the related biases. Such models are available, see e.g. Anderson and Hobbs (2002) and Lahtinen and Hämäläinen (2016).

We discuss several techniques for reducing the overall effects of biases. The general new idea is to reduce the overall effect of biases by finding a favorable path to be followed. Path is the sequence of steps, or tasks, carried out in the preference elicitation process. Typically many alternative paths are available and the choice of path can matter (Lahtinen and Hämäläinen 2016, Hämäläinen and Lahtinen 2016). Earlier, the basic debiasing approach has been to reduce biases in the individual steps that form the path. Yet, training people to avoid biases is not necessarily easy nor very successful (Hämäläinen and Alaja 2008). Reducing biases by adjusting the numerical judgments given by experts and stakeholders has also been suggested. However, it is problematic as people may not trust the results which have been technically adjusted or corrected by the analyst. An alternative approach is to test different paths and compare the results or possibly take an average of them, but this can be very time consuming.

Our first new technique is to introduce a virtual reference alternative to set the path towards a desired bias reducing direction. The second one is to introduce a virtual measuring stick attribute. The third approach is to reduce the effects of biases by the choice of the measuring stick. The fourth one is to design a path where the effects of biases cancel out. The fifth one is the intermediate restarting of the process in order to eliminate the impacts of biases that have accumulated during the earlier steps.

In a computational example we evaluate new bias mitigation methods for the Even Swaps process (Hammond et al. 1998). The methods make use of the five techniques described above. We assume a decision maker whose choice behavior exhibits both, the loss aversion bias and the measuring stick bias, and includes random response errors. This is modelled as in Lahtinen and Hämäläinen (2016). The new bias mitigation methods are compared with each other and against the attribute elimination method which is used as the standard reference method. The settings studied vary with respect to the size of the decision problem, the weight profiles used, as well as in the magnitudes of bias and random response error. In each setting, the methods are compared in randomly generated consequences tables. The performance measure used is the percentage of cases when the result is the same alternative as in a bias free process. Our analyses show that all of the proposed new bias mitigation methods perform better or at least equally well as the standard reference method.

References
Decision-making is a phenomenon we face every step of our lives. In the morning, selection of clothes to be worn in the morning, determination of the brand of the car to be purchased, determination of the stock to be invested in the stock exchange, and determination of the most suitable place to be made in the nuclear power plant can be cited as examples. If there are more than one criteria in the decision-making process, this is a Multi-Criteria Decision Making (MCDM) problem. A large number of methods have been developed from the beginning of the seventies to solve the MCDM problems. In order to achieve the best solution in a MCDM problem, different MCDM techniques can be used. Different methods may suggest different solutions. Which method provides the best solution for the problem, finds itself as a new problem in itself. In this study the regression approach has been proposed as a new approach for choosing the best MCDM method for the given problem. The proposed approach builds on the goodness of fit between decision matrix and preference ordering. Most of the MCDM methods use a decision matrix to make a preference order among alternatives. The relationship between decision matrix and preference order can be modeled by regression model. The goodness of fit of the regression model reflects the quality of the ordering. One of the most widely used tool to measure goodness of fit is the coefficient of determination. The higher the coefficient of determination of a prediction model, the better the agreement between the data and the model. The high coefficient of determination in the regression prediction model between the MCDM method results and the decision matrix reflects the suitability of the results of the method for the problem. Therefore, the MCDM method used in the model that obtains the highest coefficient of determination is the best method. In this study, TOPSIS, VIKOR and CP methods were preferred as MCDM methods. Randomly generated data set is used as application data.

In order to solve the given problem in this study, a regression approach is proposed in which the most appropriate MCDM method is selected. This recommendation can choose among methods that can make a full preference order among alternatives. The scores assigned by the MPWS methods are shaped by the given decision matrix. Therefore, there is a relationship between decision matrix and scores. This relationship can be expressed by a regression model. In this model, the criterion is independent variables and the scores assigned to the alternatives by KKV method are also included as dependent variables. We express the population regression model as follows:

\[ Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \epsilon \]

Where \( Y \) is the score value and \( X_{i,i} = 1,2,\ldots,n \) are the criteria. \( \beta_k \), \( k=0,1,2,\ldots,n \) are the parameter coefficients. For the given MCDM problem, the decision matrix and the scores assigned by the MCDM method will be an sample for predicting the master mass regression model. The estimation model:

\[ \hat{Y} = \hat{\beta}_0 + \hat{\beta}_1 X_1 + \hat{\beta}_2 X_2 + \ldots + \hat{\beta}_n X_n + \epsilon \]

Where \( \epsilon \) is the random error term of the prediction model. If we use more than one MCDM method to solve the given problem, and there is a difference in the preference order that the methods suggest, then the parameter estimates will change. In other words, different model estimates will be obtained for each MCDM method. Our mind is the first question that comes first; “Which one of these models is better?” Of course, the goodness of the model prediction implies
the goodness of fit between the decision matrix and the ranking preference. So we can say that the best model is the model with the best preference order. As a result, the best method for obtaining the best model is the MCDM method, which is the most suitable method for solving the given problem. The coefficient of determination \( r^2 \) is a very useful measure for measuring the goodness of fit between the sampling regression line and the data. In the regression models established between the decision matrix obtained by each MCDM method, the MCDM method with the highest \( r^2 \) value is the appropriate method for the given problem.

Strengths of the regression approach;
1. To arrive at a definite judgment by making a numerical score assignment for the MCDM methods,
2. Being completely objective and based on mathematical and statistical methods,
3. Preservation of decision-makers or other external influences.

Weak aspects of the regression approach;
1. Evaluation for the CRLP methods which can perform exact ranking among alternatives can do,
2. In order to be able to estimate the regression model, the number of alternatives should be more than the number of criteria.

3 - Subdividing the Criterion Cone for the Computation of Efficient Extreme Points in Multiobjective Linear Programming

Ralph Steuer, University of Georgia, USA
rsteuer@uga.edu
Craig Piercy, University of Georgia, USA
cpiercy@uga.edu

This paper is concerned with reducing the time required to obtain all efficient extreme points in multiple objective linear programming, particularly in problems with large numbers of efficient extreme points. By investigating different schemes for subdividing the criterion cone into subset cones, the paper shows how the task of computing all efficient extreme points can be split into parts. By being able to solve the parts of a given scheme concurrently, a range of options is demonstrated for being able to compute all efficient extreme points of problems possessing large numbers of such points in quite reduced elapsed time.

4 - Multicriteria Decision Planning with Anticipatory Networks

Andrzej M.J. Skulimowski, Dept. of Decision Sciences, AGH University of Science and Technology, Kraków, Poland
ams@agh.edu.pl

This paper presents some recent extensions of the Anticipatory Networks (AN) decision modelling tool in the context of their applicability in MCDM and multicriteria sustainable planning. AN provide constructive algorithms to computing nondominated solutions that comply with the anticipatory preference structure. Specifically, we will show how to apply the anticipatory decision-making principles to construct and filter scenarios that correspond to the rational future visions. AN-based assessment processes allows one to select a subset of normative scenarios, then run an AN-based backcasting. A best-compromise scenario describes the most desired future and starts from the present-day best-compromise decision.

Anticipatory networks (AN) are a new tool in multicriteria decision making that is strongly related to researching the future. It formalises multi-stage multicriteria forward planning and multicriteria backcasting. AN generalise earlier anticipatory models of decision impact in multicriteria problem solving and constitute an alternative decision model to utility or value function estimations and to diverse heuristics. In this model a multicriteria decision problem is modelled as a starting node in an anticipatory network, while the other nodes model the consequences of the decisions to be made or other multicriteria problems that depend on other problems or their consequences in a network. The decision choice is made based on a constructive analysis of future causal relations that link the outcomes of the initial MCDM problem with their future consequences. Furthermore, it is assumed that future decision makers take into account the anticipated outcomes of some future decision problem linked by the causal relations with the problem being just solved. This supplements the causal network of decision problems by relations of anticipatory feedback. The latter allow to confine the sets of admissible nondominated decisions at starting nodes of anticipation. When making their choice, the decision
makers explore the causal dependence of constraints and preferences in future decision problems on the outcomes of the decision just made. Since only some decisions may lead to desired consequences, this allows the decision makers to construct and apply an additional preference structure to the originally existing at the initial problem. Thus an Anticipatory Network is a multigraph which consists of both types, causal and anticipatory relations. Usually, it is supplemented by forecasts and exploratory scenarios regarding the future decision model parameters, a preference structure over the set of anticipatory feedbacks, an information exchange relations between decision makers which are not connected by a causal relations and so on. All they form a complex information model.

ANs modelling a real-life decision problem can be built with the following information about the future:

- Exploratory scenarios or forecasts concerning the parameters of future decision problems represented by the decision sets $U$, criteria $F$, the preference models $P$ of the future decision makers, and their attitudes towards anticipatory planning (rational/partly rational/irrational).
- The causal dependence relations $r$ linking the nodes in the network.
- The anticipatory feedback relations pointing out which future outcomes are relevant when making decisions at specified nodes.
- Algorithms filtering the plausible exploratory scenarios taking into account the preference information contained in an anticipatory network $G$ may be applied if we know that:
  - All future agents whose decisions are modelled in the network are rational, i.e. they make their decisions complying with their preference structures.
  - An agent can assess to which extent the outcomes of causally dependent future decision problems are desired. This relation is described by multifunctions linking present-time decisions with future constraints and preference structures.
  - The above assessments are transformed into decision rules for the current decision problem. It should also be assumed that the latter affects the outcomes of future problems in a known way.
  - There exists a relevance hierarchy $H_1$ in the network $G$: usually the more distant in time an agent is (modelled by a node in $G$), the less relevant the choice of his/her solution.

- There exists a family of relevance hierarchies $H_2$ of anticipatory feedbacks in the network $G$: usually the more distant in time an agent is, the less relevant the choice of her/his solution.

The above hierarchies allow the decision maker at the initial problem to derive a partial order that defines the sequence of operations in a decision selection algorithm. This decision making process is equivalent to filtering the set of all causal chains in the network that are determined by sequences of admissible decisions made along all causal paths.

We will also present a few application examples of the AN decision model, including:

- Planning the future operation and development of an innovating digital knowledge platform with multiple criteria related to financial sustainability and social benefits (cf. www.moving-project.eu).
- Building a strategy to align R&D investment projects at the regional or country level to a sustainable development strategy based on smart specializations. A real-life example refers to the strategy planning for a regional Creativity Support Centre.
- Selecting technological investment strategies for a software company. The AN allow the management to better assess the development costs and the corresponding impact on other company’s activity areas.
- Constructing multicriteria decision making models for a swarm of autonomous vehicles.

The anticipatory models benefit from a synergy with other analytical foresight and forecasting methods and IT tools such as a foresight support system (FSS) and an online multiround Delphi management system (cf. www.moving-survey.ipbf.eu).

THU-3-CON-DMS4170
Contributed Session
Thursday 13:30 - 14:50 - Room DMS4170
Session: Multi Objective Optimization
Chair: Ana Ruiz

1 - Practical Decision Making for Distribution Network Management based on Evolutionary
This study considers the practical decision making of the distribution network operator. In distribution networks, the electricity power is supplied from distribution substation to all consumers in which the line voltage is controlled within the allowable range by adjusting the sending voltage of the transformers in the substations. Since each transformers manages voltage at nodes connected to each transformer, the maintenance and replacement are also performed for each transformer. If there are M transformers in the distribution network, namely, the distribution network operator addresses M objectives optimization problem.

The voltage profile can also be adjusted by changing the states of section switches (ON or OFF) on distribution lines and hence the operation of transformers can be managed by changing the network topology depending on the states of the section switches. The distribution network reconfiguration problem is difficult to solve because the problem is non-convex and has strict constraints. In addition to that, there is a heavy computational burden to calculate the time-series voltage profile in which nonlinear power flow equations are iteratively solved.

Since the Pareto front is unknown to the network operator due to the non-convexity and strict constraints, the network operator cannot specify the preferred solution in advance. Accordingly, in this paper, we propose a method to find a preferred solution after searching the Pareto front. First, the multi-objective optimization problem is solved using the evolutionary algorithm, i.e. NSGA-III, to get approximated Pareto optimal solutions within a practical time. Since the Pareto optimal solutions are not uniformly spread in the solution space due to the non-convexity, we try to get approximate Pareto front by multiple runs of NSGA-III with different initial population. To find good Pareto front efficiently, the appropriate crossover and mutation operators based on the graph theory are used to generate the offspring with guaranteed radial network topology. Next, the network operator specifies reference points based on the obtained Pareto front. If the specification is difficult for the operator due to large objective dimensions M, visualization techniques are used so that the network operator can recognize the correlation and conflict between solutions visually. After that, better solutions for the network operator are searched by the local search. This procedure enables the network operator to find a solution within a practical time which satisfies the preference of the network operator.

2 - A Feasibility Pump and Local Search Based Heuristic for Bi-objective Pure Integer Programming

Aritra Pal, University of South Florida, USA
aritral@mail.usf.edu
Hadi Charkhgard, University of South Florida, USA
hcharkhgard@usf.edu

We present a new heuristic algorithm to approximately generate the nondominated frontier of a bi-objective integer program. The proposed algorithm employs a customized version of several existing algorithms in the literature of both single-objective and bi-objective optimization. Moreover, it has an additional advantage that it can be naturally parallelized. An extensive computational study shows the efficacy of the proposed method on the existing standard test instances in which the true frontier is known, and also some large randomly generated instances. We compare a basic version of our algorithm with NSGA-II. Also, we numerically show the value of parallelization on the sophisticated version of our approach.

3 - On the decision makers and the MCDA techniques they choose. The results of an online decision making experiment

Marzena Filipowicz-Chomko, Bialystok University of Technology, Faculty of Computer Science, Poland
m.filipowicz@pb.edu.pl
Ewa Roszkowska, University of Bialystok, Faculty of Economic and Management, Poland
e.roszkowska@uwb.edu.pl
Tomasz Wachowicz, University of Economics in Katowice, Department of Operations Research, Poland
tomasz.wachowicz@ue.katowice.pl

There is a number of research, in which the problem of selection of an adequate decision support method
and tool is studied (e.g. [2; 4]). Apart of the technical
issues, there are also various behavioral characteristics, such as the decision maker’s (DM)
cognitive capabilities, number sense or thinking mode
that may influence the use of decision support tools
and the results obtained [1; 3; 6]. Our earlier research,
focused on the multiple criteria decision support in the
online negotiation, confirmed the problems the
negotiators have with building the accurate
negotiation offer scoring systems by means of
technically simplest decision support technique such
as the direct rating (a SMARTS-like approach) [7]. All
these results show that it is both theoretically
challenging and pragmatically required to analyze the
DMs’ individual capabilities and skills in using
decision support tools as well as to recognize what are
the tools that fit best the cognitive profile of the DM
and hence, are most efficient in the decision support
process.

In this paper we analyze the applicability of selected
decision aiding methods to build the reliable scoring
system in the multiple criteria decision making
(MCDM) problem. The online MCDM experiment
conducted by means of dedicated Electronic Survey
Platform (ESP) is described, in which more than 1000
participants took part, mostly the bachelor and master
students of five Polish universities. The students-
oriented decision making problem implemented in the
ESP was simple but not trivial; it required building the
ranking of five alternatives each describing a potential
flat to rent for the forthcoming semester. All five
alternatives were described by means of five
evaluation criteria and were efficient (no Pareto-
domination occurred). For each criterion different
evaluation scale was used; e.g. there was a purely
quantitative criterion (rental cost) expressed by means
of crisp values, as well as the mixed
quantitative/qualitative one such as number of rooms,
which simultaneously specified their organization
(kitchenette, open kitchen etc.) or the quantitative
“commuting time” expressed by means of intervals.

The experiment consisted of the six following stages:
(1) filling a pre-decision making questionnaire
(personal and demographical data collected); (2)
learning the decision making problem; (3) subjective,
holistic declaration of the ranks of alternatives (no
decision support used); (4) analyzing the problem with
the decision making support provided; (5) comparing
the results obtained and (6) filling the post-decision
making questionnaire.

Three decision support methods were implemented in
stage four: direct rating (SMARTS-like scores
allocation), TOPSIS and AHP. Within stage five the
participants were asked to compare the results
obtained by means of different support techniques and
choose the one that was capable to reflect their
preferences best. We compared their choices with the
subjectively defined rankings in the pre-decision
making stage to control the consistency level of their
decisions. Then, within stage six, they were asked to
evaluate in details each of decision support technique
describing their pros and cons (both open and close
questions were used) and choose one of them, which –
according to their subjective opinion – is most
universal and could generally be applied to any
decision making problem. We compared their
decisions with those made within stage five to find
whether their evaluations are concordant.

Surprisingly, we found that very many DMs selects
other techniques as universal from those they had
chosen earlier as the ones best representing their
preferences.

In stage six the different profiling mechanisms were
also implemented to determine the general decision
making profiles of the participants. In different runs of
the experiment either Rational-Experiential Inventory
[5] or Bruce-Scott test [8] were used. Based on these
tests’ results we tried to verify, if the DM’s choices
and support technique evaluation depend on the DM’s
profile. Unfortunately, no sound conclusions on this
could be drawn neither from REI nor Bruce-Scott
tests.

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References


4 - A new approach in MCDM: Supporting DM decision and stakeholders strategy choice using quantitative information from sensitivity analysis

Nolberto Munier, Valencia Polytechnic University, Spain
nolmunier@yahoo.com

Eloy Hontoria, Universidad de Cartagena, Spain
eloy.hontoria@upct.es

Fernando Jimenez, Valencia Polytechnic University, Spain
ffjimenez@ingenio.UPV

This paper deals with sensitivity analysis and the examination of results obtained using Multi Criteria Decision-Making Models. Nowadays, most of the Decisions-Makers do not have a clear methodology to ascertain the most important criteria to be varied; they just act over the criterion with the maximum weight, which variation does not produce any relevant information, other than indicating when the ranking changes.

These authors deem that the actual procedure used in most, if not all models, does not fulfill the needs of the decision-maker and/or stakeholders of a company, promoter or owner. The reason is that variations of certain inputs of the problem in order to examine the behaviour of the solution found, does not contribute in providing a clear panorama of the situation, especially when variations are due to external factors for which there is no control.

This paper proposes an innovative methodology for analysing the behaviour of the solution found, that is, the response of the output to variations of key inputs. The usefulness of this new approach for sensitivity analysis can be appreciated by considering that it takes into account how the main objectives of the company are satisfied, by given quantitative and graphical information of their evolution, that is increases or decreases as a function of potential variations that may occur in real life. It allows stakeholders to make quantitative comparisons between potential effects and the values that the company has established a priori.

Because the full quantitative and graphic information it supports the DM decisions, and allows him to answer questions form the stakeholders relative to his decision. Regarding stakeholders the quantitative information given on benefits, costs, environmental issues etc, gives them the possibility of adopt the most convenient strategy, which may even reverse the selection of the best alternative delivered by the MCDM model, in this case SIMUS.

Friday, 9:00-11:00

FRI-1- DMS4101
Session: Award Talks
Monday 9:00 - 10:00 - Room DMS4101
Chair: Theodor Stewart
Friday, 11:30-12:20

Friday, 11:30-12:20

FRI -2-CON-DMS4120
1 - A new group target setting model for performance analysis

Cong Xu, The university of Manchester, United Kingdom
136603990@qq.com
Huaying Zhu, Manchester university, United Kingdom
december.zhy@gmail.com
Jian-Bo Yang, Manchester university, United Kingdom
jian-bo.yang@manchester.ac.uk
Yu-Wang Chen, Manchester University, United Kingdom
Yu-wang.Chen@manchester.ac.uk

How to set appropriate target plays an essential role in organizational performance analysis and improvement. The target setting process normally involves multiple decision makers with different knowledge backgrounds, which can make the process complicated. In this research, we propose a new piecewise linear model based on Data Envelopment Analysis (DEA) and Evidential Reasoning (ER) approach. In this model, the opinions from a group of decision makers with different weights are aggregated to search the most preferred target in a continuous possibility set by referencing existing peers’ performances. Comparing with traditional DEA or Multiple objective optimization models, the proposed model are more effective when decision makers are not sensitive for the target in a certain range and when a group of decision makers need to find a most preferred solution in a continuous range instead of finite alternatives. The model has been applied to help a Chinese state-own bank set targets for its 112 branches.

2 - On the MCDEA model and its extensions - A critical reflexion based on a case study

João Clímaco, INESC-COIMBRA, University of Coimbra, Portugal
jclimaco@fe.uc.pt
Ana Paula Rubem, Decision-Aid Department - Center for Naval Systems Analysis, Brazil
anarubem@bol.com.br
João Mello, Production Engineering Department - Fluminense Federal University, Brazil
jcsmello@pesquisador.cnpq.br
Lídia Meza, Production Engineering Department - Fluminense Federal University, Brazil
lidia_a_meza@pq.cnpq.br

DEA is a technique enabling the calculation of a single performance measure (efficiency) to evaluate DMU’s (Decision Making Units).

In many cases the classical DEA models have not sufficient discriminant capabilities regarding the efficiency of the DMU’s. This is the case when “the number of DMU’s under evaluation is not large enough compared to the total number of inputs and outputs” (Li and Reeves, 1999)). Secondly, a DMU can be efficient with non-zero multipliers in a few variables.

(Li & Reeves, 1999) presented a tri-criteria model, incorporating additional objectives besides the classical DEA objective function (designated by MCDEA) with the aim of mitigating the above referred to limitations of DEA. They propose an approach for DEA in which additional objective functions are integrated in the classic input oriented CCR multipliers model. The additional objectives can contribute to restrict the multipliers flexibility. The first objective is the classical efficiency maximization; the second is an equity function (a min-max deviation function); and the third one minimizes the sum of the deviations of all DMU’s under analysis.

The TRIMAP package (Cl’maco & Antunes, 1989; Antunes et al., 2016) is an interactive environment dedicated to tri-objective linear programming models. Using its graphical means, is particularly interesting combining TRMAP with the Li and Reeves MCDEA Model. Regarding this model, the knowledge of the weights space decomposition, as obtained through TRIMAP, allows the evaluation of the non-dominated solutions stability, being specially interesting the evaluation of DEA efficient solutions stability. Moreover, the eventual existence of optimal alternatives concerning the classical DEA function can also be verified. If they are non-dominated regarding the tri-objective MCDEA model, its identification is obvious on the graphical decomposition of the triangle. Another key graphical issue is the very easy
identification of non-dominated solutions optimizing simultaneously more than one objective function of the MCDEA model. These issues can help in the discrimination of the DMU’s as well as the identification of solutions with acceptable multipliers distribution, if possible without nil multipliers (Cl’maco et al., 2008). Moreover, (Soares de Mello et al., 2009) proposed a TRIMAP-DEA index, in general enabling the complete ranking of the DMU’s. Roughly speaking, it is a percentage of the best value of the classical DEA objective function (where this percentage is defined by the ratio between its indifference region area in the weight space and the total weight space area.

Furthermore, related approaches were proposed. First, note that the MCDEA related goal programming approaches are out of the scope of this paper. In this paper we will consider the following models: a bi-objective MCDEA-like (Bio-MCDEA) model, proposed by (Ghasemi et al., 2014), solved using a weighted sum of two objectives of MCDEA; and an approach that combines the use of the more restrictive weights derived from the MCDEA model with the cross-efficiency evaluation procedure, thus increasing discrimination and obtaining a complete ranking of the units, proposed by (Yadav et al., 2014). Finally, in (Rubem and Brandão, 2015), it is proposed an MCDEA approach trying to improve the TRIMAP-DEA index, prioritizing the non-dominated solutions of highest stability.

In this communication, a critical reflection and a comparison of the above referred to approaches based on a case study is carried out. We will use a problem of educational evaluation, previously studied (Gomes Jr et al., 2011). It concerns the evaluation of undergraduate distance-learning centers, located at different cities in the state of Rio de Janeiro, Brazil.

We also discuss the conclusions of some experiences carried out in order to improve the Tri-DEA index efficiency. Furthermore, a possible extension of this work could incorporate the use of a dual formulation of the MCDEA model. A preliminary work on this direction, using partial duals for the MCDEA, was proposed by (Carvalho Chaves et al., 2016). Following this path, we walk a bit more in this direction with the help of the above referred to case study.

References

PO, vol. 29, 97-110.

FRI -2-CON-DMS4130
Contributed Session
Friday 11:30 - 12:10 - Room DMS4130
Session: Evolutionary Multi objective Optimization
Chair: Maria Joao Alves
1 - Multi Objective Optimization Approach for Multi-Layers Network Analysis

Asep Maulana, Leiden Institute of Advance Computer Science, Leiden University, Netherlands
a.asep.maulana@liacs.leidenuniv.nl

Michael Emmerich, Leiden Institute of Advance Computer Science, Leiden University, Netherlands
m.t.m.emmerich@liacs.leidenuniv.nl

Complex network analysis has increasingly got a big attention from academia, industries and governments. Two major disciplines in complex network analysis are community detection and centrality. Community detection seeks to partition the network into clusters, where nodes within a cluster are well connected with each other, but they are not well connected to nodes outside the cluster. Centrality is a method in finding the most influential node / vertex in the network. Different measures of centrality are proposed in the literature, some focusing more on shortest path distances and others on eigenvalues related to nodes. Community detection algorithm for network analysis is mainly accomplished by the Louvain Method that seeks to find communities by heuristically finding a partitioning with maximal modularity. Besides many network centrality methods have been proposed to in identifying different key players in a social setting such as

- Eigenvector centrality and Page rank, which focus on the importance of the nodes that a certain node is connected to
- Degree centrality, which focuses on the number of peers to which a node is connected
- Betweenness centrality, which considers the number of shortest paths in the network that pass through a certain node
- Closeness centrality, which measures distance from a certain node to all other nodes

Whereas algorithms for finding communities and central nodes are well studied for canonical graph models, they are poorly understood for so called multiplex networks, that is, networks consisting of multiple layers of edges (sharing the same node set). In such networks, each layer can, in principle, give rise to another optimal partitioning into communities or another most central node. In this work, we view the problem of finding optimal communities or finding the most central node as a multi-objective optimization problem.

In case of community detection, a combinatorial optimization problem needs to be solved, which is NP hard already in the single objective case. Therefore, we proposed heuristic methods, namely Evolutionary Many Objective Optimization, to compute Pareto fronts between different modularity layers. Then we group the objective functions (layers) based on whether their community structure is in conflict, indifferent, or complementarily. As a case study, we compute the Pareto fronts for model problems and for economic data sets and data sets from flight networks in order to show how the network modularity tradeoffs between different layers can be computed and analyzed.

Centrality measures are used to identify the most important or most influential node. But in the real world, with more complicated data sets, we need not only to identify a single player but a set of key players. For network centrality, enumeration algorithms are sufficient to find Pareto efficient set, but the interpretation of such sets is a topic of research, too, and we propose similar methods as for community detection in multilayer networks. They can be used to propose a Pareto optimal set of key players in a single multiplex network. In addition to the different types of edges that occur in multiplex networks, also the various different definitions of centrality can be seen as different objectives. It is investigated how it will influence the set of Pareto efficient solutions if also trade-offs between such different centrality measures are taken into account. Examples will be on the analysis of the world trade network, where countries form the nodes and trade in different types of commodities form the weighted different edge sets. It turns out to be the case that only a small number of seven out of 207 countries are non-dominated and there is a strong overlap with the G8 countries. Our method allows a much more detailed analysis of what makes these countries key players in trade and reveal patterns that are of interest in macro-economic studies. The case studies of this paper provide evidence on the usefulness of multicriteria analysis in multiplex network science and besides our first results there are many unsolved problems, such as the development of algorithms for finding influential sets of nodes, the
analysis of data sets from domains other than economy, and the scalability of methods for big data.

2 - A comparison of Differential Evolution and Particle Swarm Optimization to compute “extreme” solutions in semivectorial bilevel problems

Maria João Alves, CeBER and Faculty of Economics of University of Coimbra / INESC Coimbra, Portugal
mjalves@fe.uc.pt
Carlos Henggeler Antunes, University of Coimbra, Portugal
ch@deec.uc.pt

Bilevel programming deals with optimization problems with a hierarchical relation between two decision makers (the leader and the follower), who make decisions sequentially in a non-cooperative manner. The two decision makers control different sets of variables and attempt to optimize their own objective functions subject to interdependent constraints. The leader sets his variables first. Then, the follower reacts by choosing an optimal candidate for his objective function on the feasible choices restricted by the leader. This choice affects the leader’s objective, so the leader must anticipate the reaction of the follower. This type of sequential decision-making situation appears in many aspects of resource planning, management and policy making, including energy markets, transportation network design and traffic management. Bilevel programming problems may have multiple objective functions at one or both levels. Problems with a single objective function at the upper level and multiple objective functions at the lower level are usually called semivectorial bilevel problems.

Multiple objectives at the lower level add particular complexities to the bilevel problem because, for each setting of upper level variables by the leader, a set of nondominated solutions exists to the lower level problem which poses difficulties for the leader to anticipate the follower’s reaction. The most frequent approach in the literature to deal with semivectorial bilevel problems is the optimistic approach, which assumes that the follower accepts any nondominated solution to the lower level problem. Thus, the optimistic solution is the solution to the semivectorial bilevel problem that presents the best leader’s objective value considering that the follower’s choice among his nondominated solutions for each upper level variable setting is always the best for the leader. Another approach is the pessimistic one, which assumes that the leader is risk-averse and prepares for the worst case. The pessimistic solution is the one that gives the best leader’s objective value when the follower’s decision among his nondominated solutions for each upper level setting is the worst for the leader. In addition to optimistic and pessimistic solutions, there are other types of solutions that can also provide useful information to the leader about the risk he is running when making a specific decision. In particular the following solutions may be relevant for decision support purposes: the result of a failed optimistic approach – deceiving solution – i.e. the outcome whenever the leader believes that the follower will pursue his interests but the follower does not react accordingly; and, on the other hand, the solution resulting from a successful pessimistic approach – rewarding solution – i.e. the outcome if a pessimistic approach is pursued by the leader and the follower’s reaction is the most favorable to the leader.

We have developed algorithmic approaches based on Differential Evolution (DE) and Particle Swarm Optimization (PSO) aimed to compute these four “extreme” solutions to the semivectorial bilevel problem: optimistic, pessimistic, deceiving and rewarding solutions. The proposed algorithms are intended to approximate the four “extreme” solutions in a single run. For that purpose, lower level optimization procedures using multiobjective versions of DE and PSO meta-heuristics are embedded within an upper level search, also based on the same meta-heuristic. Whilst the lower level algorithms search for the follower’s nondominated solutions for each upper level variable setting, it also guides the search for extreme solutions according to the leader’s objective, i.e. the search privileges the areas where the follower’s nondominated solutions that provide the best or the worst leader’s objective value are located. Different variants of DE are investigated and tested on several benchmark problems. A comparison of the DE algorithms with the approach based on PSO is presented.

FRI -2-CON-DMS4140
1 - Risk preference modeling for portfolio selection
Cristinca Fulga, Bucharest University of Economic Studies, Romania
fulga@csie.ase.ro

In this talk, we present an integrated methodological approach for selecting portfolios which is focused on incorporation of investor’s preferences in the Mean-Risk framework. Our goal is to propose an alternative methodology for defining, measuring and optimizing risk that addresses some of the conceptual shortcomings of the Mean-Risk framework such as the disregard of investor’s attitude towards risk and implicit assumption of neutrality to loss aversion. The key in our proposed methodology is a risk measure called ESLA that, for continuous return distribution functions, can be represented in terms of the conditional expectation of the distribution tail, where the tail is determined by the critical return level characterizing the loss-averse investor. Our contributions can be summarized as follows.

We begin by defining ESLA, then we show the relations of the proposed risk measure with CVaR, and LPM of first order (LPM1), establish its properties, study the link with stochastic dominance criteria, and discuss practical aspects regarding the calculation in the case of scenario-based portfolio optimization.

Next, we describe the portfolio selection methodology in two stages in which investor’s loss aversion is fully taken into consideration: firstly, the investment opportunity set is determined (in our case, the Mean-ESLA efficient frontier), and secondly, one single preferred portfolio is selected from the efficient frontier. We consider three types of investors characterized by three different classes of utility functions with loss aversion. The empirical study is targeted on assessing the differences between the Mean-ESLA efficient frontier and the classical Mean-Variance, Mean-CVaR and Mean-LPM1 frontiers. We measure the loss of welfare incurred by using another model instead of the proposed one using a proximity index in the EU framework. Then, in order to assess how much the portfolios really differ in terms of their compositions, we use a dissimilarity index based on the l1 norm. We also were concerned by the role and influence of loss aversion parameters values and constraints. A test was performed to study how the models behave when using various constraints. Firstly, the usual non-negativity constraint was replaced by a set of box constraints. As expected, as a result of shrinking the interval of variation of each security return and consequently reducing the feasible region, the similarity increases. For the final test, it is assumed that short selling is allowed. As we expect, in this case the values of the dissimilarity indices increase compared with the other types of constraints.

The analysis shows that the proposed model is not dominated by any of the classical models. Moreover, the optimal/efficient solutions of the Mean-ESLA model differ markedly from the classical models Mean-Variance, Mean-CVaR and Mean-LPM1 as the dissimilarity indices show and, in terms of utility, Mean-ESLA is frequently similar, but also sometimes preferred to classical models.

2 - Evolving SMART Cities: Identifying Social Indicators from Rodent Neurobehavioral Simulation to Enhance the Prosocial Multiple Criteria Public Housing Assignment Model
Gordon Dash, University of Rhode Island, USA
ghdash@uri.edu

Nina Kajiji, University of Rhode Island & The NKD Group, Inc, USA
nina@nkd-group.com

Tiffany Donaldson, University of Massachusetts, Boston, USA
tiffany.donaldson@umb.edu

Overview

In the urban city when community leaders, data scientists, technologists and companies join forces around a set of core goals, a city gains the potential to evolve to SMART status. This movement is promoted by unlocking new solutions in management areas such as safety, energy, climate preparedness as well as reinvigorating the prosocial and efficient allocation of residents to the available supply of public housing apartments. This paper extends the uni-objective apartment assignment model to a formulation that
includes hierarchical and prosocial specifications. Stated differently, we propose an MCDM model for SMART city evolution based on social indicators translated from rodent neurobehavioral simulation. Prior to stating the operational form of the multiple objective assignment model (MOAM), we turn our attention to the vexing issue of how best to identify and measure per capita factors that underlie social behavior. To this end, the research conducts a study of the seven areas in the rat brain known to underlie the neurobehavioral factors of fear, anxiety, and reward circuitry. Metric translation of these recorded neurobehavioral factors leads to the direct formulation of per capita social indicators. Along with environmental factors, the translated social indicators form the basis of the proposed MOAM.

Methodological Approach
In the animal simulation we describe gender-differentiated behavior among mature Long Evans rats phenotyped for high- or low-anxiety Trait (HAn/LAn). The experiment is designed to elicit a measurable understanding of animal responses to fear, anxiety and stress when rats are housed in alternate rearing environments. Investigated environments include: a) the social environment (SE) and b) the isolated environment (IE). The experiment also interrogates the effect of rearing in both open- and elevated-spaces. This design mimics the urban high-density and high-rise apartment-based project community. The effect of the stimulant drug amphetamine on behavioral and physiological behavior is added to the experiment to further mimic the animal’s reaction to induced stress. Following extant research, postmortem we measure the c-fos protein levels in seven right- and left-brain regions known to be implicated in fear/anxiety, fear/reward, escape circuitry and cognitive control of emotional responses.

We begin the statistical analysis by computing the means and standard deviations for the c-fos measurements. This is followed by a confirmatory factor analysis to investigate the interrelationship of the left- and right-brain regions. Next we explore the effects of the three independent variables - Sex, Trait, and Environment - on the c-fos measurements for each of the brain region through the use of a MANOVA model and a multivariate radial basis function artificial neural network model (MRANN). We found translatable concepts from the statistical analysis. For example, when female rats are faced with a fear-inducing event we find Trait explains how the rodent approaches escape decision-making. By translation, to augment the reality of the MOAM we hierarchically goal-equate the following prosocial objective: to assign Trait identified head-of-household female applicants to any available apartment in a community building that is bounded by a risk-minimizing location-distance from the city central district.

Results: Evolving the Behavioral OR MOAM

The mixed-integer nonlinear goal programming (MXNLGP) method of Dash and Kajiji (2014) is a recognized solution algorithm for combinatorial MCDM. The approach permits a formal activation of an ordered prosocial goal set. The abbreviated canonical combinatorial goal program stated below is specified completely in the full version of the manuscript.

\[
\text{MINLGP} = \min \ Z = [P_1(h, h^*), P_2(h, h^*), \ldots, P_m(h, h^*)]
\]

\[
\begin{align*}
ST. & \quad Ax + By + h^- - h^* = b \\
 & \quad x, f, h^*, h^* \geq 0, f \in \mathbb{Z}^p, \text{ and, } x \in \mathbb{R}^{n-p}
\end{align*}
\]

In the absence of integrality constraints=0. The specification b is the m-component vector of goal targets and h- and h+ are m-component column vectors that capture goal under- and over-achievement, respectively. In this statement, we define the optimal solution to the convex MXNLGP, x-star, as the one that satisfies all hierarchical levels as much as possible. For the purposes of this research, MXNLGP is adapted to specify a MOAM by incorporating the following assignment constraints (not shown in text abstract):

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The full specification MOAM includes additional goal constraints for apartment location implications and more. By way of example, included are goals that consider the weighted travel time from apartment location to facilities in the Central Business District (CBD). Based on a per capita social indicator score, proximity to the CBD is also a rank-ordered allocation goal for worthy applicants. A number of other lower-order goals complete the specification of the full model. The model reality statement is rounded-out
with community-wide preference goals that treat the broader concept of emotional control when confronted with stress and fear-inducing events.

Discussion and Conclusions

The investigation presented in this paper adds to the body of MCDM research in two important areas. First, this investigation draws upon neuroscience and translational science by introducing an animal simulation to uncover social indicators that effectively represent factors underlying public policy decision-making. Second, the proposed MOAM extends the traditional uni-objective apartment assignment problem to include both prosocial policy metrics and multiple hierarchical optimization objectives. This important advancement more adequately blends society’s complex social goals with the urban city’s quest to achieve and retain a SMART designation.