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Opinion Makers Section

New frontiers for MCDA: from several indicators to structured models and decision aid processes

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Introduction

A multicriteria decision aid (MCDA) process is developed by means of interaction with decision maker(s) and stakeholders, but it may also be oriented towards facilitating the Intelligence phase of a decision process when a decision system (with rules and formal relationships between decision makers and with other actors in the decision process) has not yet become active. This situation arises frequently when a decision problem is complex or not well structured. If there is time to develop a "simulating" approach to the real problem, a study that includes modelling and the application of methods can clarify the situation and its results can be proposed to facilitate new decision processes.

This simulating approach needs clear and complete attention to the specific incremental nature of this learning process, which includes and integrates the modelling and validation of each conceptual or formal result (Landry et al. 1983). A cyclic application of a method can facilitate and control the development of this process and the analysis, as well as the use of the temporary results in the various steps of the process. Each application implies a clear definition of all the inputs, and a careful and critical analysis of each result, in order to use this information to converge towards a final model or to formulate new treatment hypotheses for the problem situation. A "good" SW tool could facilitate this approach aiding the "visualization" of the limits of a result and of its positive or negative evolution in a way that is generated from recurring modelling cycles.

A simulating approach may also be motivated by a criticism of some policy making processes, and it could have the aim of improving the quality of indices, which are then used to obtain evidence in order to set specific goals and to measure the progress that has been made towards these goals. A multicriteria (MC) application may be developed in relation to an international composite index, to remedy some of the methodological problems when a weighted sum is computed using ordinal data (Mailly et al, 2014), or to outline how an indicator can be generated and why this indicator is essential in policymaking (Scarelli and Benanchi, 2014). In the aforementioned case, an MC model was developed, without decision makers or stakeholders, in relation to a pilot case, in order to underline the limits of the adopted resilience indices and to demonstrate, by means of a new resilience model and an MC application, that MCDA "exists" and can be very useful in decision processes that have the aim of increasing resilience.

Starting from the result of this simulating approach, some criticisms and improvement proposals were developed in relation to the original model, which had been influenced by the limited availability of adequate data and the not so consistent nature of the family of criteria that had been deduced from literature. A result analysis, as a tool that facilitates MC modelling, was described in (Norese, 2006), in relation to some complex cases and to always more structured laboratories that were proposed to a large number of degree and master course students (more than 3500 over the last sixteen years). In the last few years, the same logic of learning has been applied in laboratories for doctoral students and in some master theses, in relation to actual problems, in order to facilitate the modelling of not so clear decision situations and the understanding of how some MC methods can be used in unstructured problem situations. The students have now arrived at a good problem formulation and model structuring stage, and they have learned to criticize their models when they produce strange or unacceptable results as well as how to consistently improve their models and results. The only great remaining difficulty is in relation to the role that an SW tool could play (but currently does not play) in this process.

The next sections propose the definition of the resilience problem and a sequence of some ELECTRE III applications to the original model and some variants, in order to underline how the analysis of each new result can orient the sequence of changes and to what extent the comparative visualization of the results can facilitate an

identification of limits in the evaluations and in some model parameters. The potential role of a good SW tool is underlined by means of some figures that show some of the ELECTRE results and which should be visualized together during the modelling process, in order to understand which relationships connect a result to some model components. This procedure could be suggested to those people who are involved in IT innovation and SW development projects, in relation to the difficulties that the end users encounter in MCDA.

1. Resilience and MCDA

The term resilience stems from the Latinverb *resilire* (rebound), and *resiliens*was originally used to refer to the pliant or elastic quality of a substance. Resilience in engineering is the capacity of a material to withstand impulsive forces, while in ecology it is defined as the capacity of an ecosystem to return to the point of equilibrium that existed before a disruption of either an anthropic nature (pollution) or natural nature (climate, earthquake, landslide and so on). In the last few decades, the concept of 'resilience' has gained much ground in a wide variety of academic disciplines, including research on not only engineering and ecological sciences (which include climate change and disaster management), but also on psychology (the capacity to react and to face the adversities of life), medicine (as the patients' reaction to a treatment of therapy), or law (as a community's capacity to react and integrate new rules or proceedings of local authorities). Each definition includes concepts, such as flexibility, adaptation or reaction.
Resilience seems to be the answer to a wide range of problems and threats, and has therefore garnered the attention of policymakers and researchers from different fields and disciplines. It could be useful to design a reflexive management process that guides policymakers or other actors through the steps of understanding which factors they can influence to strengthen the resilience property of the system (Duijnhovena and Neef, 2014).
ANDROID - Lifelong learning Programme to increase society's resilience to disasters of human and natural origin (http://www.disaster-resilience.net) proposes the resilience definition that is used hereafter: *resilience is something we can grow in ourselves, in our family and in our communities*, as the result of an education activity addressed to the prevention and minimization of negative effects (of adversities, natural events, disasters, …). Therefore, resilience, in this context, can be seen as the capacity of the administrators to face the risk of a catastrophe, their level of interest, time, resources and efforts devoted to it (the social life sphere). The resilience concept should be considered as interactions among the several factors that can influence the various spheres of social life in different ways. These factors may be synthesized as environmental, socio-political and economics factors. A combined analysis of the four spheres led to an innovative study on the territory and its resilience, which was conducted in order to propose the results to the policy makers and stakeholders of territorial processes.
In this context, some questions may be posed: is it possible to evaluate the resilience of some territorial units, starting from specific indicators? Is it possible to say that one territory is more resilient than another and to offer some explanations? How can an accurate evaluation be made and finalized to further interventions? How can critical factors of resilience be pointed out and used to facilitate focused investments in order to assure more safety of the examined territorial assets? Could management and financing plans for vulnerable communities be generated or facilitated by this combined analysis, in relation to different administrative sectors, at a Regional, National or International level? Can the awareness of the real problems be improved by a transparent resilience evaluation in the involved communities, which include citizens and administrators?
In order to answer some of these questions, an MC model was developed to evaluate the resilience of some territorial units, that is, twenty-two municipalities belonging to the Ombrone river hydrographic basin in the Tuscany region in Italy, where several floods events have occurred in recent years (Scarelli and Benanchi, 2014). The logical structure of the model and the identification of available data, in relation to the large numbers of indicators that had been proposed in the literature, were the first steps of the work on this pilot case. The last steps involved a difficult definition of the preference parameters (that is weights, indifference and preference thresholds, the need to activate the discordance principle and the relative veto thresholds), without interaction with an activated decision system, and an ELECTRE III application to the pilot case.

2. Result analysis in modelling processes

A preference elicitation process proceeds through an interaction between decision-makers and analysts in which decision-makers express information about their preferences within a specific aggregation procedure **(**Figueira et al, 2005). Decision-makers can directly provide information on the values of the preference parameters (direct elicitation), but the understanding of the precise meaning of each parameter may be difficult for decision-makers and therefore elicitation can be activated indirectly by posing questions, whose answers can be interpreted through an aggregation procedure.
Inference procedures have been developed to elicit parameter values from action ranking or assignment to categories examples. However, these preference elicitation or inferring procedures cannot be used when a decision system is not active. In these situations, which aim to facilitate future decision processes, analysing the results of the application of an MC method to a provisional model could be the correct way of improving and validating both the understanding of the whole problem situation and the model. An analysis that puts the results into question may lead to an important communication space and an occasion of learning.

In the analysed case, a careful analysis of the model and ELECTRE III application and results was considered essential to verify whether this resilience evaluation was accurate enough, could give suitable explanations to the different situations in the Ombrone basin and could be used to facilitate improvement actions.
The study started with an analysis of the results of the ELECTRE III application and of its possible limits, and continued with an examination of the model elements that could negatively influence the result.
Some change hypotheses were made and a sequence of ELECTRE III applications to the original model and the proposed variants was provisionally planned, because the analysis of each new result could orient the sequence of changes. The comparative visualization of the results facilitated the identification of possible limits in the model parameters, evaluations and/or structure.

2.1 The result and the model parameters

The result of an ELECTRE III application is a classification of compared actions, from "best to worst", which is represented by a *final partial graph*, i.e. a pre-order that is developed as the intersection of the two complete pre-orders resulting from two distillation procedures, that is, the descendant procedure and the ascendant one (Figueira et al, 2005). The final partial graph can include different paths, the longest of which can be visualized as the vertical and considered the main path, while each lateral path indicates a situation of incomparability and underlines a distance (of one or more classes and sometimes even of several ones) between some action positions in the two distillations. The presence of different paths is more frequent when several actions are compared, and the lateral paths may be visualized above all in the intermediate part of the graph. The number of lateral paths grows if the comparability of some actions is not so high, but a high number of paths can sometimes be the sign of a difficult definition of some model parameters and above all of the veto thresholds.
When MC modelling is particularly difficult, the result, in terms of final partial graph, often presents several incomparable actions. This event has been observed in some particularly complex cases (Balestra et al., 2001; Cavallo and Norese, 2001) and tested and verified in several laboratories with students at their first experience in MC modelling, who could be considered just like inexpert practitioners (Norese, 2006). The frequent final partial graphs with several incomparable actions were considered to be the consequence of incomplete or unstructured models, or of non-consistent or wrong definitions of some parameters. When the reasons for these possible erroneous actions were analysed and eliminated step by step, the number of incomparable actions was always reduced.
In the resilience case, the model included not a few actions (22 municipalities) and could have presented some elements of uncertainty, because it was not created for a specific decision problem, but only to improve future decision processes, and because it synthesized logical inputs from literature and analytical inputs from the few available but not so reliable and consistent data.
The final partial graph that resulted from the ELECTRE III application to the model is presented in figure 1, with fifteen actions in the vertical path and seven actions in the lateral paths, which are only present in the intermediate part of the graph. It can be observed that the municipality that is incomparable with the maximum number (6) of other municipalities is Trequanda (TREQU in the figure 1) and there is a maximum number of only two actions in the same class. The only element that caught our attention was the presence of Siena in the last positions. Siena is the main city in the county, with more than 50,000 inhabitants, while the population of the other twenty-one municipalities is always less than 5,000, except for five municipalities which have populations of about 7,000 or 9,000 inhabitants. For this reason,Siena is not easily comparable with the other municipalities.

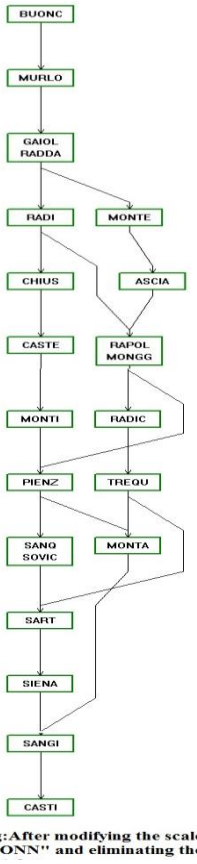

Figure 1 – Result of the original model

As a consequence, Siena was eliminated from the set of actions, and it was believed that this measure would have changed the result to a great extent. However, the result without Siena was not so different (see figure 2), with 15 actions always being present in the vertical path and six in the lateral ones. Some small changes occurred in the intermediate part, where three actions were included in the same class, the same actions which, with another two, were first in the vertical path and then resulted to be in a lateral one, while three of the lateral ones moved into the

main path. Essentially, the ELECTRE III result seemed to be not so sensitive to the Siena elimination.

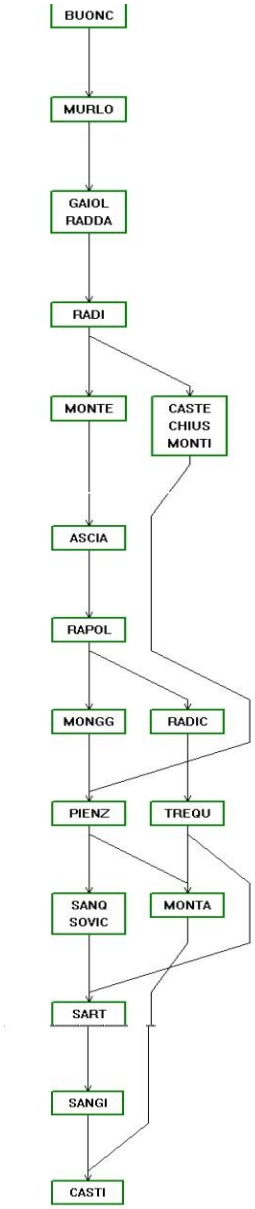

Figure 2 – Result without Siena

At this point, some small changes were introduced to improve certain thresholds of indifference and preference that were too large, and the result changed the situation considerably in relation to each small change (see the graph resulting from a combination of all the small changes in figure 3). When some veto thresholds were introduced, because the original model had not included any veto threshold, the result became disastrous (see figure 4). All the parameter changes that were introduced step by step to improve the model produced different results, and when all the changes were introduced together it was evident (as can be seen in figure 3 and above all in figure 4) how sensitive the result of the ELECTRE III application to this model and to some parameter variants was.

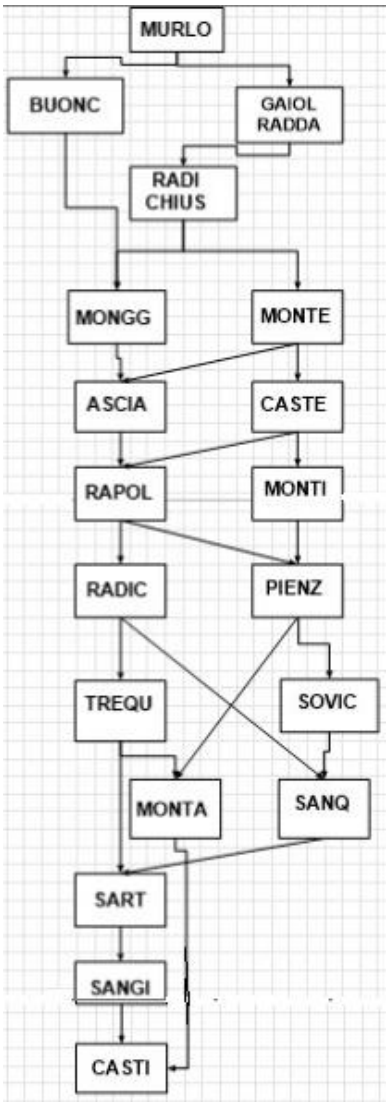

Figure 3 – Result of a combination of small changes

The first five positions of the classification in figure 3 include the same actions as figure 2. It can be observed that the last seven positions are not so different, and some small changes in the central part of the graph can be considered acceptable. However, the main path, which should be the longest, no longer exists, and there are two paths with almost the same number of actions, plus some lateral paths.

Several paths characterize the result of the ELECTRE III application to the model variant that includes all the changes (see figure 4). However, just one head action is not included in this graph and a similar strange situation is shown at the end of the ranking. This result is a clear sign that something is wrong in the model and small changes in its parameters only underline that the structure and contents of the model should be analysed.

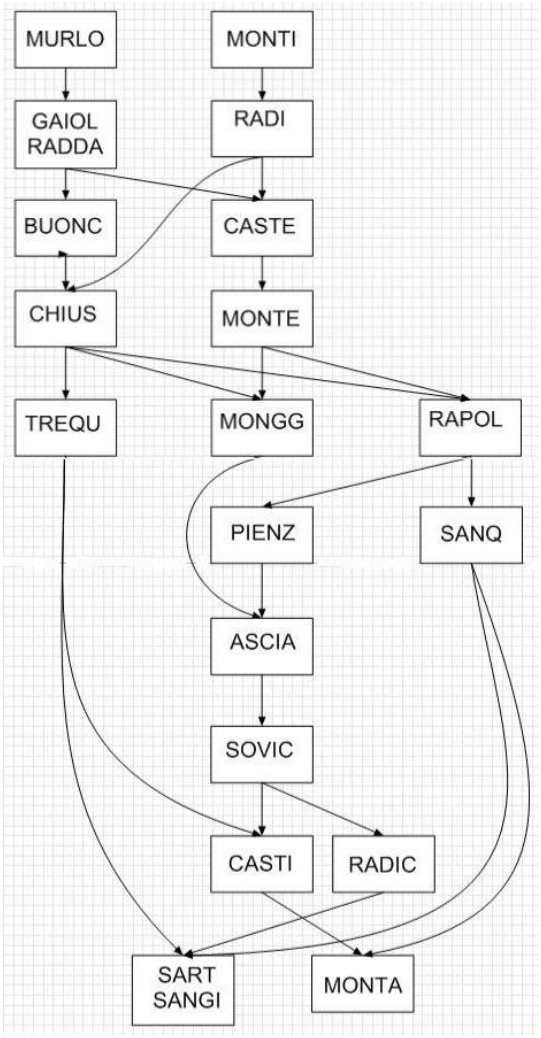

Figure 4 – Introduction of some veto thresholds

2.2 The model and its structure

The model, which was first analysed in terms of parameters (thresholds and modelling of the discordance principle) and in terms of the nature of the action set, was then studied in terms of structure (main conceptual aspects and consistent family of criteria that analytically deal with these aspects) and evaluation process (choice of data-indicators to be used in the evaluations).

The structure of the model only apparently results to be consistent with the multidimensional definition of resilience. The model that was deduced from literature consists of 14 criteria, and the environmental aspects are included with almost the same importance as the socio-economic ones. However, while a lot of possible indicators of the resilience environmental aspects are available, indicators of social or economic resilience are not easily defined and not frequently included in institutional data bases. Therefore, several indicators that were suggested in the literature to deal with socio economic resilience are not easily available or are even inconsistent with the analysed socio-economic context. A careful reading of the meaning of all the criteria and the indicators that were used for the evaluations indicates that there are more environmental criteria than socio-economic ones and they show a net prevailing importance (78%). Moreover, some indicators that were used for the evaluations are not so consistent with the criteria to which they were associated.

A new model was created to include only 7 of the original 14 criteria, with the "clearest and most reliable" indicators. They deal with three main aspects: Reaction capability, risky or adverse to risk Behaviour of the actors and Environmental and social awareness.

Reaction capability is facilitated if the Reaction time, which is evaluated in terms of the ratio between the active population and the young plus old population, is high (the indicator for this criterion was taken from INSTAT, the National institute of Statistics), if the Territorial desirability (touristic attractiveness, as evaluated by the Touristic Office of the Siena Province) motivates citizens and administrators to preserve the territorial qualities and to prevent any kind of negative impact, and if a high average value of Spendable income of the citizens generates resources for the public administration to prevent disasters (source: Siena Province).

The Behaviour of the actors, in the analysed area, could indicate an insufficient awareness of the risks for the territory, as can be seen for the Urbanization criterion, where the % of urbanized area (elaborated by means of GIS) is a sign of limited rainfall absorption, and therefore of flood risk, and for the CO_2 emissions criterion (source: Siena Province), where a high level of emissions does not imply only alteration of the atmosphere, but also limited sensitivity to the territory needs.

Environmental and social awareness can be expressed by means of two criteria: the first is Environmental awareness, in terms of percentage of differentiated waste (source: Siena Province), and the other is Progress in the social life, in terms of percentage of women in the waiting list for a job (source: Siena Province).

The new thresholds of indifference, preference and veto that were proposed in the analysis described in 2.1 can also be used for this model, while the importance coefficients are new but maintain the aim of balancing the main aspects, and the criteria in relation to each aspect. Together with this first base scenario, another three weight scenarios were proposed and used, each of which represented a different way or policy of improving resilience. The first scenario was mainly oriented towards educating people about resilience, the second was oriented towards training people on how to react to a disaster and the third towards basing resilience improvement on funds that could be assigned to the municipalities of the involved territory.

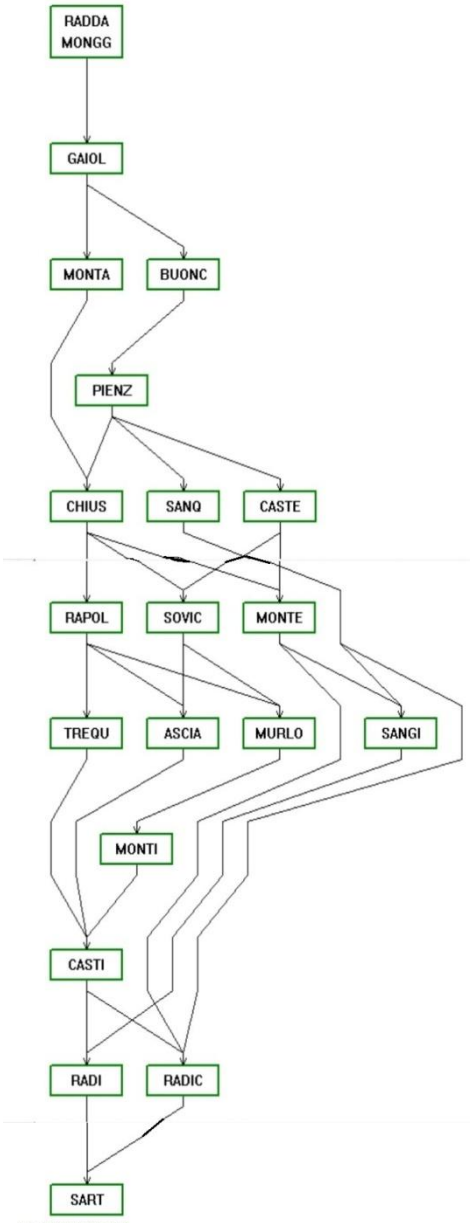

Figure 5 – ELECTRE application to the new model

ELECTRE III was applied to the new model, in relation to the “balanced” scenario, and the result is shown in figure 5, with both the head actions and the others at the end of the ranking again appearing clear. Eleven actions are included in the longest path while the others appear in the lateral paths, above all in the intermediate part of the graph. The municipality that results to be incomparable with the maximum number (11) of other municipalities is San Quirico d’Orcia (SANQ). There are only a few evident changes in the ranking, above all as far as MONTI is concerned, which has moved from the first position to the last group of actions. RADI has also moved from the second to almost the last position, while MONTA was in the last or almost the last position in the original model and is now in the third position. Other municipalities have now become more resilient, they are PIENZ, SANQ and above all MONGG, which was preceded by 9 actions and is now in the first position, while MURLO is less resilient.

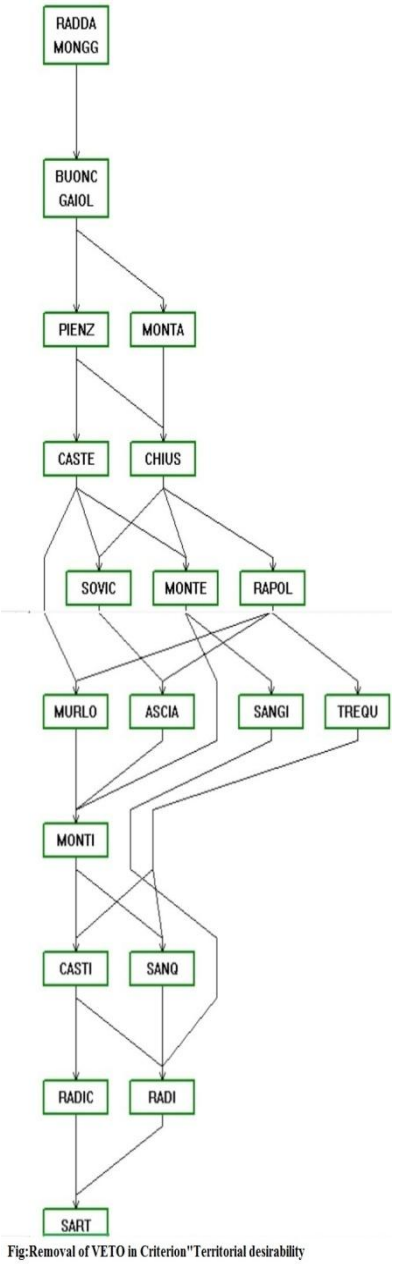

Figure 6 – A new result for a single veto threshold deactivation

A high number of incomparable actions in the final partial graph is often the consequence of a veto threshold that has had a heavily impact on the result. In order to test this possibility, the model was partially changed and each time one of the veto thresholds was deactivated. In only one case did a single veto threshold deactivation evidently change the result, above all the position of SANQ, which was the most incomparable action and its position has now become clear (see figure 6): it is evidently not resilient. However, even in this case the result has not changed structurally and the first, the intermediate and the last action groups are the same.

The other three weight scenarios were tested and these results (see figure 7) also maintain the same distinction between first, intermediate and last action groups. There is only a partial change for MONTI, which tends to pass from the intermediate group to either the first or the last group.

At this point, the result analysis moved on to the analysis of the few "strange" actions, above all that pertaining to San Quirico d'Orcia (SANQ), Monticiano (MONTI), Radicofani (RADI) and Montalcino (MONTA), and of some of the best and the worst municipalities. Some remarks, which could be useful for the improvement of the model, have arisen from this analysis. Most of the analysed actions are municipalities with just a few people and a mixture of economic activities (agriculture, cattle breeding, handicraft, commerce and tourism). However, some of them, which may be small, intact and beautiful Middle-Age villages, or small cities that are very famous throughout the world for their wine or touristic attractiveness, are different and in fact these are the municipalities that show the strangest results. For this reason, the possibility of using ELECTRE Tri in relation to the new model is currently being examined. This would mean accepting this "natural" incomparability and assigning the municipalities to resilience categories.

3. Final remarks and recommendations

An analysis of an MC model, which was developed without decision makers to underline the limits of the adopted resilience indices, and the application of ELECTRE III to this model, can be considered as a sort of sensitivity analysis, that is, a study on how the uncertainty of an output can be connected to different sources of uncertainty in the model structure and parameters, which are the inputs of the ELECTRE III application. Some alternative assumptions on the choice of the parameters (and then on the model structure), which could generate uncertainty or criticalities in the results, were tested to determine their impact on the results, and were then used to increase the understanding of the expected and unexpected relationships between the model and results of an ELECTRE application. The first outcome could facilitate the modelling process in this kind of technical learning process. An identification of the inputs that cause significant uncertainty in the output should orient attention towards improving a model that cannot be validated by means of a natural interaction between decision makers and analysts. A comparison of some strange elements of a result with a different type of information about these elements (the second outcome, which includes a detailed analysis of each strange element) can be used to orient a new cycle of modelling.

When a model is produced by a culture that associates information above all to a large amount of data, and several inexpensive data-indicators may be available, the logical consequence can be a model with a high number of indicators-criteria. The result of this sort of sensitivity analysis, which could identify inputs that have no effect on the output, or even redundant parts of the model structure, could be a simplification of the model.

In this case, a result analysis procedure was used to orient a sequence of parameter changes and a variant of the original model. A comparative visualization of the results facilitates the identification of the limits of some model parameters, evaluations and criteria. An SW tool could play an important role in this modelling process, by facilitating the visualization of the impact on the results that is generated by each parameter assumption or modelling scenario. An SW tool could include and visualize parameters that describe the main elements of a final partial graph and its evolution during the modelling process and could also propose other visualization tools, such as the Surmesure diagram that is described in (Rogers et al, 2000). Some difficulties that the end users encounter when they use ELECTRE III are linked to the not so easy interpretation of its results, above all when the problem is new and several actions are compared.

A model-based process has been used to facilitate this simulating approach (Norese, 2016). The different steps of this learning process are currently being used to enhance communication between modellers and decision makers, to explain logics, difficulties and methodologies of analysis to some stakeholders/decision makers who, in the Piedmont Region, have to face the problem of activating new participatory processes and of finding and allocating resources in answer to the needs of communities of users. A new MC application is currently underway, again adopting a simulating approach, but this time in relation to a river basin in Piedmont. The analysed application has been considered the starting point for a decision aid intervention throughout this territory.

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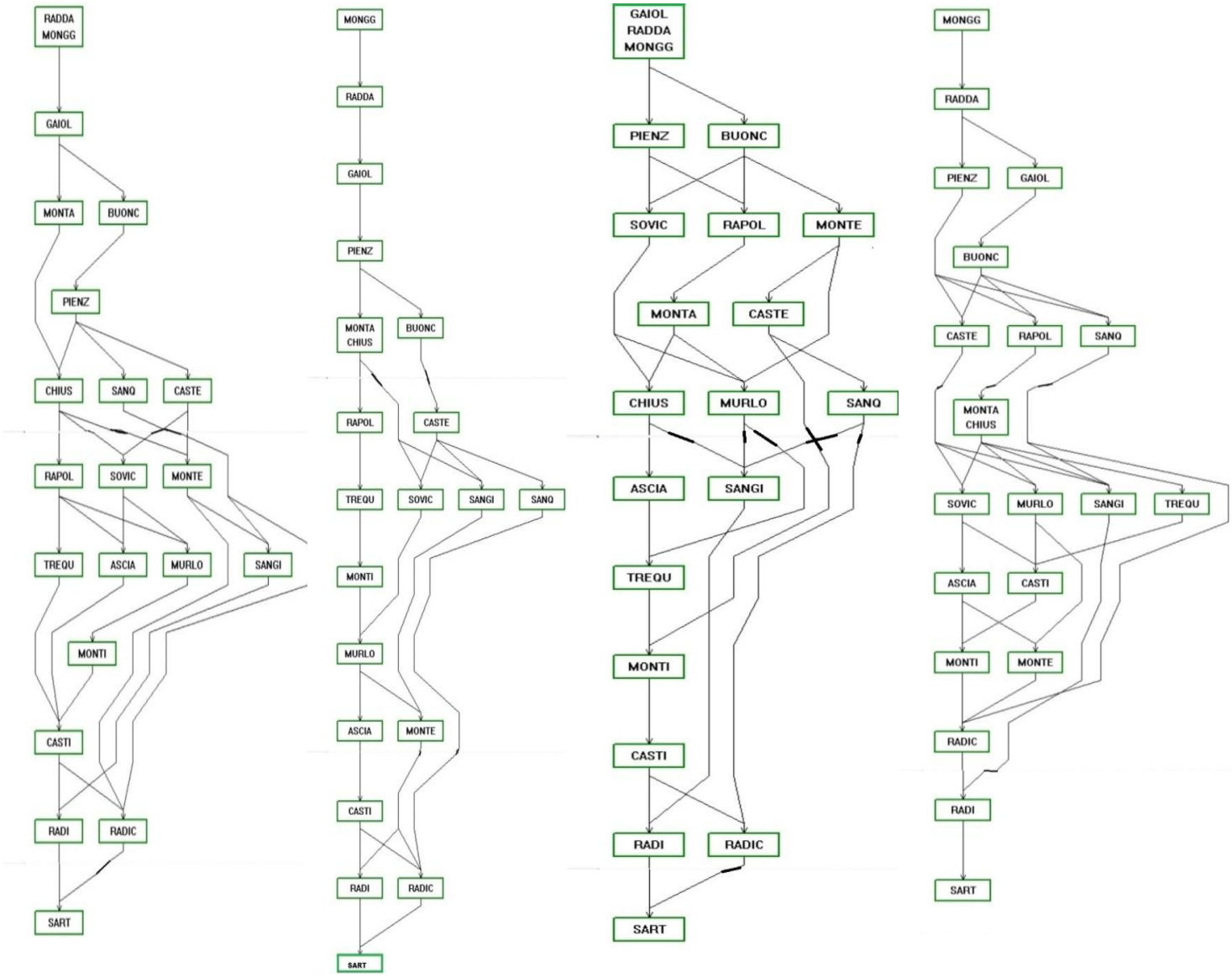

Figure7 – Results in relation to the balanced and the other weight scenarios

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MCDA Research Groups

RED-M: The Ibero-American Network of Multicriteria Evaluation and Decision Making

Javier Pereira

Executive Secretary RED-M

Summary

The Ibero-American Network of Multi-Criteria Evaluation and Decision (RED-M, www.redmsociety.org) aims to mobilize the scientific potential through different mechanisms of cooperation and dissemination, with the purpose of promoting the development and implementation of Multi-criteria Decision Analysis methods and technology aiding to find solution to decision problems regarding the economic and social development in Ibero-America. RED-M is an interactive network of practitioners, specialists and scientific programs working as nodes contributing to each other. We understand the collaboration as a space that allows the enrichment of scientific activities, through cross-fertilization of the following disciplines, but not limited to: Decision Theory, Operations research, Computer's Science, Discrete Mathematics, Cognitive Psychology and Machine Learning.

Overview

The Ibero-American Network of Multi-Criteria Evaluation and Decision (RED-M, www.redmsociety.org) was created in 1997 by a set of pioneering colleagues realizing that a relevant number of Latin American scientists, graduate students and practitioners, working on Operations Research and Computer Science, were also dedicated to the research and application of methods and technologies related to the broad field of Multi-Criteria Decision Analysis (MCDA). As an outcome of a former meeting, held in Chile, the RED-M was created.

From the very beginning, one of purposes of RED-M has been the dissemination of scientific works and the collaboration through the active participation of their members in regional and world-wide conferences. Thus, RED-M has held specialized sessions and tracks in CLAIO (Latin-American Conference of Operations Research), EURO MCDM, EURO INFORMS, EPIO (Argentinean School of Operations Research), ICHIO (Chilean Institute of Operations Research) and SMIO (Mexican Society of Operations Research). As a consequence of these cooperation works, books, book chapters and journal publications have been possible, enhancing the network expansion.

Currently, European and Latin American active members of RED-M include scientists, professionals and graduate students from Argentina, Brazil, Chile, Colombia, Cuba, Ecuador, Mexico, Peru, Portugal, Spain, Uruguay and Venezuela. Interests of researchers and professionals include, but not are limited to, MCDA/MCDM, GDSS, Multi-objective optimization, MCDA-MOEM, MCDA methods, Fuzzy-Sets, Behavioural MCDA, MCDA epistemology, DSS.

RED-M Meetings

Since the first meeting held on Chile in July 1997, eight other meetings have been successfully undertaken:

- 1997, Santiago, Chile
- 1999, Mexico City, Mexico
- 2007, Sinaloa, Mexico
- 2009, Jalisco, Mexico
- 2011, Rio de Janeiro, Brazil
- 2013, Concepcion, Chile
- 2014, Monterrey Mexico
- 2015, Bahía Blanca, Argentina
- 2016, Santiago, Chile

In these meetings, the aim is dissemination of knowledge concerning the approaches and methodologies pertaining to the broad field of MCDA, covering sub-fields such as theoretical developments, applications, evolutionary algorithms, robustness analysis, etc. It also is expected that a policy of expansion and development of MCDA in Ibero-American countries will emerge from every meeting, which will lead to cooperative projects involving professional, researchers, students, and industry in Latin America. Invited speakers to the meetings had come from Brazil, Chile, Cuba, France, Mexico, Poland, Portugal, Spain, and United States. Besides cooperation between researchers from different countries books and journal

articles published in Mexico have emerged from these meetings.

IX RED-M will indeed take place in Santiago de Chile, jointly with the Latin American Conference on Operations Research, XVIII CLAIO 2016 (www.claio2016.cl), from 2nd to 6th October at the Pontificia Universidad Católica de Chile. Following the spirit of previous RED-M meetings, the IX RED-M is designed to promote scientific and academic collaboration among professionals and researchers working with MCDA in Ibero-American countries. It is also expected that this sixth meeting will allow for the promotion of a process of cross-fertilization of disciplines such as Decision Theory, Computer Science, Discrete Mathematics and Artificial Intelligence.

About 400 attendants are expected for the joint meetings of XVIII CLAIO and IX RED-M. Among the activities there will be a plenary session by Dr. João Clímaco, from the INESC-Coimbra, at the Coimbra University. In his plenary session Dr. Clímaco will present the subject "Multi-Criteria Analysis in Sustainability Assessment".

Challenges

After the consolidation of RED-M as a space for presenting advances and innovation on MCDA applications and research in Latin America, new challenges appear: building a panorama aiming to know how broadly MCDA is included in Latin American graduate programs; promoting the active presence on multi-national collaborative research funding programs. Technical sessions of the IX RED-M are expected to cover these challenges. As part of its outreaching efforts, organizers of the RED-M will discuss educational initiatives of MCDA in Latin America. Also similar to previous meetings, policies of expansion and development of MCDA in Ibero-American countries will be discussed that will hopefully lead to cooperative projects involving professional, researchers, students, and industry in Latin America.

RED-M Board

The RED-M Board is in charge of vision, mission and strategies concerning the maintenance and development of our network. It is also responsible for main decisions regarding the conferences organization and scientific commitments.
The current Board includes the following researchers:

- Juan Carlos Leyva, Universidad de Occidente, México
- Laura Plazola, Universidad de Guadalajara, México
- Carmen Belderraín, ITA, Brazil.
- Luiz Autran Gomes, IBMEC, Brazil
- Javier Pereira, ITESM, México

Software

Bensolve
Solving Multiple Objective Programs and Beyond

Benjamin Weißing and **Andreas Löhne**

Friedrich Schiller University Jena, Germany

Abstract

The present article depicts the use of *Bensolve*, a software package for solving *Vector Linear Programs* (VLP). It is shown how *Multiple Objective Linear Programs* (MOLP) can be solved with *Bensolve*. An overview about the background as well as the various applications of *Bensolve* is provided. To this end, we formulate the problem class, illustrate the algorithm in use and discuss the role of duality. The applications range from classical MOLPs in radio therapy treatment planning over several aspects of the equivalent problem of *Polyhedral Projection* (PP) to the computation of set-valued risk measures.
Bensolve is an open source implementation of outer approximation algorithms for solving VLPs. It is written in the C Programming Language, the source code is available at http://bensolve.org.

Solving MOLPs

In *Multiple Objective Optimization* (MOO), problems with several, contradicting objectives are considered. For a standard textbook, see for example (Ehrgott, 2005). A vector-valued objective function maps variables from the (high-dimensional) decision space to outcomes in the objective space, which usually is of considerably lower dimension. In the important special case of a *Multiple Objective Linear Program* (MOLP) one has a linear, vector-valued objective function which is to be minimized over a convex polyhedral constraint set. Apart from trivial cases, a single decision which leads to an outcome where all the objectives are minimal at the same time does not exist. Therefore, the question which decision is incorporated ultimately lies beyond the scope of the MOLP model. Usually, an entity called *Decision Maker* (DM), responsible for deciding between a set of different outcomes, is employed. In this context *solving an MOLP* can be interpreted as endowing the DM with all relevant information for making a rational decision. Clearly, a DM would not pick an alternative which is not *minimal* in the feasible image. (An alternative is called minimal whenever no other alternative exists which is strictly better in one component and not worse in the remaining ones. Minimal points are also called *nondominated* in the literature.) It seems to be most sensible not to impose any further knowledge or restriction on the preference of the decision maker. Hence, to make a profound decision, the DM needs to know all minimal outcomes. The collection of all these points constitutes the so-called *Pareto efficient frontier*. A representation of this Pareto front can be computed by *Bensolve*.

The partial order used in the objective space is not restricted to the component-wise less-or-equal relation usually used in MOLPs. In contrast to an MOLP a *Vector Linear Program* (VLP) admits for different partial orderings of the outcome space to reflect possible trade-offs between the different objectives. The ordering is generated by a polyhedral pointed convex cone with nonempty interior, the *ordering cone*. In *Bensolve*, the user may supply directions (primal generators) or normals to containing halfspaces (dual generators) to specify the ordering cone. If not provided by the user, the usual ordering cone consisting of all vectors with nonnegative entries is used as a default (This effectively means the problem becomes an MOLP).
Considering a VLP, the image of the feasible set under the objective function is a convex polyhedron in the outcome space, the *feasible image*. Clearly, the feasible image can be described as the extended convex hull of its vertices and extremal directions. However, some of those vertices or extremal directions may be dominated by other alternatives. In order to avoid them, *Bensolve* computes a representation of the so-called *upper image*. This polyhedron is the Minkowski sum of the feasible image and the ordering cone. (The upper image may also be interpreted as infimum when considering the embedding of the problem in a *Set Optimization* context, see for example (Löhne, 2011).) The upper image usually has an easier structure than the feasible image, but every point which is minimal in the feasible image is also a minimal point of the upper image. On the other hand, all vertices of the upper image are minimal in the feasible image. Similarly, every extremal direction of the upper image is either minimal or belongs to the ordering cone. Hence, the Pareto front of the problem is contained in the boundary of the upper image. For details, see for example (Löhne, 2011) and (Hamel et al., 2014).

Algorithm

The algorithms are based on the outer approximation algorithm proposed by (Benson, 1998) and its improvements, see for example (Ehrgott et al., 2012) and (Hamel et al., 2014). The general idea of the primal algorithm is to maintain an outer approximation of the upper image. After computing a *simple* initial outer approximation, it is refined successively by intersecting it with affine halfspaces supporting the upper image. In order to compute those, a vertex of the outer approximation is chosen. If this vertex does also belong to the upper image, this vertex (and a variable generating it) are stored. If this vertex does not belong to the upper image, an affine halfspace supporting the upper image and not containing the chosen vertex is computed. The outer approximation is then refined by intersecting it with the affine halfspace. This procedure is repeated until every vertex of the outer approximation is also a vertex of the upper image, meaning both polyhedra coincide.
The test whether a chosen vertex of the outer approximation belongs to the upper image and the computation of a supporting affine halfspace in the case it does not can be carried out by solving a (single) *Linear Program* (LP). The LP-solver currently in use by *Bensolve* is the *GNU Linear Programming Kit* (GLPK). The computation of the intersection of the polyhedral outer approximation with an affine halfspace is done by *vertex enumeration*.

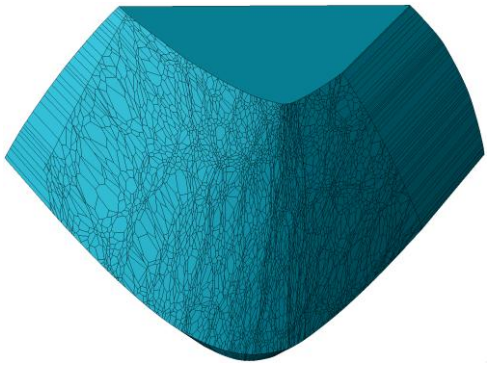

Figure 1. Approximation of the upper image of an MOLP investigated in (Shao & Ehrgott, 2008). See also (Löhne & Weißing, 2016b) for numerical results.

The algorithm described above may also be used to obtain approximate solutions: Instead of verifying whether a given vertex of the outer approximation belongs to the upper image, it is checked whether the distance (measured in terms of an interior direction of the ordering cone) of this vertex to the upper image lies below a given threshold. In *Bensolve*, this threshold can be defined by the user. When the approximation is translated in direction of the parameter by at least the error threshold, it becomes an inner approximation of the upper image.
The user can specify a direction lying in the interior of the ordering cone, called *duality parameter vector* in *Bensolve*'s reference manual. If it is not provided, it is automatically computed. In the special case of an MOLP, for instance, it defaults to the vector in the image space where all entries are equal to one. The choice of this parameter has influence on the dual problem as well as on the approximative solution.

Duality

Apart from the upper image of the primal problem, *Bensolve* additionally computes the *lower image* of the *dual problem*. The dual problem here is based on *geometric duality*, see (Heyde & Löhne, 2008). An important feature of this duality theory is that the dual problem is a VLP again. The dual problem is a maximization problem with a special ordering cone. In analogy to the primal problem, the Minkowski sum of the feasible image of the dual problem and the ordering cone is called lower image. The vertices of the lower image correspond to the facets of the upper image. Those facets, in turn, correspond to different weightings of the components of the objective function.
In the course of the algorithm, affine halfspaces supporting the upper image are computed consecutively. The outer approximation polyhedron is updated by intersecting it

with those affine halfspaces. The normal vector of such an affine halfspace is normalized and stored as a point contained in the lower image. In this way, a shrinking outer approximation of the upper image is accompanied by a growing inner approximation of the lower image. *Bensolve* also admits using a *dual algorithm*, where a successively decreasing outer approximation of the lower image is computed. Naturally, in this case an inner approximation of the upper image is used. The dual algorithm can be interpreted in terms of the upper image in the following way: The outer approximation of the lower image corresponds to an inner approximation of the upper image.

Applications

Radio Therapy Treatment Planning

As every MOLP is a special instance of a VLP, every MOLP can be solved by *Bensolve*. In (Shao & Ehrgott, 2008), a classical example for an MOLP is considered. There, finding an optimal treatment plan for destroying tumour cells is modelled as an MOLP: The body of the patient is compartmentalized into several so-called voxels. The decision variables then describe to how much radiation the different voxels are exposed. The three objectives are to apply an intensity as high as possible to the tumour cells while limiting the impairment of non-affected and critical organs. The authors provide numerical tests of solving different instances of this problem with Benson's outer approximation method. Numerical experience solving one of those problems approximately with *Bensolve* can be found in (Hamel et al., 2014) and in (Löhne & Weißing, 2016).

Polyhedral Projection

A *Polyhedral Projection Problem* (PP) describes the mapping of a (high-dimensional) convex polyhedron into a space with significantly smaller dimension. The goal is to find a representation of the projected polyhedron in terms of intersecting affine half spaces as well as in terms of a convex-conic combination. It was shown recently, that a PP can be expressed equivalently as MOLP (compare Löhne & Weißing, 2016a) and thus can be solved utilizing *Bensolve*.
An important application of Polyhedral Projection is provided by calculus rules for convex polyhedra: Convex polyhedra are usually represented as convex-conic combination of points and directions or as intersection of affine half spaces. Several operations, like the Minkowski sum, the intersection or the convex hull of the union of convex polyhedra given in this form can be formulated by introducing artificial variables. This results in the description of a higher dimensional polyhedron. To obtain the desired resulting polyhedron in the original image space, the artificial variables need to be eliminated. This means the high dimensional polyhedron is projected onto the original image space. In this way, set operations on convex polyhedra lead quite naturally to a PP. Similarly, polyhedral convex functions can be treated. Examples are the conjugate and the infimal convolution of two functions.

Global Optimization

The aim in Global Optimization is to find globally optimal solutions for scalar optimization problems which are non-convex in general. In important special cases, the search for a solution can be reduced to the vertices of a polyhedral constraint set. Enumerating all these vertices is NP-hard in general. In order to avoid the computation of all vertices, an approximation scheme combined with a branch & bound procedure can be used. This is done in (Ehrgott & Shao, 2016) for the class of *Multiplicative Programming Problems* (MPP). As *Bensolve* uses refining outer approximations, it can be modified to solve MMPs in this way: One only needs to employ a rule which vertex of the current outer approximation is to be cut off in the subsequent iteration.

Set Optimization

Several different approaches to solve optimization problems with objective functions mapping to sets rather than to scalars or vectors can be found in the literature. A prodigiously fruitful method is the so-called lattice approach, compare (Hamel et al., 2015) and the references therein for an overview. The main idea here is to embed the problem into a complete lattice in order to be able to work with infimum and supremum. Solutions to Set Optimization problems can then be defined as sets with two properties: Every element of the solution set should be minimal with respect to a certain partial order; and the solution set itself generates the infimum of all possible function values in the embedding lattice. (Note that while in scalar optimization minimality and infimum attainment concur, those concepts diverge in Set Optimization.).
In order to solve a polyhedral Set Optimization problem (meaning the graph of the set-valued objective map is polyhedral convex and the constraints are linear), the algorithm presented in (Löhne & Schrage, 2013, 2015) may be used. In order to obtain a description of the infimum of the problem, a corresponding VLP, the so-called *vectorial relaxation* needs to be solved. This can be done using *Bensolve*.

Mathematical Finance

A signifying application of Set Optimization (see above) can be found in mathematical finance. Here, a non-standard ordering cone can be used for modelling proportional transaction costs between different commodities. In this setting, set-valued risk measures can be defined, see (Hamel & Heyde, 2010) and (Hamel et al., 2011) and the references therein. With set-valued risk measures, vectors of different commodities are allowed as compensation for the risk inherent to a portfolio. This is in contrast to scalar risk measures, where all the different assets are expressed and evaluated in terms of a single asset (the numéraire, for instance cash), ignoring the transaction costs occurring upon exchange between the

different assets. The computations of a set-valued variant of the risk measure Average Value at Risk (AV@R, also known as Conditional Value at Risk or Expected Shortfall) is carried out by solving a VLP, compare (Hamel et al., 2013) and (Hamel et al., 2014).

Computation of Non-Shannon Inequalities

An application in information theory can be found in (Csirmaz, 2015): The goal is to describe the entropy region of a finite set of jointly distributed random variables by information theoretic inequalities. If N random variables are considered, then the entropy region is a set in a $2^N - 1$-dimensional space. The Shannon inequalities are well-known information theoretic inequalities. The intersection of their corresponding halfspaces is a proper superset of the entropy region if more than two random variables are considered. In the case of four random variables, there exist linear information theoretic inequalities which are not of the Shannon type. Those can be found by solving an MOLP with 10 objectives (The originally 15-dimensional problem is transformed to a 10-dimensional one by using non-trivial properties of the entropy region.). Computational experience regarding instances of this problem class solved by *Bensolve* can be found in (Löhne & Weißing, 2016b).

Problem Sizes

The size of a VLP consists of the number of objectives, the number of constraints and the number of (decision) variables. In order to be tractable, the number of objectives needs to be considerably small. The limit of variables and constraints is given by the LP-solver in use, while the number of objectives is primarily limited by the vertex enumeration. The vertex enumeration part of the algorithm is heavily sensitive to an increase of the objective space dimension. In the problem library MOPLIB (http://moplib.uni-jena.de) one can find instances of MOLPs where the objective size ranges from 2 up to 27. By contrast, the numbers of constraints and variables can be quite high. MOPLIB offers problem instances with up to 300k variables and 25k constraints.

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FITradeoff: a new decision support system for multiple criteria decision making with partial information

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Introduction

One of the major challenges of modeling preferences in MCDM/A is to evaluate the scaling constants (or weights) of criteria in the aggregation procedure. In MAVT, the alternatives are valued directly by the weighted sum based on the value functions of its consequences in each attribute and do so by considering the related scaling constants. A particularly relevant issue is how best to obtain the value of these scaling constants. This is perhaps the reason why many procedures for eliciting scaling constants in the additive model have been proposed. Riabacke et al. (2012) discuss several of these procedures.

The tradeoff procedure proposed by Keeney & Raiffa (1976) is a procedure for eliciting weights for the additive model in the context of MAVT, and has a strong axiomatic foundation (Weber & Borcherding, 1993). According to behavioral studies (Borcherding et al., 1991), this procedure presents about 67% of inconsistencies when applied. Alternatively, the procedure for eliciting swing weights (Edwards & Barron, 1994) simplifies the modeling, but it nevertheless presents 50% of inconsistencies. Both procedures use complete information in order to assess the weights.

The Flexible and Interactive Tradeoff (FITradeoff) elicitation method uses partial information about a Decision Maker's (DM) preferences to elicit scaling constants and so to determine the most preferred alternative of a specified set, according to an additive model (de Almeida et al., 2016). This method is consistent with the preference elicitation structure of the standard tradeoff procedure (de Almeida et al., 2016). Indeed, FITradeoff method follows the classical tradeoff procedure as it too has an axiomatic foundation and properties but FITradeoff has the advantage of requiring the DM to answer fewer questions and these are cognitively easier for the DM during the elicitation process. Thus, since FITradeoff generates results similar to those of the classical tradeoff procedure, the expectation is that the rate of inconsistencies will be lower because the DM needs to make less cognitive effort as only partial information is required.

FITradeoff Elicitation Process

The elicitation procedure is conducted in FITradeoff in an interactive and flexible way: the DM answer questions about strict preference relations and the FITradeoff Decision Support System (DSS) systematically evaluates the potentially optimal alternatives. The procedure may be suspended as soon as a solution is found with the information thus far available (de Almeida et al., 2016). The FITradeoff DSS also allows the DM to see partial results that can be displayed graphically at any point during the process. With these results, the DM can choose whether or not to continue the process, depending on whether the partial results are already sufficient for his/her purpose. The FITradeoff DSS works as illustrated in Fig. 1.

Once the intra-criteria evaluation is done, i.e., the marginal value functions are defined for all criteria, there is a step related with ranking the criteria weights. The partial information associated with the ranking is used to run the Linear Programming Problem (LPP) model (de Almeida et al., 2016). If a unique solution is found considering the available weight space, the process is complete. If not, the DSS model will ask the DM for preference relations between consequences in order to reduce the available weight space until a unique solution is found or DM is not willing to proceed.

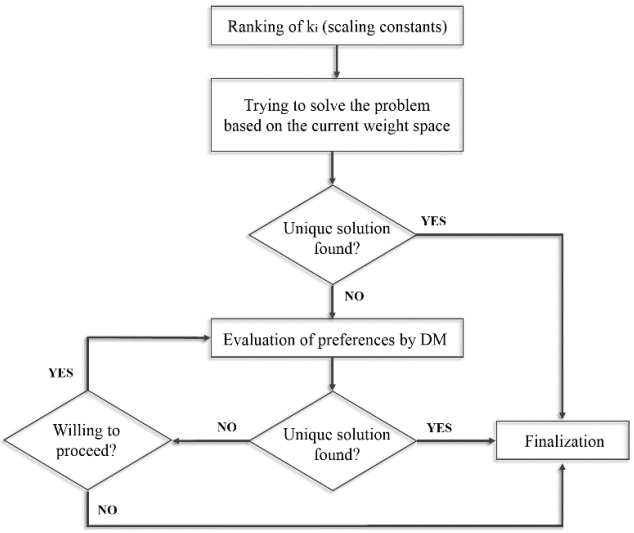

Fig.1. Procedure for the FITradeoff DSS (adapted from de Almeida et al., 2016).

The preference relations are obtained by asking the DM to choose between two consequences. FITradeoff, unlike standard tradeoff, does not require the DM to establish the exact point of indifference, since the questions are based on strict preference, which is cognitively easier to declare than identifying indifference points is. This is a critical issue on the traditional tradeoff procedure (Weber & Borcherding, 1993) that FITradeoff attempts to overcome.

In each cycle of the interactive process, the DSS model aims to evaluate whether the information obtained already allows there to be an appropriate solution for the problem. If a unique solution is found, then the DSS conducts the DM to the finalization step, in which the ranges of weights supporting the solution are computed which then leads to the final recommendation. Otherwise, the interactive process continues until a unique solution is found or the DM chooses not to give additional information (de Almeida et al., 2016).

Since this is a flexible process that is developed only for what is strictly required, it avoids overloading the DM with a large amount of questions. It also asks questions that require less cognitive effort from the DM to answer.

FITradeoff Decision Support System

The FITradeoff Decision Support System is a software developed for the Windows platform and is available for download on request at www.fitradeoff.org/download. It is important that a request be made so as to keep users informed of future updates of the software. Fig. 2 shows some screens of the software environment.

The FITradeoff website has a tutorial about how to input data into the software, a video lecture and other teaching resources related to this method.

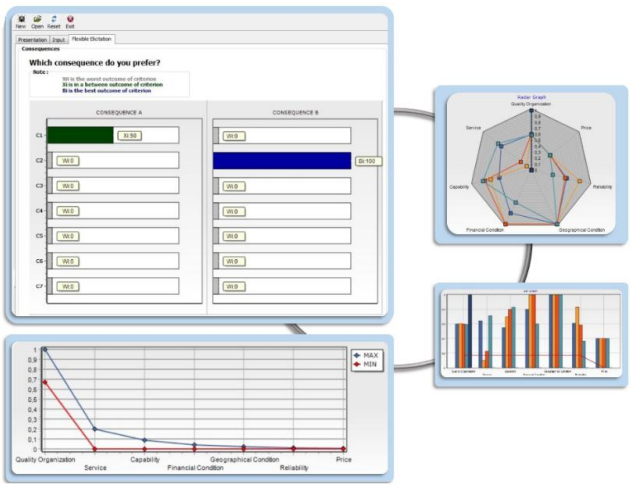

Fig. 2. FITradeoff software environment.

Illustrative example

An example of a supplier selection problem is presented by Barla (2003) and the FITradeoff method is applied by de Almeida et al. (2016). A set of 10 subcontractors is evaluated by using seven criteria to be maximized, such as Quality organization (g1), Service (g2), Capability (g3), Financial condition (g4), Geographical condition (g5), Reliability (g6) and Price (g7). The elicitation process of the FITradeoff DSS asks seventeen tradeoff questions in order to find the final recommendation. The ranges of the criteria weights that define a unique non-dominated solution is: w1 (0.19–0.16); w2 (0.17–0.15); w3 (0.16–0.14); w4 (0.15–0.13); w5 (0.15–0.13); w6(0.14–0.11); w7(0.12–0.09). The FITradeoff method uses a flexible and interactive procedure for eliciting weights and avoids the need to estimate the precise values of these criteria weights. This is an important advantage compared with other elicitation methods and arises because only partial information rather than exact values about the criteria weights needs to be obtained.

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About the 84th Meeting

The 84th workshop of the EURO Working Group Multicriteria Decision Aiding took place at the University of Vienna, Austria on September 22-24, 2016, and was organized by Rudolf Vetschera from that university. The location of the workshop was the building of the faculty of Business, Economics and Statistics located at Oskar-Morgenstern Platz 1, which, as most participants in the workshop agreed, is a nice address for holding a workshop on decision making.

The topic of the workshop was "From axioms to applications: Bridging the gap between theory and practice in MCDA". In total, 61 papers were submitted to the workshop, covering a wide range of topics from conceptual foundations to specific applications, and 49 persons actually participated in the workshop. Out of these papers, 16 papers were selected for presentation at the meeting, and 30 were included in the program as discussion papers. Presented papers were organized into five technical sessions. Two sessions dealt with applications, one of them had a specific focus on MCDA applications in environmental problems, the other was mainly devoted to urban planning. Two of the theoretical sessions focused on current developments in decision making methods with a focus on robustness in one session and in handling incomplete and conflicting information in the other session. A session that highlighted the relationships between MCDA and multiobjective programming concluded the workshop.

A scientific highlight of the workshop was the keynote presentation on Friday noon given by Fabio Maccheroni from Bocconi University on the topic "Model Uncertainty, Robustness, and Multicriteria Decision Analysis". The high scientific quality of all papers, and the intense discussion both in the sessions and during the coffee breaks, made the workshop a scientifically very successful event.

In addition to the scientific program, conference participants met for a conference dinner in a cellar dating back to the 13th century in the center of Vienna. On Saturday, many participants of the meeting took part in an excursion to the Wachau region including a visit to the

cellars of Langenlois, where participants could not only see how wine is produced, but also taste the final product.

PROGRAMME / PROGRAM

Thursday, Sept. 22

12:00 –13:00 Registration and Snacks
13:00 –13:30 Opening

13:30 –15:00 *Session 1:* Environment, Chair: José Figueira

- Valérie Brison, Marc Pirlot: Geographic expected utility model and application to risk assessment.
- Jafar Rezaei, Laura Groenendijk, Goncalo Homem De Almeida Correia: Measuring public transport station quality using a node-place-experience model and BWM.
- Judit Lienert, Alice Aubert, Valerie Belton, Fridolin Haag, Mika Marttune: Bridging the gap between scientific rigor and practical application in environmental decisions.

Discussion papers

- Tuomas Lahtinen, Raimo P. Hämäläinen, Juuso Liesiö: Supporting environmental decision making with portfolio decision analysis.
- A. Mendas, M.A. Gacemi, A. Mebrek: MCDM and GIS to evaluate land suitability.
- Raffaele Attardi, Issam Banamar: Urban Sprawl Ranking of Italian cities using a temporal extension of PROMETHEE II method.
- Alkaios Sakellaris, Yannis Katsaros, Nikolaos Matsatsinis: Reduce the semantic gap in content-based image retrieval with MCDA methods - an application in Cultural Heritage.
- Valentina Ferretti, Elisa Gandino: From Spatial SWOT Analysis to MCDA and choice experiments- an integrated approach for historical heritage management in a new World Heritage site

15:30 –17:30 *Session 2*: Robustness in MCDA, Chair: Milos Kadzinski

- Sally Giuseppe Arcidiacono, Salvatore Corrente, Salvatore Greco: Robustness concerns for PROMETHEE methods dealing with an hierarchy of interacting criteria.
- Athanasios Spyridakos, Nikolaaos Tsotsolas, Eleftherios Siskos: Robustness incensement into the additive value models estimated by UTA methods through the elimination of the criteria rank reversals.
- Mladen Stamenković: Stepwise benchmarking with indirect preference elicitation.

Discussion papers

- Werner Toth, Harald Vacik: A comprehensive uncertainty analysis of theAnalytic Hierarchy Process methodology in the context of environmental decision making.
- Eduardo Fernandez, Jorge Navarro, Rafael Olmedo: Comparative analysis of the effectiveness of several outranking-based multi-criteria sorting methods.
- Ihsan Alp, Ahmet Oztel: A new approach to selection of the best MCDM methods.
- Stelios Tsafarakis, Nikolaos Matsatsinis: Calibrating the Bradley-Terry-Luce choice rule using MCDA.

Friday, Sept. 23

9:00 –10:30 *Session 3*: MCDA Applications, Chair: Judit Lienert

- Jun L. Gao, Xiang Y. Xu, Gui Y. Cao, Yurii M. Ermoliev, Tatiana Y. Ermolieva, Elena Rovenskaya: Modelling water-energy-food nexus and resource trade-offs between energy and agricultura - Case study of Shanxi region, China.
- Roxane Lavoie, Irène Abi-Zeid, Francis Marleau-Donais: Elaboration of a collaborative process based on the MACBETH approach for the assessment of street potential in Quebec City.
- Alessandra Oppio, Valentina Ferretti, Alberto Colorni: Generating combinations of alternatives for urban regeneration: a Decision Analysis approach.

Discussion papers

- Diana Neves, Carlos A. Silva, Patrícia Baptista, Matilde Simões, José Rui Figueira: Development of a sustainable energy strategy using a multi-criteria analysis: the case study of Odemira municipality.
- Simon Hirzel, Julia Michaelis, Martin Wietschel: Using PROMETHEE to identify the most promising energy carrier to complement electricity in a largely electric world.
- Elisa Amodeo, Alessandro Luè, Eliot Laniando, Simona Muratori: Multi-criteria decision aiding to support stakeholder engagement in the electric transmission planning.

- De Vicente y Oliva, M., Manera Bassa, J., Jiménez Blanco, F.J.: Using ELECTRE III-H to produce a Spanish Business Incubator ranking.
- Christine Huttin: A RUM model on physicians' choice sets and health care financing systems
- Christine Huttin: A random utility model on economics and critical decision points in clinical practice.
- Gabriela Fernández Barberis, Mª del Carmen García Centeno, Mª del Carmen Escribano: Analysis of economic freedom in Europe: A multi-criteria approach

11:00 –12:00 *Keynote session*, Chair: Salvatore Greco
Fabio Angelo Maccheroni: Model Uncertainty, Robustness, and Multi Criteria Decision Analysis.

13:00 –13:30 Preparation of next meeting

13:30 –15:00 *Session 4*: Handling inconsistency in MCDA, Chair: Roman Slowinski

- Matteo Brunelli: Inconsistency and intransitivity estimation in valued preference relations.
- K. Belahcene, C. Labreuche, N. Maudet, V. Mousseau, W. Ouerdane: Explaining robust additive utility models by sequences of preference swap.
- DenisBouyssou, Marc Pirlot: Duality between strict and non strict outranking relations from an axiomatic point of view.

Discussion papers

- Miłosz Kadziński, Krzysztof Ciomek, Tommi Tervonen: Heuristics for prioritizing pair-wise elicitation questions with additive multi-attribute value models.
- Sami Kaddani, Daniel Vanderpooten, Jean-Michel Vanpeperstraete: OWA model with partial preference information.
- Jana Krejčí, Věra Jandová, Jan Stoklasa, Michele Fedrizzi: Computing interval weights for incomplete pairwise-comparison matrices of large dimension - a weak-consistency based approach.
- Debora Di Caprio, Francisco J. Santos-Arteaga, Madjid Tavana: SVIKOR - MCDM with stochastic data, subjective expert judgments and different risk attitudes of decision makers.
- Konrad Kułakowski: Analytic Hierarchy Process - HRE perspective

15:30 –17:30 *Session 5*: Optimization and MCDA, Chair: Walter Gutjahr

- Iraklis - Dimitrios Psychas, Magdalene Marinaki, Yannis Marinakis, Nikolaos Matsatsinis: Parallel multi-start multiobjective Influenza Virus Algorithm for multiobjective energy reduction open vehicle routing problema.
- Emmanouela Rapanaki, Iraklis-Dimitrios Psychas, Magdalene Marinaki, Yannis Marinakis, Nikolaos Matsatsinis: Clonal selection algorithm for thesolution of the multiobjective route-based fuel consumption multi-depot vehicle routing problem with uniformly distributed customers.
- Juergen Branke, Salvatore Corrente, Salvatore Greco, Walter Gutjahr: Building preference models from imprecise information.
- Masahiro Inuiguchi: Estimating interval weights from interval pairwise comparison matrix.

Discussion papers

- Maciej Nowak, Tadeusz Trzaskalik: Interactive methods in multiobjective dynamic programming.
- Irinel Dragan: On a family of cooperative TU games associated with a Multicriteria Optimization problema.
- Lavoslav Čaklović: Potential Method theory and software.
- Roman Słowiński, Jerzy Błaszczyński, Bartosz Prusak: Multi-objective optimization of rule ensembles.
- Boggia A., Fagioli F.F., Massei G., Paolotti L., Rocchi L.: Spatial multicriteria analysis: applications and further development.
- Kannan Govindan, Ronja Ehling, Miłosz Kadziński: Evaluation of sustainable third-party reverse logistics provider.
- Wlodzimierz Ogryczak, Tomasz Sliwinski, Bartosz Kozlowski: Modeling multiple goals for periodic vehicle routing and scheduling problems.
- Devika Kannan, Frederik Schirdewahn: Systematic literature review on low carbon supplier selection using content analysis
- Marlon Braun: On robust scalarized preferences using multi-modal methods in multi-objective optimization.
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Summer School

12th MCDA/M Summer School, Recife-Pernambuco, Brazil

The 12th MCDA/M Summer School took place in Recife-Pernambuco, Brazil, from 18th to 29th July 2016. It included 26 guest lectures, 14 casework sessions and 5 different case studies, covering the following topics: An Introduction to MCDA/MCDM; Applications in real world problems; Value-Focused Thinking and Problem Structuring; Preference Modelling; Outranking Methods; MAVT/MAUT (Multi-Attribute Value/Utility Theory); Robust Ordinal Regression; Decision Rule Approach; MCDM Group Decision; Interactive Methods of Multi-objective Optimization (IMMO); Multi-objective Combinatorial Optimization (MOCO); Evolutionary Multi-objective Optimization (EMO); Fuzzy Modelling in MCDM Problems; Decision Deck; "Meet the editor": Scientific writing and strategies of publications. A student

poster session was also organized, which allowed students to present their work and interact with each other with respect to their ongoing research. A slot, first mooted in the preliminary program, was included on the “MCDM community and History” (which also described society), since this was a good opportunity to cement and strengthen the future of the MCDA/M community. Two new sessions were introduced during the event: a new slot on Multi-objective optimization and a slot for “Biases in Decision Making”. For further details, see http://cdsid.org.br/mc-summer-school2016/program/.

We had 44 participants, who came from 17 countries: 60% were from Europe (Austria (3 participants), Belgium (1), Finland (1), Germany (1), Hungary (1), Italy (3), Netherlands (4), Norway (1), Poland (1), Portugal (4), Spain(3), Turkey (3), 27% from Brazil (12), 7% from Mexico (3), 4% from India (2), 2% from USA (1). It was a very fruitful event for the students since they were constantly able to exchange knowledge, discuss and make first attempts at tackling real world and real life decision problems, discuss recent developments in MCDA/M methods and practices, learn of software developments and examine situations in which different MCDA/M approaches may be considered as tools to be used in solving complex problems as discussed throughout case study sessions. We are really grateful to all lecturers who contributed to making this event a special occasion for all participants. Their names, in first name alphabetical order, are: Adiel T. de Almeida, Carlos M. Fonseca, Danielle C. Morais, José Rui Figueira, Martin J. Geiger, Matthias Ehrgott, Milosz Kadzinski, Murat Köksalan, Petr Ekel, Ralph L. Keeney, Roman Słowiński, Salvatore Greco, and Sandra Huber. For the case studies, we are grateful to Martin Geiger for his support in planning and structuring the cases studies, and also to Danielle Morais, Luciana H. Alencar, Rodrigo Ferreira, Sandra Huber and all lecturers for mentoring during the casework sessions. We had interesting and well-crafted group presentations at the final session for case studies.

On Sunday 24th July, we went to the Brennand Factory and Studio (an architectural ensemble and sculptural garden with a great variety of sculptures and paintings produced by Francisco Brennand – a sculptor from Pernambuco) and the Ricardo Brennand Institute (a museum with a permanent collection of historic and artistic objects of various provenances and one of the largest collections of armory in the world. It holds the world's largest collection of paintings by Frans Post -the first major artist to paint scenes of colonial Brazil of the early-mid 17th century. After this excursion, we had the Banquet in a traditional Brazilian Barbecue Restaurant, where lecturers and participants let their hair down and this included dancing samba and frevo to the sound of live music. It was a really fantastic moment during which all participants and lecturers mingled and joined in the fun!!! (see photos and videos at http://cdsid.org.br/mc-summer-school2016/photos/).

At the closing session, the participantsorganized a funny presentation, at which they thanked everyone who had contributed to the Summer School and this even included staff of the venue hotel. Besides, all participants received acertificate of completion stating the credits accomplished (signed by the Dean of Research and Post-Graduate Program and the Director of the Post-Graduate Program of Management Engineering of the Universidade Federal de Pernambuco).

Some impressions by participants can be seen at http://cdsid.org.br/mc-summer-school2016/impressions-by-participants/.

We are extremely grateful to all those who contributed to making this Summer School a resounding success for all of us! Our sincere thanks to the Scientific Committee, to the organizing committee for their selfless support since the very beginning. We also thank our sponsors CAPES, CNPQ, FACEPE, PRONEX, INSID, IPSID and the International Society on Multiple Criteria Decision Making – which funded the registration of 14 participants.

We are looking forward to meeting you all again!!

Danielle C Morais and Luciana H Alencar

Forthcoming meetings

- **7th International Workshop on Multiple Criteria Decision Making’17,**

  April 2–4, 2017, Ustroń, Poland

International Workshop on Multiple Criteria Decision Making (IWoMCDM) is a scientific event organized every two years in Jaskółka Hotel in Ustroń at the south of Poland among the charming hills of Beskidy Mountains by Department of Operations Research, University of Economics in Katowice, in cooperation with Polish Mathematical Society Upper Silesia Branch, INFORMS Polish Section and Polish Operational and Systems Research Society.

It is devoted to the theory and applications in the field of multiobjective optimization, goal programming and multiple criteria decision aid. IWoMCDM papers, after the blind review process, are published in the international

journal Multiple Criteria Decision Making (ISSN 2084-1531).

IWoMCDM has been organized from 2005 and accompanies Polish National Conference on Preference Modeling and Risk. In the both events more than 100 participants usually take part, which gives an opportunity to discuss and solve scientific problems in a circle of professionals or start the cooperation and joint future research.

Papers submitted to IWoMCDM should be focused on:

- multiobjective mathematical programming,
- multiattribute utility theory,
- MCDA methods,
- data envelopment analysis,
- interactive methods,
- fuzzy approach,
- meta-heuristics,
- group decision making,
- other theoretical and applicational MCDM issues.

The papers submitted to IWoMCDM'17 may be up to 40000 characters long.

The important dates are as follows:

- Registration: 15.01.2017
- Abstract submission: 15.01.2017
- Abstract approval: 30.01.2017
- Full paper submission: 31.03.2017
- Fee payment: from 01.12.2016 to 15.03.2017

IWoMCDM fee is 350 EUR. The registration fee includes: accommodation (full board), conference materials and publication in Multiple Criteria Decision Making vol.12 (2017) or vol. 13 (2018).

For more details see http://www.iwomcdm.ue.katowice.pl/

We are looking forward to seeing you in Ustroń in April 2017!

Tadeusz Trzaskalik

Workshop Chair

- 4-5/2/2017

AISGSB17 - 2nd International Workshop on AI for Smart Grids and Smart Buildings
San Francisco, California, USA
http://www.cs.nmsu.edu/aisgsb17

- 8-10/2/2017

EfS2017 - Energy for Sustainability 2017 -- Sustainable Cities: Designing Cities and Communities for the Future
Funchal, Madeira, Portugal
http://www.efs2017.uc.pt

- 24/2-7/3/2017

ELAVIO 2017
Buenos Aires and Miramar, Argentina
http://www.ic.fcen.uba.ar/elavio/index.html

- 26-28/2/2017

INOC2017 - 8th International Network Optimization Conference
Lisbon, Portugal
http://inoc2017.fc.ul.pt/

- 19-22/3/2017

EMO 2017 - 9th International Conference on Evolutionary Multi- Criterion Optimization
Münster, Germany
http://www.emo2017.org

- 19-21/4/2017

EvoStar 2017
Amsterdam, The Netherlands
http://www.evostar.org

- April 2017

85th Meeting of EURO Working Group on MCDA
Padova, Italy
Organizer: Chiara D'Alpaos

- 11-12/5/2017

PROMETHEE days 2017
Portsmouth, UK
http://www.port.ac.uk/promethee

- 5-8/6/2017

CEC-2017 - IEEE Congress on Evolutionary Computation
San Sebastian, Spain
http://www.cec2017.org

- 4-7/7/2017

MIC 2017 - 12th Metaheuristics International Conference
Barcelona
http://mic2017.upf.edu/

- 10-14/7/2017

MCDM 2017
Ottawa, Canada
http://sites.telfer.uottawa.ca/mcdm2017/

- 17-21/7/2017

28th IFIP TC7 Conference 2017 on System Modelling and Optimization
Middle East Technical University, Ankara, Turkey
http://iam.metu.edu.tr/ifip17

- 17-21/7/2017

IFORS 2017
Québec City, Canada
http://ifors2017.ca/

- 19-22/9/2017

ParaoptXI -11th International Conference on Parametric Optimization and Related Topics
Charles University, Prague, Czech Republic
http://paraoptxi.fsv.cuni.cz

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- 6-8/9/2017

OPTIMIZATION 2017
Lisbon, Portugal
http://optimization2017.fc.ul.pt

- 6-8/9/2017

OR 2017 International Annual Meeting of the German OR Society (GOR)
Berlin, Germany
http://www.or2017.de/

- September 2017

86th Meeting of EURO Working Group on MCDA
Paris, France

- 25-27/10/2017

ADT 2017 - 5th International Conference on Algorithmic Decision Theory
Luxembourg
http://sma.uni.lu/adt2017

- 8-11/7/2018

EURO 2018
Valencia, Spain

- 23-26/6/2019

EURO 2019
Dublin, Ireland

Seminars

SEMINAIRE « MODELISATION DES PREFERENCES
ET AIDE MULTICRITERE A LA DECISION »
Responsables : Bernard ROY, Daniel VANDERPOOTEN
(le mardi à 14h00 – salles à préciser)

Prochaines réunions
18 octobre 2016 Conférence de **Sonia Toubaline**
LAMSADE – Université Paris Dauphine
Problème de gestion de production électrique à court-terme dans les vallées hydrauliques

15 novembre 2016 Conférence de **Remzi Sanver**
LAMSADE – Université Paris Dauphine
Evaluationwise strategy-proofness

13 décembre 2016 Conférence de **Sami Kaddani**
LAMSADE – Université Paris Dauphine / DCNS Research
Somme pondérée et OWA avec information préférentielle partielle en optimisation multi-objectifs

Web site for Announcements and Call for Papers:
www.cs.put.poznan.pl/ewgmcda

Books

Multiple Criteria Decision Analysis State of the Art Surveys

S. **Greco**, M. **Ehrgott**, J.R. **Figueira** (Eds.)

International Series in Operations Research & Management Science,Vol. 233, Springer.

In two volumes, this new edition presents the state of the art in MultipleCriteria Decision Analysis (MCDA). Reflecting the explosive growth in thefield seen during the last several years, the editors not only presentsurveys of the foundations of MCDA, but look as well at many new areas andnew applications. Individual chapter authors are among the mostprestigious names in MCDA research, and combined their chapters bring thefield completely up to date.
Part I considers the history and current state of MCDA.
Part II presents the foundations of MCDA.
Part III looks at outranking methods.
Part IV is devoted to Multiattribute Utility and Value Theories.
Part V looks at Non-Classical MCDA Approaches.
Part VI deals with Multiobjective Optimization.

http://www.springer.com/us/book/9781493930937

Decision Sciences: Theory and Practice

Raghu Nandan **Sengupta**, Aparna **Gupta** and Joydeep **Dutta**

CRC Press, Taylor & Francis
ISBN: 9781466564305

This handbook is an endeavour to cover many current, relevant, and essential topics related to *decision sciences* in a scientific manner. Using this handbook, graduate students, researchers, as well as practitioners from engineering, statistics, sociology, economics, etc., will find a new and refreshing paradigm shift as to how these topics can be put to use beneficially. Starting from the basics to advanced concepts, authors hope to make the readers well aware of the different theoretical and practical ideas, which are the focus of study in *decision sciences* nowadays. It includes an excellent bibliography/reference/journal list, information about a variety of datasets, illustrated pseudo-codes, and discussion of future trends in research.
Covering topics ranging from optimization, networks and games, multi-objective optimization, inventory theory,

statistical methods, artificial neural networks, times series analysis, simulation modeling, decision support system, data envelopment analysis, queueing theory, etc., this reference book is an attempt to make this area more meaningful for varied readers. Noteworthy features of this handbook are in-depth coverage of different topics, solved practical examples, unique datasets for a variety of examples in the areas of *decision sciences*, in-depth analysis of problems through diagrams/charts and detailed pseudo-codes, and discussions about software.

https://www.crcpress.com/Decision-Sciences-Theory-and-Practice/Sengupta-Gupta-Dutta/p/book/9781466564305

Robustness Analysis in Decision Aiding, Optimization, and Analytics

Michael **Doumpos**, Constantin **Zopounidis**, Evangelos **Grigoroudis** (Eds.)

International Series in Operations Research & Management Science, Springer.
ISBN: 978-3-319-33121-8

Provides a unique overview of the fundamental aspects of robustness in OR/MS and the state-of-the-art advances in the related research, adopting a broad perspective that covers different established and emerging OR/MS fields, namely decision aiding, optimization, and analytics
Illustrates the robustness issues raised in real-world problems in different fields in engineering and management, and their resolution with innovative OR/MS methodologies
Editors and authors are leading authorities on the topics covered

http://www.springer.com/de/book/9783319331195

Articles Harvest

(This section is prepared by Salvatore CORRENTE, salvatore.corrente@unict.it)

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Announcement:

The "Useful links" section of the group's homepage

(www.cs.put.poznan.pl/ewgmcda)

is being enlarged. Contributions of URL links to societies, research groups and other links of interest are welcome.

A membership directory of the European Working Group on "Multiple Criteria Decision Aiding" is available at the same site. If you would like to be listed in this directory please send us your data (see examples already in the directory).

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Web site for the EURO Working Group "Multicriteria Aid for Decisions"

A World Wide Web site for the EURO Working Group on "Multicriteria Aid for Decisions" is already available at the URL:

http://www.cs.put.poznan.pl/ewgmcda/

Web site Editor: Milosz Kadzinski
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This WWW site is aimed not just at making available the most relevant information contained in the Newsletter sections, but it also intends to become an online discussion forum, where other information and opinion articles could appear in order to create a more lively atmosphere within the group.

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