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DECISION AIDING



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INTRODUCTION

The topic for the 84th meeting of the EURO Working Group on Multi-Criteria Decision Aiding, to be held September 22-24 2016 in Vienna, is “From Axioms to Applications: Bridging the gap between theory and practice in MCDA”. The papers included in this booklet show that this topic was received very well by members of the working group. We received a large number of submissions covering both theoretical developments of MCDA methods and actual applications, from which we were able to compile the selection of over forty papers included in this booklet.

The theoretical papers included show the current state of development of MCDA methods, and the problems being discussed in this area. A particular focus of these developments is based on the fact that decision makers often provide only incomplete or conflicting information about their preferences. Therefore, issues of robustness of MCDA methods, and the problem of dealing with inconsistent inputs are important current research topics. We have devoted two distinct sections of the program to these topics, and the keynote presentation on “Model Uncertainty, Robustness, and Multi Criteria Decision Analysis” also takes up the same theme. A third theoretical session focuses on the interface between traditional multicriteria decision aid, which often takes place in the context of multi-attribute problems of deciding among an (often small) number of alternatives, and multiobjective optimization, often dealing with combinatorial problems. This session also highlights the longstanding research tradition of our university on multicriteria metaheuristic methods of optimization.

MCDA is a field that has applications in many different domains, and this multitude of potential applications is clearly visible in the breadth of applied papers that were submitted to this meeting. Nevertheless, there are two fields of application which are particularly well represented in the submissions, and which we have made the main topics of the applied sessions in the program. The first one is the area of environmental problems, which has been a strong application area of multicriteria methods since the early days of the field. The second, and more recent one, is regional planning. Several applied papers in the workshop describe how multicriteria methods can be used in this context, and in particular how geographic data and MCDA methods can be fruitfully combined.

The scientific program thus offers a wealth of information on new methods and applications of MCDA. Apart from that, we hope that the workshop will provide ample opportunities to establish new contacts, discuss interesting topics with colleagues, and strengthen old or create new ties within the group.

Rudolf Vetschera
on behalf of the organizing committee

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A New Approach to Selection of the Best MCDM Methods

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ABSTRACT

Decision-making is an activity that everyone makes it at every moment of life. If there is more than one criteria in the decision-making process in question, this is a Multi-Criteria Decision Making (MCDM) problem. Numerous methods have been developed to solve MCDM problems since the beginning of seventies. Various methods are available for achieving the best solution in the MCDM problems. Different methods could propose different solutions. To find which method provides the best solution for the problem, it come across as a new problem in itself. In this study, the regression approach has been proposed as a new framework for selection the best MCDM method for given problem. The proposed approach is built upon the relationship between the decision matrix and preference ranking. The most of MCDM methods make an order of preference among the alternatives by using the decision matrix. The relationship between decision matrix and preference ranking can be demonstrated by the regression model. The goodness of fit of the regression model, reflects the quality of the ranking. The coefficient of determination is a useful tool to measure the goodness of fit. The MCDM method used in the model which obtained the highest coefficient of determination is the best method. The financial performance analysis of 25 real estate investment trust firms that traded in Borsa İstanbul is evaluated as application. The TOPSIS, MAUT, CP, PROMETHEE and VIKOR methods are selected as MCDM methods. Entropy method is preferred for criteria weighting. The proposed regression approach presents an opportunity of exact and objective analysis among the MCDM methods. In addition, since regression approach consists of basic mathematical and statistical tools it is very useful. Therefore the proposed approach is expected to make a significant contribution to the literature.

Keywords: Multi Criteria Decision Making, Regression Analysis, Entropy, Coefficient of Determination.

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Multi-criteria decision aiding to support stakeholder engagement in the electric transmission planning

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ABSTRACT

To meet the European 20-20-20 targets and the objective of a largely decarbonized energy sector by 2050, a considerable expansion of the electric transmission grid is considered necessary for a large-scale integration of renewable energy sources. At the same time, transmission lines can have environmental and socio-economic impacts during both the construction and the operation phases. This can lead to opposition from stakeholders and citizens, and therefore slow down or block the authorization and realization process.

Within the INSPIRE-Grid project, co-funded by the European Commission under the 7th Framework Programme (www.inspire-grid.eu), we propose Multi-Criteria Decision Aiding (MCDA) as an approach to support grid planning processes. Energy planning is a field that is quite suitable for MCDA methods because it is subject to many sources of uncertainty, long time frames and capital-intensive investments, along with featuring multiple stakeholders and conflicting criteria.

We structured a criteria tree to assess transmission alternatives, considering three main areas: (1) monetary costs, e.g. investment, operating, maintenance and decommissioning costs; (2) environment and health, e.g. air pollution, biodiversity, landscape, land use, noise, GHG emissions, electromagnetic fields; (3) socio-economic aspects, e.g. impacts on economy (agriculture, tourism, etc.), property values, security of supply, electricity prices, transmission grid losses, etc. We used an additive value function under imprecise information, using variable interdependent parameters subject to constraints. Within this framework, a precise elicitation of the trade-offs between the criteria is not necessary; therefore, stakeholders were asked to rank the criteria and, when sensible, to specify additional information about the relative importance of the criteria.

The proposed approach was used in two Norwegian real cases, i.e. the realization of the Bamble-Rød and Aurland-Sogndal lines, where we elicited the preferences of different stakeholders with the support of the national transmission system operator, Statnett. The interaction with the stakeholders was conducted in one case with single interviews, in the other one in a group discussion.

MCDA made transparent the preferences of all the stakeholders involved (e.g. planning authorities, transmission system operators, citizens) and helped to display the trade-offs among criteria, so that the stakeholders could consider the advantages and disadvantages of proposed alternatives. MCDA cannot claim to unify or synthesize different systems of values, in case of conflictual decision process. Nevertheless, MCDA may allow participants to structure the debate and facilitate negotiation, especially by supporting a climate of confidence and by providing a common understanding of the problem.

Keywords: Multi-criteria decision aiding, stakeholder engagement, conflict management, electric transmission planning, infrastructure assessment.

Robustness concerns for PROMETHEE methods dealing with a hierarchy of interacting criteria

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ABSTRACT

PROMETHEE [1] are among the most applied methods in Multiple Criteria Decision Aiding (MCDA). However, despite their widespread adoption, the basic version of these methods does not take into consideration some characteristics of multicriteria decision problems that are very relevant in real world applications, such as:

- robustness concerns regarding imprecise evaluations of alternatives and plurality of compatible preference parameters (weights of criteria, and indifference and preference thresholds);
- interaction between criteria [2];
- consideration of a hierarchy of criteria that will permit to handle efficiently the greater and greater quantity of available data.

Even if different extensions of the PROMETHEE methods have been proposed to take into account all these aspects singularly, we propose to deal with all of them simultaneously presenting a new version of PROMETHEE methods which incorporates:

- Robust Ordinal Regression (ROR) [4] and Stochastic Multicriteria Acceptability Analysis (SMAA) [5], permitting to deal with robustness concerns,
- use of proper coefficients permitting to represent interaction between criteria,
- Multiple Criteria Hierarchy Process (MCHP) [3], permitting to deal with a hierarchy of criteria.

A didactic example will illustrate the proposed methodology.

Keywords: PROMETHEE methods, Hierarchy of Criteria, Interaction between criteria, Robust Ordinal Regression, Stochastic Multiobjective Acceptability Analysis

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Urban Sprawl Ranking of Italian cities using a temporal extension of PROMETHEE II method

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ABSTRACT

Assessing the evolution over time of urban sprawl of cities is gaining stronger attention by the scientific community, policy-makers and the broad public (1). The analysis of such a complex task is mostly performed by making use of mono-criterion evaluation, while the application multicriteria methods is barely explored (2).

Global trends in land-use change for urban growth and development are a current relevant phenomenon that questions the actual efficiency of land-use policies in preserving natural uses of the soil as an unrenovable resource (3). A major challenge for local land-use policies is the increase of their own efficiency while limiting the transformation of natural soil for artificial land-uses (4).

An appropriate assessment of land-use policy efficiency should consider the different drivers causing land-use change in terms of ecosystem integrity and provisioning of ecosystem services (5).

Moreover, land-use is typically evolving over time based on social and economic junctures. In this dynamic context, an assessment of urban sprawl based on a temporal multicriteria method will allow decision makers to identify good and bad practices in the management of land-use.

To achieve this task, we have selected a recent extension of PROMETHEE II to temporal evaluations (6). This new approach will assess the urban sprawl since 1990 by comparing various cities with respect to environmental, social and economic criteria. The result consists of monitoring the global ranking of these cities. In addition, the temporal GAIA plan allows to get a visual evolution of each area during the assessment period.

The advantage of this approach is that it considers time into the assessment process in order to increase knowledge and provide deeper understanding of the urban and regional planning domain.

Keywords: Urban planning, multicriteria decision aid, temporal evaluations, PROMETHEE II, Gaia plan.

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Explaining robust additive utility models by sequences of preference swaps

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ABSTRACT

As decision-aiding tools become everyday more popular-but at the same time more sophisticated, it is of utmost importance to develop their explanatory capabilities [PC07]. Some decisions require careful explanations, which can be challenging to provide when the underlying mathematical model is complex. In this work we shall concentrate on explanations in the context of decisions involving multiple criteria. More precisely, we propose to construct pieces of evidence that support unambiguously a binary preference relation between two alternatives described along multiple attributes. Our explanation engine takes inspiration from the *even-swaps* method [HKR98], an elicitation procedure assuming an additive value model of preferences and based on trade-offs between pairs of attributes. The idea is to use similar sequences as explanations of a recommendation. The problem with such a process is that it requires each new generated option to be equally preferred to the initial one, which is poorly adapted to the context of incomplete preferences. To circumvent this issue, we propose a generalization of *even-swaps* to *preference swaps*, and simply exhibit a comparison between alternatives. To keep the sequence as simple as possible, we aim at constructing a sequence of low-order preference swaps between two alternatives, in the sense that two successive alternatives in the sequence only differ on a few criteria. In the end, the resulting explanations can be appreciated through the number of swaps and the order of the most complex swap involved in the explanation. An interesting feature of this explanation engine is that it can be shown to operate on any value-based decision models satisfying some basic axiomatic properties. We propose thereafter to instantiate the engine by relying on a *robust additive utility model* [GSFM10]. The robust is constructed according to preference information provided by the decision maker. However, contrary to the classical additive models, in the robust approach the relation holds if any possible completion of the available preference information yields the preferential statement. In order to provide a solid mechanism to construct explanations for robust relations, we come up with a new characterization of the robust relation, based on the notion of *covectors*, which facilitates its implementation in the

explanation engine. In a nutshell our proposal is thus to decompose a robust preference into several simpler recommendations. This work tackles different questions: are such explanations guaranteed to exist, in particular if we restrict the order of swaps? And if they do exist, can we exhibit upper bounds on their length? As we shall see, the answer to this question crucially depends on the number of distinct values referenced by the preference information. In binary domains, we provide an efficient algorithm which constructs such explanations.

Keywords: Multicriteria decision-making, Explanation, Necessary preference relation

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Spatial multicriteria analysis: applications and further development

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ABSTRACT

In the last twenty years spatial multicriteria issues have been increasing, both as importance in the theoretical field and as number of applications. This growth is not surprising, due to the inner multiple and conflicting nature of the spatial analysis. In case of issues involving planning, its conflicting nature emerged even more strongly, because in this context also the social and economic objectives affect the final results. In such a context, multicriteria analysis is a powerful instrument for better understanding reality.

Several are the fields of application. Among them, the most covered issues are land slide (Barredo, et al., 2000, Lee & Choi, 2004; Komac, 2006; Feizizadeh and Blaschke, 2013; Wu and LI, 2015), flood risk assessment (Bana and Costa, 2004; Levy 2005; Mokrech et al., 2012; Fernandez et al., 2016), site selection (Vatalis and Manoliadis, 2002; Kontos, et al., 2005; Sener et al. 2006; Wang, et al., 2009; Geneletti, 2010; Massei et al., 2014); and vulnerability assessment (Chen et al., 2003; Ying et al. 2007; Setegn et al., 2009; Galiana-Martin and Karlsson, 2012; Alvarado et al., 2016). Methods applied in the case studies are several. However, AHP and Fuzzy approaches seem to be preferred, in particular in engineer field.

Although the great number of applications, most of them are based on formal and indirect integration between GIS and MCDA. However, indirect integration, which means that the two systems do not share the same database and interface, is only the basic step of integration. Best solution is the complete integration (Greene et al., 2010; Malczewski, 2006; Massei et al., 2014), which allows the integration between the database and interface.

The present work presents three tools which completely integrate MCDA-GIS, by means of two of the most common and widely used GIS open source software, QGIS (QGIS Development Team, 2013) and GRASS GIS 6.4 svn (Grass Development Team, 2012a, 2012b). The development of modules or plugins in existing GIS software guarantees a broad potential public, which means also applications in new fields. Moreover, the addition and development of MCDA methods is potentially limitless, thanks to the open source environment.

The integrated MCDA-GIS models here presented are: *r.mcda*, developed for raster data in GRASS GIS, *VectorMCDA* and *GeoUmbria SUIT*, both developed in Quantum GIS for vector data. The applications proposed by the research group of Applied Economics of

University of Perugia (Italy), in relation to these type of instruments, are mainly focused on environmental evaluations, sustainable development, territorial planning and analysis. The MCDA methods implemented in the different tools are several, but it is possible to increase the number. Furthermore, another big issue is the integration with the Decision Deck project (Mayag *et al.*, 2012) which focuses on the collaborative development of Open Source software tools, to support complex decision aid processes. A module for granting the MCDA data interoperability is under active development and testing phase.

Keywords: MCDA-GIS integration, Spatial Decision Analysis, Sustainable development

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Duality between strict and non strict outranking relations from an axiomatic point of view

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ABSTRACT

Outranking relations such as produced by the Electre I or II or the Tactic methods are based on a concordance and non-discordance principle that leads to declaring that an alternative is « superior » to another, if the coalition of attributes supporting this proposition is « sufficiently important » (concordance condition) and if there is no attribute that « strongly rejects » it (non-discordance condition). Such a way of comparing alternatives is rather natural and does not require a detailed analysis of tradeoffs between the various attributes. However, it is well known that it may produce binary relations that do not possess any remarkable property of transitivity or completeness. The axiomatic foundations of outranking relations have recently received attention. Within a conjoint measurement framework, characterizations of reflexive concordance-discordance relations have been obtained. These relations encompass those generated by the Electre I and II methods, which are non-strict (reflexive) relations. A different characterization has been provided for strict (asymmetric) preference relations such as produced by Tactic. In this presentation we shall briefly review the various kinds of axiomatizations of outranking relations proposed so far in the literature. Then we analyze the relationships between reflexive and asymmetric outranking relations in a conjoint measurement framework. Co-duality plays an essential rôle in our analysis. It allows us to understand the correspondence between the previous characterizations. Making a step further, we provide a common axiomatic characterization for both types of relations. Applying the co-duality operator to concordance-discordance relations also yields a new and interesting type of preference relation that we call concordance relation with bonus.

Keywords: outranking methods, conjoint measurement, concordance-discordance relations, axiomatic characterization

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Building Preference Models from Imprecise Information

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ABSTRACT

We consider the problem of building preference models from pairwise comparisons. Thereby we take into account that in practice, decision makers (DMs) are not able to make arbitrarily precise judgments when comparing solutions. This is modeled by assuming that if the utility difference between two solutions is smaller than some threshold δ , the user is unable to say which of the two solutions is better and will respond by stating indifference. Our preference model then has to capture the DM's utility function as well as learn the indifference threshold.

For a given set of alternatives and based on the framework of robust ordinal regression, we ask the question which pairs of alternatives should be shown to the DM to maximize learning, and when one can stop the process and be confident in having identified a good solution.

Keywords: Preference learning, Imprecision, Indifference

On robust scalarized preferences using multi-modal methods in multi-objective optimization

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ABSTRACT

Scalarized preferences assign a real number to every element of the Pareto front of a multi-objective optimization problem. This approach induces a total order on the objective space and allows the identification of global preference optima. Human preferences, however, can often only be modeled imperfectly using scalarization techniques. Although a scalarization function may closely represent a decision maker's (DM) true preference, there may exist hidden features that cannot be captured by the function itself [1]. Sometimes, the global preference optimum identified by the scalarization function is even counterintuitive to the DM's own expectations. This is, for example, the case when using a weighted sum on a multi-objective minimization problem featuring a concave Pareto front. In said scenario, only extreme points of the Pareto front can be identified as global preference optima [2]. Extreme points, however, seldom pose an interesting choice as they do not provide a balance between the different objectives that are optimized [3].

We therefore propose taking additionally local preference optima on the Pareto front into account during the decision making process. Local preference optima are close in the scalarized preference space, but possibly far apart in the objective space [2]. Since these optima possess similar scalarization values, they are expected to be the best candidate solutions complying with the decision maker's preferences. On the other hand, their spatial distance is expected to compensate for the hidden features that cannot be captured by the scalarization function. By providing the DM with multiple choices, we aim at making the optimization effort more robust with respect to the inexactness of the scalarization function.

Recently, evolutionary multi-modal methods have been successfully applied to black box optimization problems. In black box optimization, no information about the structure of the problem is known besides input to output relations that can be exploited to speed up the search process [4]. Scalarization functions may comprise multiple complex mathematical operations that possibly introduce undesirable properties such as non-differentiability to the optimization problem [5,6]. Multi-modal techniques, therefore, appear to be very suitable in identifying local preference optima on the Pareto front as we do not want to impose any restrictions on the mathematical structure of the scalarization function. The scalarization function itself can be conceived as black box that takes elements of the objective space as inputs.

Such an approach is especially useful for problems possessing more than three objectives [7].

Comparing solutions to these problems is often difficult, since trade-offs cannot be easily visualized. The multi-modal approach allows the identification of a few most promising candidate solutions among which the DM can make his final choice.

Keywords: scalarization function, robust preferences, multi-objective optimization, multi-modal optimization

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Geographic expected utility model and application to risk assessment

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ABSTRACT

In the field of land management, it is usual to have a geographic map, representing a region under study, and divided into geographic units. Each unit is assessed on an ordinal scale describing its degree of suitability for some usage, for instance housing, or its state of degradation with respect to sustainable development criteria. We call such a map a decisional map. After a while, and for example, after the application of some policies aiming at improving the situation, the state of the units has evolved. For some units, the state has improved, and for some others, it has deteriorated. What we want to know is whether the global state of the map has improved or not. So, we have developed several formal models to help a decision maker to express his preference over maps. One of them is based on an expected utility function and is able to take into account some geographic aspects such as the proximity to habitations, roads or watercourses. We provide axioms under which the decision maker's preference can be represented by this model. We also illustrate an elicitation process used to determine the model's parameters on a real-world example, which is the risk assessment of an industrial project.

Keywords: Maps comparison, expected utility, elicitation, risk assessment

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Inconsistency and intransitivity estimation in valued preference relations

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ABSTRACT

Pairwise comparisons in the form of valued preference relations have been used to solve multi-criteria decision making problems requiring the elicitation of subjective judgments. For example, the AHP uses pairwise comparisons (Saaty, 2013). It is widely agreed that preferences should, if possible, be rational or close to rationality. Hence, many indices have been proposed to measure the inconsistency and the intransitivity (two types of deviations from rationality conditions). These indices have been proposed heuristically, and only recently formal studies have been undertaken to define a set of axioms (Brunelli, 2016; Brunelli and Fedrizzi, 2015). These axioms represent properties which seem to be justified and should hold for all inconsistency indices, to guarantee that they provide a fair representation of inconsistency.

Inconsistency and intransitivity represent violations of two different properties, one weaker than the other, and thus they have been studied separately. However, one important question regards the existence of indices, i.e. functions, which can estimate the inconsistency and intransitivity of a valued preference relation. Can such functions exist? Starting from the axioms introduced to characterize inconsistency indices we can show that, if continuity is required to hold as a property of the function, then it is *not* possible to conjointly estimate inconsistency and intransitivity. Conversely, if continuity is not imposed, then it seems feasible to devise such indices.

Keywords: Preference relations, Pairwise comparisons, inconsistency, intransitivity.

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Potential Method theory and software

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ABSTRACT

Preference multigraph is directed multigraph with non-negative weights which may be interpreted as an aggregated preferences of a group of decision makers or several criteria. The nodes in the graph represents the alternatives in consideration, and the arc-weights represents the intensity of the preference between two nodes. The ranking of the graph nodes is obtained as the solution of the Laplace equation of the graph.

This simple model may be integrated in the complex decision structures: hierarchical structures, self-dual structures (when the weights of the criteria are not known), reconstruction of missing data in the measurement process when some proxy data are given), classification process (medical diagnostics), classical multi criteria ranking (including ordinal ranking and with given intensity of the preference), group decision making and many others.

We are going to present the software which is entirely written in python and GUI which is written in PyQt5.

Basically, there are two applications in the software, one for data in table format, and the other for complex hierarchical structures (still under development).

Using ELECTRE III-H to produce a Spanish Business Incubator ranking

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ABSTRACT

We present in this paper a methodology to produce a ranking of business incubators and business accelerators in Spain. Rankings for business incubators have become increasingly popular last years. Most of these rankings devote much effort to collecting information but, however, use very simple techniques for the final elaboration of the ranking (using for example a simple weighted mean). We propose to use a hierarchical ELECTRE III (or ELECTRE III-H) to produce a multicriteria ranking where, unlike other business incubators rankings, compensation between criteria is not allowed but incomparability between incubators is allowed. Besides, the hierarchical structure of the problem makes easier to work with a large set of criteria because they can be grouped by types and reasoning is clearer for the decision maker. This approach let us offer a much more realistic panoramic of the Spanish business incubators.

An important part of the paper is also devoted to the information collecting and an analysis of the availability of this information is presented. We focus on the difficulty of obtaining information about the success of the enterprises once they have left the incubator.

Keywords: Multicriteria decision methods, ELECTRE III-H, business incubators, rankings.

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SVIKOR: MCDM with Stochastic Data, Subjective Expert Judgments and Different Risk Attitudes of Decision Makers

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ABSTRACT

We extend the VIKOR multi-criteria decision making methodology to solve problems characterized by:

- stochastic data determining the coefficient of variation from each decision alternative;
- subjective judgments of experts when assigning relative importance weights to the different decision criteria: the corresponding weights are elicited using the fuzzy analytic hierarchy process method;
- differences in the attitude of decision makers (DMs) towards risk and its effect on their subjective beliefs.

We present a case study in the banking industry to demonstrate the applicability of the proposed method. We also compare our results with the results derived from a stochastic version of the super-efficiency data envelopment analysis (DEA) model to exhibit the efficacy of the procedures and algorithms. In particular, we illustrate how differences in the beliefs of

DMs modify the ranking obtained relative to the one derived from the stochastic super-efficient DEA model.

Keywords: Multi-criteria decision making; VIKOR method; Stochastic data; Subjective judgments; Risk attitudes.

On a family of cooperative TU games associated with a Multicriteria Optimization problem

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ABSTRACT

A cooperative TU game is defined by a characteristic function, which associates some worth with each coalition. The main classical problem is that of allocating fairly to players the worth of the grand coalition, when this coalition is formed. Such an allocation is found by using either efficient values, like the Shapley Value, the Weighted Shapley Value, etc., or the normalization of a non efficient value like the Banzhaf Value, the Semivalues, etc. In earlier works, ([1], [2]), we introduced the Inverse Problem for efficient and non efficient values. The solutions of these problems are given by an explicit formula, that shows the family of all games with an a priori given value.

In the present paper, to a Multicriteria Optimization problem we associate a cooperative TU game, as follows: for a criterium I , we get an optimal value $L(i)$ of the associated optimization problem. If L is the vector of the optimal individual values for all n criteria, then we define a family of games on the player set N , by using the explicit formula for the solutions of the Inverse problem, associated with a chosen value from Game Theory. By using a more recent work, ([3]), we may choose in this family a game for which the value is in the Core of the game. Now, by the algorithm shown in another work ([4]), we compute the generalized nucleolus of the game, to be a solution of the MOP problem. Many new problems for designing an optimal economic system, will occur if we shall choose a Semivalue, and the owners of the criteria are bargaining on their weights in the Semivalue. An example, is illustrating the above approach.

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From Spatial SWOT Analysis to MCDA and choice experiments: an integrated approach for historical heritage management in a new World Heritage site

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ABSTRACT

One of the fundamental features of policy processes in contemporary societies is complexity, namely the plurality of points of view actors adopt in their interventions and of criteria upon which they base their decisions, as well as the presence of uncertainty and intangible elements, and the need to adopt easy to use and transparent tools in order to be able to justify both the results and the processes in front of the public. This study develops a multi-methodology intervention designed and deployed to support planning and management of a new World Heritage site in Italy, i.e. the vineyard landscape of Langhe, Roero and Monferrato in Northern Italy. The proposed framework develops through four subsequent phases and experiments with an integrated approach based on mixed Decision Analysis (DA) and Operations Research (OR) analytics, i.e. Spatial SWOT Analysis and Multicriteria Decision Aiding in Phase 1 (problem identification - knowledge phase), Stakeholders' Analysis and Spatial Multicriteria Decision Aiding in Phase 2 (problem formulation - planning phase), and Choice Experiments during Phase 3 (problem solving - design). The whole study has been developed in close collaboration with the La Morra Municipal Authority, one of the stunning components of the Core UNESCO Area. 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, bridging the gap between traditional OR/MS rooted in mathematical models and problem structuring methods, community engagement and capacity-building.

Keywords: mixed methods, analytics, multiple criteria decision analysis, group decision process, Spatial SWOT Analysis, Geographic Information Systems

Comparative analysis of the effectiveness of several outranking-based multi-criteria sorting methods

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ABSTRACT

In the framework of outranking-based multi-criteria sorting methods, the most widely used approach is ELECTRE TRI (Wei, 1992; Roy and Bouyssou, 1993), recently renamed as ELECTRE TRI-B. This method has been criticized because defining the reference profiles is often a difficult task, especially when the decision-maker has only a vague idea about the boundary between two consecutive categories. Almeida-Dias et al. (2010) proposed the ELECTRE TRI-C method, in which each category is defined through a single characteristic reference action. But when the object to be assigned is incomparable with most actions in the reference set, ELECTRE TRI-C may suggest ill-defined (imprecise) assignments. According to Figueira et al. (2013), if each category is defined by a set of several reference actions, it enriches the definition of categories and allows narrower ranges of categories to which an action can be assigned. Some papers have addressed the size of the reference set and its importance in achieving a good characterization of the categories. ELECTRE TRI-nC was proposed as a generalization of ELECTRE TRI-C (Almeida-Dias et al., 2012) and the THESEUS method was suggested for handling the preference information contained in more general reference sets (cf. Fernandez and Navarro, 2011).

In this contribution the effectiveness of each method is characterized by i) its capacity for suggesting precise and appropriate assignments; ii) the probability of suggesting imprecise assignments, and iii) the probability of suggesting wrong assignments.

This paper has several aims: First, by comparing ELECTRE TRI-C with nC and THESEUS, to determine the real impact of handling larger reference sets. We are also interested in studying to what extent the effectiveness of the methods is influenced by the number of criteria and categories, the cardinality of the reference set (in case of ELECTRE TRI-nC and THESEUS), and the way in which this set is chosen or populated.

Those dependencies have not been characterized. Their formal theoretical analysis is very hard; so, we choose to perform an experimental analysis in which a great diversity of decision maker preferences is simulated, and many reference sets are built following different policies. Thus, the methods' performances are explored in a very wide range of simulated decision maker preferences, categories, criteria, and reference set cardinalities. The reference sets are built in two ways: i) randomly, by simulating cases in which a decision maker *accepts* objects previously assigned, so (s)he neither sets nor controls their multi-criteria description; ii) the decision maker starts from a basic set in which each category is represented by one object, and (s)he goes enhancing the reference set by making new assignments of objects that are only slightly different from those already assigned, and whose multi-criteria description is controlled by her/him.

The results underline the importance of a) the decision maker's consistency with the outranking model; b) the number of reference objects and their distribution per category; and c) the number of criteria. Our concluding remarks allow identifying contexts for which a particular method may be more appropriate.

Keywords: multiple criteria analysis; sorting; fuzzy outranking relations

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ANALYSIS OF ECONOMIC FREEDOM IN EUROPE: A multi-criteria approach

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Abstract:

The degree of economic freedom is a problem that has worried the countries all over the world. Different indices have been developed to measure the economic opening of each country on the basis of macroeconomic and financial variables.

The aim of this paper is to obtain a ranking among European countries in terms of different indices that are indicators of the economic freedom level. For the analysis PROMETHEE methods have been applied. The study was made with data from 2016.

Keywords: Multi-Criteria Decision; economic freedom; index of economic freedom; PROMETHEE Methods.

Modelling water-energy-food nexus and resource trade-offs between energy and agriculture: Case study of Shanxi region, China

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ABSTRACT

China's reliance on coal has raised a number of urgently pressing environmental issues. Of these, the greenhouse gases emissions and air pollution are well known, whereas the land deterioration and high water consumption are less evident, albeit not less severe. The Chinese government has actively started addressing the environmental problems related to the coal mining industry. However, the traditional approach to governance is lacking coordination between sectors and thus decisions made to improve a part of the system, are often suboptimal

to its other parts. Herein, we put forward a regional spatially-detailed cost-minimizing model of coal and agriculture production utilizing the common (scarce) land and water. We apply the developed model to Shanxi province, China. By means of the scenario analysis, we find out that water availability imposes the most severe constraint to the allocation of land between coal and agriculture production; outline the sets of feasible coal and agriculture productions under different scenarios of the availability of water resources and demonstrate how sensitive the optimal production is to a particular water availability scenario. We demonstrate how the developed model can help select an optimal portfolio of coal production technologies and an optimal crop allocation accounting for energy-food-water-environmental security constraints. Among the main conclusions from the analysis is that under different scenarios of water provision, the model suggests quite different scenario-dependent solutions. Under different water availability scenarios, the portfolios of coal production technologies are quite different. Practical implementation of such solutions can lead to high adaptation costs if other scenario occurs. It has been also shown that reliance on the average values can be seriously misleading. Planning developments under uncertainties requires solutions which are optimal and robust, i.e., in all scenarios regardless of what water availability scenario occurs.

Keywords: cost-minimization, water scarcity, food- and energy-security

Evaluation of sustainable third-party reverse logistics provider

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Abstract

The pressure from legislation and customers has brought the companies to consider reverse logistics in order to gain a competitive advantage. Due to the fact that reverse logistics is a complex procedure and requires an adequate system, companies consider the outsourcing of their logistics operations. The reverse logistics operations is done by so called third-party reverse logistics provider (3PRLP). Since a great amount of research already covers the selection and evaluation of 3PRLP, this paper shall extend this research in that it also lays a focus on the sustainability performance of 3PRLP. The ELECTRE III methodology as a multi-criteria decision making approach is used to select the suitable provider. The critical success factors that lay the basis for the criteria are drawn from a literature review and classified into the three aspects of sustainability: environmental, economic, and social. In order to weight the criteria the revised Simos procedure is used. The approach will be underlined by a numerical example that is used in the case study. It has been solved using a dedicated algorithmic workflow constructed with a software platform called `diviz`.

Keywords: Sustainable 3PRLP; ELECTRE III; diviz

Using PROMETHEE to identify the most promising energy carrier to complement electricity in a largely electric world

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ABSTRACT

Increasing electricity production from renewable sources is a key strategy for reducing greenhouse gas emissions in many countries. The use of biomass is limited due to resource restrictions and the competition with the use for food production and industrial applications. Therefore electricity production by photovoltaics and windmills will dominate in the future. However electricity cannot substitute fossil energy carriers in all applications. For long-term storage, long distance transport and certain industrial applications, electricity is not an adequate energy carrier. For these purposes, renewable electricity has to be used to produce other energy carriers like hydrogen, methane or methanol. There are several such energy carriers that could potentially play an important role in a future energy system largely dominated by electricity generation from renewable sources. As all these energy carriers require further technological enhancements and/or infrastructural developments, the question is which would be the most promising one.

To address this question we will carry out an investigation of three areas of application that play an important role in a largely electric world: electric long-term storage systems, light duty commercial-vehicles and tractor trailers. In each of these areas, a set of energy carriers has been chosen and a common set of evaluation criteria has been identified by interacting with representatives from an electric utility. In total, a set of nine criteria including for example specific costs, technological efficiency and public acceptance have been analyzed. For assessing the cost-based criterion, an economic calculation model has been developed. Its output along with data for the other criteria is used as input to a PROMETHEE model. The elicitation of criteria weights is based on the SRF-method.

In our contribution, we will shed light on the question which energy carrier could be the most promising one to complement electricity in Germany's energy system of 2050 as seen from today's perspective. Furthermore, we will also address some procedural challenges related to the application of the PROMETHEE method in practice.

Keywords: PROMETHEE; SRF; energy storage; future electricity system

A random utility model on economics and critical decision points in clinical practice

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ABSTRACT

The methodology can be used for calibration of existing econometric models used for forecasting health care expenditures especially with pharmaceutical and physician expenditures. It fits the policy level especially for medical policy, since it targets disease economic modeling and integrates the type of disease models from medical schools.

Sensitivity analysis is one of the recent methods for calibration, and the type of cost sensitivity simulators developed with ENDEPUSresearch methodology is to integrate choice models on economics and physicians treatment choices to elasticity estimates in various kinds of step models that have been used so far in estimation of demand for pharmaceutical care and other health care services. (steps models have been extensively discussed especially since the Rand experiment on health insurance and different contributions from Manning et als on demand for care for instance). This methodology will help for instance in new configurations of alternative elasticity measurements, of potential use to adjust health care financing systems in transition at different levels of aggregation.

A RUM model on physicians' choice sets and health care financing systems

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ABSTRACT

This research uses interstate comparisons to demonstrate how physicians' choices sets are impacted by cost awareness to patients 'economics, product economics and other financial pressures. This step continues the theoretical development of the 3P theories (Harms et al, 2002; Huttin, 2006, 2007, 2012). We can observe opposite decision shifts for critical decision points for diagnostic and treatment choices in clinical practices for similar clinical cases, under different health system budget constraints and their regulatory environment.

A random utility model is proposed. Research on different types of choices sets are used to identify the type of random utility models that model how variations of preferences from physicians help to manage variations between different national health care financing systems.

Data are extracted from the endep/biomed database for 600 physicians, transcripts from qualitative focus groups and estimates from the centralized database of 6 patients' surveys on cost of medicines (www.endeplux.org).

Two types of cost data are used: stated data from intention surveys and effective diagnostic, procedure and drug utilization data. Intention data are classified in Cost to the System (CostS), cost to the Physician (CostPh) and cost to the Patient (CostPa), using pair of country comparisons (French-German; Italian-French, American, Canadian (Huttin and endepresearch group, Huttin-Endepusresearch, Gafni et als,McMaster University, Canada).

A comparative intercountry framework is used to weight differently choice sets in a health care financing system. A generalization will be proposed with a list of different possible combinations $a\text{CostS}+b\text{CostPh}+\text{CostPa}$ for each physician i among N physicians in J Health financing systems.

The RUM model will help the calibration of structural models for expenditures, stratifying patients with or without experience to health systems in latest forms of RS-SP models (e.g. Thaler,1999; Hess, Train and Polak,2006; Egan KJ, 2010).

Keywords: Random utility model, physicians' pharmacist patients' choices sets, costs studies

Estimating Interval Weights from Interval Pairwise Comparison Matrix

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ABSTRACT

In Interval AHP [1], the priority weights are estimated as intervals to represent the vagueness of decision maker's evaluation. In this method, the inconsistency of the pairwise comparison matrix is assumed to come from decision maker's vague evaluation. When an interval pairwise comparison matrix $([a_{ij}^L, a_{ij}^R])$ is obtained, two estimation methods, the lower model and the upper model were proposed (see [1]). In the lower model, the interval weights $[v_i^L, v_i^R], i = 1, 2, \dots, n$ are estimated so as to maximize the total spreads under constraints that interval ratios $[v_i^L/v_j^R, v_i^R/v_j^L]$ are included in $[a_{ij}^L, a_{ij}^R]$ for $i \neq j$. On the other hand, in the upper model, the interval weights $[w_i^L, w_i^R], i = 1, 2, \dots, n$ are estimated so as to minimize the total spreads under constraints that interval ratios $[w_i^L/w_j^R, w_i^R/w_j^L]$ include $[a_{ij}^L, a_{ij}^R]$ for $i \neq j$. It is strongly expected that the sum of widths of $[w_i^L, w_i^R], i = 1, 2, \dots, n$ is bigger than the sum of widths of $[v_i^L, v_i^R], i = 1, 2, \dots, n$. However, in this paper we show that this expected relation does not always hold. We give a counter-example when the given interval pairwise comparison matrix is totally consistent. In the example, we show that the reverse relation holds. This example reveals an implicit property of the other estimation method [2] based on goal programming. We investigate conditions for the true interval weights to be uniquely estimated from the totally consistent interval pairwise comparison matrix. We show that the different solutions of the lower and upper models are equivalent in alternative comparisons when the given interval pairwise comparison matrix is totally consistent. Considering this property, we propose a modified interval weight estimation method from interval pairwise comparison matrix.

Keywords: Interval weights, AHP, linear programming

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OWA model with partial preference information

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ABSTRACT

In multi-objective optimization, the Decision Maker (DM) is interested in efficient solutions, which cannot be improved simultaneously in all criteria. The image of an efficient solution in the criterion space is called a nondominated point. Two standard approaches are used to solve a multi-objective optimization problem: compute the entire set of nondominated points or choose an aggregation model, elicit preference information and determine an optimal solution according to this model.

The first approach exhibits all potentially interesting tradeoffs. The main difficulty, especially in Multi-Objective Combinatorial Optimization (MOCO) problems, is related to the large size of the nondominated set. This often results in prohibitive computation times particularly for exact algorithms. Moreover, most of the solutions presented to the DM are actually irrelevant with respect to his/her preferences. The second approach consists in using a preference model, which aggregates the criteria using a scalarizing function. This function requires specific parameter values reflecting the DM's preferences. These parameters are highly dependent on the elicitation methods, which may lead to substantially different results. In particular, Yager [4] introduced the ordered weighted average (OWA) aggregation. Instead of assigning weights to specific criteria, the OWA operator considers the ordered values of a point. For example, in location problems, clients should be considered impartially and the OWA operator could be appropriate in this context.

In order to address the issues of these approaches, it may be relevant to adopt an intermediate approach using a scalarizing function whose parameters are only partially specified. The weighted sum scalarization with partial information on weights has been applied in the field of Multiple Criteria Decision Making [3]. More recently, the OWA operator with partial information on weights has also been studied [1]. After determining a set of possible weights representing the DM's preferences, a partial preference relation is defined as follows: a solution is preferred to another one if its OWA value is better for every possible weight in the weight set. Typically the set of weights is determined by constraints reflecting ordinal information on the weights (e.g. ranking of the weights by order of importance). Preference elicitation is much less demanding than when requiring precise values. Our approach consists in generating the nondominated set with respect to this partial preference relation. Compared with the Pareto nondominated set, we generate a substantially smaller set of potentially interesting solutions for the DM with a great

computational time saving. We especially focus on MOCO problems although the presented concepts are more general. After studying some properties of this preference relation, we present an approach based on a previous work on the weighted sum [2] to deal with an arbitrary weight polytope constructed from the DM's preferences. Numerical experiments illustrate the practical applicability of our approach.

Keywords: Multi-objective optimization, Ordered Weighted Average, Partial information.

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Heuristics for prioritizing pair-wise elicitation questions with additive multi-attribute value models

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ABSTRACT

Additive value models are widely used in normative Multiple Criteria Decision Analysis. Direct elicitation of the value model preference parameters can impose excessive cognitive burden on the decision maker. Indirect techniques that employ pair-wise questions have been proposed for lowering the elicitation effort. In all practically relevant problems more than a single question needs to be answered for arriving at a sufficiently precise outcome. The selection and ordering of questions affect the number of answers required for ranking the decision alternatives. However, evaluating all possible questions and answers is intractable due to the search space being, in the worst case, of factorial size. This paper develops heuristics for prioritizing pair-wise elicitation questions based on (1) necessary preference relations, (2) extreme ranks attained by the alternatives, (3) pair-wise preference indices, and (4) rank acceptability indices. We also introduce three metrics for assessing quality of a question prioritization heuristic. Numerical results allow us to identify a subset of heuristics that score well on our metrics in a variety of problem settings. This conclusion was validated in a real-world experiment where 101 subjects answered pair-wise questions to rank 10 mobile phone packages evaluated in terms of 4 criteria.

Keywords: Multi-attribute value theory, Pair-wise comparisons, Preference learning, Preference inference

Systematic literature review on low carbon supplier selection using content analysis

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ABSTRACT

Purpose – Given the evolving importance of low carbon emissions, the goal of this paper is to offer a systematic literature review on supplier selection papers that incorporates carbon emissions into the criteria set, in order to provide guidance in this topic, uncover research gaps and saturation and present new research paths. Further it will be explored how the research within this important topic has changed over the years.

Design/methodology/approach – By using content analysis a total of 29 relevant papers has been investigated comprehensively in a broad spectrum of research dimensions. The qualitative discussion of the observations is complemented by a quantitative assessment using contingency analysis to show the interplay of certain supplier selection model dimensions.

Findings – The paper provides knowledge accommodation and creation helps future researchers and practitioners in applying approaches effectively according to the circumstances and provides and shows and guides future research approaches.

Originality/value – The paper is one of first study to review the literature dealing with low carbon supplier selection

Keywords: Low carbon; Supplier selection; content analysis

Article Type: Review paper

Computing interval weights for incomplete pairwise-comparison matrices of large dimension - a weak-consistency based approach

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ABSTRACT

Multiple-criteria decision making (MCDM) and evaluation problems dealing with a large number of objects are very demanding. Particularly when the use of pairwise-comparison (PC) techniques is required. A major drawback arises when it is not possible to obtain all the PCs, due to time or cost limitations, or to split the given problem into smaller subproblems. In such cases, two tools are needed to find acceptable weights of objects: an efficient method for partially filling a pairwise-comparison matrix (PCM) and a suitable method for deriving weights from this incomplete PCM. This paper presents a novel interactive algorithm for large-dimensional problems guided by two main ideas: the sequential optimal choice of the PCs to be performed and the concept of weak consistency [1]. The proposed solution significantly reduces the number of needed PCs by adding information implied by the weak consistency after the input of each PC (providing sets of feasible values for all missing PCs). Interval weights of objects are computed from the resulting incomplete weakly consistent PCM adapting the methodology for calculating fuzzy weights from fuzzy PCMs [2]. The computed weight intervals thus cover all possible weakly consistent completions of the incomplete PCM. The performance of the algorithm is illustrated by a numerical example and a real-life case study.

Keywords: Incomplete pairwise comparison matrix, guided decision support, weak consistency, large-dimensional problems, interval weights.

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Analytic Hierarchy Process - HRE perspective

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ABSTRACT

Pairwise comparisons (PC) is a well-known method for modeling the subjective preferences of experts. Experts judgments form the set of paired comparisons on the basis of which the final numerical ranking is synthesised. The Heuristic Rating Estimation (HRE) method proposes a slightly different use of the paired data. According to HRE the priorities (weights) of some alternatives can also be a priori known. Therefore, there is no need to recalculate their priorities. As a result, priorities are synthesized only for new alternatives, whilst the weights of other alternatives remain unchanged.

Due to the similarities between HRE and Analytic Hierarchy Process (AHP) a natural question arises about the relationship between these two techniques. The aim of this paper is to compare AHP and HRE and discuss the relationship between them. Special attention will be devoted to the hierarchy, missing in HRE and present in AHP. An attempt to analyze to what extent HRE can support AHP will also be undertaken.

Keywords: AHP, HRE, pairwise comparisons

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Supporting Environmental Decision Making with Portfolio Decision Analysis

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ABSTRACT

This paper seeks to help the environmental practitioners analyze their decision problems as portfolio problems. In portfolio decision making one searches for a set of actions, i.e. a portfolio, with desirable overall impacts. To solve such problems one needs to consider multiple objectives, interactions among the actions, and their resource efficiency. This paper discusses and compares different portfolio modelling approaches available for such challenging tasks. A general portfolio decision analysis framework is provided which consists of steps ranging from the problem framing and structuring, to the modelling and the analysis of results. Use of the framework and the Robust Portfolio Modeling method and software are illustrated. This method enables the use of incomplete preference information and interval valued consequences data, which can be an important.

Elaboration of a collaborative process based on the MACBETH approach for the assessment of street potential in Quebec City

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ABSTRACT

In a context where a street is expected to accommodate different transportation modes and user types, how can public authorities assess and take into account the various municipal stakeholders' concerns? Close collaboration and communication between the different municipal departments is essential to ensure high quality urban planning projects. More often than not, consultation protocols are ill-defined or inexistent. There is therefore a need for a systematic collaborative approach that can take into account different points of views, especially when dealing with complete street design principles.

This study presents a decision-making process for the rehabilitation and redesigning of streets in Quebec City. More specifically, the objective is to identify the higher priority streets that should be redesigned as complete streets. The process, based on MACBETH (Bana E Costa et al., 2012), helped reach consensus among the different services by building a common vision for the development of complete streets. In order to attain our objective, five group workshops and many individual workshops were organized with a dozen of Quebec City municipal employees representing different municipal services, including specialists in environment, planning, transportation and urbanism. The workshops aimed at identifying their professional concerns, defining criteria, comparing and weighting the criteria as well as building attractiveness scales to measure their preferences. A total of eleven criteria were constructed and compared during the workshops. The results have been aggregated to create a Complete Street Priority Index and have been integrated in a geographic information system with a map representation. The user-friendly tool facilitates decision-making for the city officials who have to choose which streets to redesign according to complete streets principles.

Keywords: MACBETH, group decision, transportation planning

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Bridging the gap between scientific rigor and practical application in environmental decisions

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ABSTRACT

Most environmental problems are “messy”: Their framing might be unclear and deciding about what and who should be included or excluded is difficult. Usually, there are serious trade-offs between environmental and socio-economic objectives, resulting in strong conflicts of interest. Natural scientists or engineers focus on specific aspects, which involve, for example, large sets of biological indicators to measure “environmental sustainability”, or complex modeling to predict outcomes of interventions. However, interventions are often financed by public money and may affect lay people. Thus, the interests of stakeholders and the general public should be included in decision-making, even if their factual knowledge about the natural or engineered system is limited. Environmental decisions are often long-term, and what we decide today will influence future generations. Predictions about the impact of decisions on environmental systems are inherently uncertain; but over long time ranges, there is additionally deep uncertainty about future developments. In typical environmental decisions, one would also aspire that the elicited preferences are stable over a longer time range and persist beyond a single situation.

The model(s) used in MCDA should ideally capture these aspects. On the other hand, in real-world decision support, there are often serious time and budget limitations, which may tempt us to use overly simplified MCDA approaches. The focus of our work at the water research institute Eawag is to contribute to bridging the gap between scientific rigor and practical application. In this talk I will give a short overview of some of our research addressing selected issues identified above: (1) Arguably, framing aspects have been neglected in the MCDA community. A recent review aims at identifying the advantages, but also limitations of combining Problem Structuring Methods (PSMs) with MCDA (Marttunen et al., in prep.a). (2) Objectives hierarchies in MCDA that include ecological or technical indicators requested by environmental scientists can be overly large; which can induce problems and evoke biases in later MCDA (Marttunen et al., subm.). We are therefore currently exploring systematic ways to reduce the number of objectives without losing crucial issues of the decision problem (Marttunen et al., in prep.b). (3) To increase the understandability of environmental decision problems for lay people, we aim at “translating” outputs from wastewater treatment plants (in

this application example), characterized by technical indicators, to ecological effects (Haag et al., in prep.). (4) If the general public is involved in decision-making, preferences should be elicited from a large number of people. Using online surveys for preference elicitation has been criticized, but may be viable in some cases (Lienert et al., 2016); online surveys can also be used for experiments to test, for example, preference stability over time. A new approach to better involve lay people is the use of serious games for preference elicitation (Aubert and Lienert, in prep.). (5) Combining scenario planning with MCDA seems very promising to deal with large future uncertainty (Lienert et al., 2015; Scholten et al., 2015). We look forward to lively discussions about our research ideas.

Keywords: environmental decisions, MAVT, objectives hierarchies, preference elicitation, problem structuring

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Model Uncertainty, Robustness, and Multi Criteria Decision Analysis

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ABSTRACT

In most decision problems consequences of the various alternative actions depend on states determined by a generative mechanism representing some physical or social phenomenon. Model uncertainty arises because decision makers may not know this mechanism. Two types of uncertainty result, aleatory uncertainty within models and model uncertainty across them.

This talk addresses the recent developments of the field with a special focus on the need for robustness and discusses some implications for Multi Criteria Decision Analysis.

MCDM and GIS to evaluate land suitability

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ABSTRACT

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

Keywords: MultiCriteria Decision Analysis, Decision support system, Geographical Information System, Land suitability for agriculture.

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Development of a sustainable energy strategy using a multi-criteria analysis: the case study of Odemira municipality

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ABSTRACT

Municipalities have great conditions to test strategies and policies towards energy efficiency and climate change mitigation, and consequently enhancing local development, as a way to create new dynamics on local labor, environment and, in general, on the community.

The present study developed a sustainable energy strategy for Odemira, the largest municipality of Portugal, using a multi-criteria decision aiding approach. The main goals were to increase the renewable production and decrease the CO₂ emissions, which consequently generate socio-economic and environmental benefits. Having that in mind, after a data collection stage, a public consultation was promoted. The population and municipality services were questioned about the main problems of the municipality, and proposals to overcome them were suggested.

The proposals focused on three main areas of intervention. For the residential sector, the solutions span from integrating renewable technologies as solar photovoltaics, solar thermal and heat recovers. For the public sector, the solutions include integrating self-consumption units on service buildings and at the waste treatment plants, converting public lighting technology to LEDs, and retrofitting the gas boilers of the municipality pool to heat pumps or biomass boilers. Finally, for the transportation sector, the solutions include the electrification of the municipality vehicle fleet, and the creation of transportation services either from remote

locations or from the train station to the main city, to avoid the use of individual transportation.

At a second stage, the criteria for the decision analysis were presented to the representatives of the inhabitants, which had to choose the priority between financial, social-welfare, and techno-environmental criteria, as well as regarding its sub-criteria, as financial impact, payback, job creation, contribution to welfare, reduction of CO₂ emissions, increase of renewable energy production, avoided fossil fuels consumption, and local environmental and land impact.

Finally, on a third moment, the values on each sub-criteria of each of the designed proposals were shown to the population, which was asked to rank the best proposals. Then, the population was confronted with the ranking computed on the ELECTRE III software, given by the previous chosen criteria.

The results showed that on the scalable proposals (the ones from the residential sector and public lighting), the rankings between the population and the software were the same, while for the rest of the measures small differences appeared. These differences may be related to context issues, such as the existence of an open call for applications for public funding, or pre-defined ideas of certain buildings energy costs. The main recommendations by the population were related to implementation details of such proposals.

The application of this type of methodologies helps municipalities to define a better and more solid energy strategy, while meeting the needed CO₂ reductions, opening new opportunities as applying to the Covenant of Mayors or capitalizing the image of a green municipality. Most of all, it aids the decision makers to support their options and inform the population about the specific measures based on quantitative data.

Keywords: multi-criteria decision analysis, sustainable energy, municipality strategy

Interactive methods in multiobjective dynamic programming

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ABSTRACT

We consider discrete problems, in which both the sets of states and the sets of decisions are finite. We assume that the process is evaluated with respect to multiple conflicting criteria. Our goal is to propose effective tools to help the decision maker to identify the most preferred strategy.

We will discuss the following groups of methods:

- a) the methods based on direct paradigm, which assumes that the decision maker express his/her preferences in relation to the values of the criteria,
- b) the methods based on indirect paradigm in which preferences are articulated in relation to trade-offs between criteria.

We will also characterize potential real-life applications of the proposed techniques in business management. Among them, first of all strategic management issues and especially project portfolio management problems will be considered.

The aim of the presentation is a brief characteristics of our recent results. The results obtained by us in previous research allows us to formulate the hypothesis that the methods based on interactive approach will be an effective tool supporting decision makers in solving multiperiod decision making problems.

Keywords: Multiobjective dynamic programming, interactive methods, direct paradigm, indirect paradigm.

MODELING MULTIPLE GOALS FOR PERIODIC VEHICLE ROUTING AND SCHEDULING PROBLEMS

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ABSTRACT

Implementation concepts of a decision support system for large-scale periodic time-dependent vehicle routing and scheduling problems with complex constraints supporting planning and management of mobile personnel tasks (sales representatives and others) is discussed. Complex nonuniform constraints with respect to frequency, time windows, working time, etc. are taken into account with additional fast adaptive procedures for operational rescheduling of plans in presence of various disturbances. Five individual solution quality indicators with respect to a single personnel person are considered. This paper deals with modeling corresponding multiple goals and representation of them within the scalarizing achievement function providing fairness of individual achievements together with possibility of importance weighting. The Weighted Ordered Weighted Averaging aggregation approach uses importance weights to affect achievement importance by rescaling accordingly its measure within the distribution of achievements rather than by straightforward rescaling of achievement values.

Keywords: Multicriteria decision making, Efficiency, Fairness, Weighted Ordered Weighted Averaging Aggregation

Generating combinations of alternatives for urban regeneration: a Decision Analysis approach

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ABSTRACT

Large urban development projects launched over the past thirty years have shown some critical issues related to the implementation phase. As a consequence, the current practice seems oriented toward minimal and widespread interventions known as urban catalyst rather than to large developments, in order to achieve a satisfying balance among environmental quality, economic growth and social wellbeing. The concept of urban catalyst refers to interventions that can be built in a short time and spontaneously are able to improve the surrounding environment. On one side, this new idea of planning might solve the problem of large developments' feasibility evaluation, but on the other side it rises an evaluation demand related to both the generation and the selection of coalition of interventions (elementary actions) within a multidimensional and multi-stakeholder decision context. This study aims to propose a framework for the generation of feasible coalitions of actions in the context of urban regeneration processes and for their evaluation using a Multi Criteria Decision Aiding (MCDA) approach. Given the decomposition of the concept of feasibility into three main criteria (environmental, economic and social), the proposed evaluation framework supports decision makers in exploring different combinations of actions in the context of urban interventions meant as catalysts. Two parallel focuses will underpin the proposed framework. The first focus will concern the modelling and evaluation of synergies among different combinations of alternative projects. The second focus will concern the inclusion of stakeholders' preferences and values in the evaluation process of the different combinations of interventions. A first test of the evaluation framework on a pilot case study of urban regeneration in the city of Milan (Italy) is proposed. This paper will contribute to the debate on how to innovatively design policies and programs by exploring the use of MCDA and Operational Research in the innovative field of "urban ago-puncture".

Keywords: Feasibility analysis, Coalitions of projects, Urban ago-puncture, Synergy, Multicriteria Decision Aid

Parallel Multi-Start Multiobjective Influenza Virus Algorithm for Multiobjective Energy Reduction Open Vehicle Routing Problem

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ABSTRACT

In this paper, two different versions of the Parallel Multi-Start Multiobjective Influenza Virus Algorithm (PMS-MOIVA) are proposed for the solution of the Multiobjective Energy Reduction Open Vehicle Routing Problem when all the customers have only demands (MDEROVRP) or only pick-ups (MPEROVRP). The PMS-MOIVA is an Artificial Immune Systems algorithm that simulates the process of annual evolution of influenza in an isolated human population. The first version of the algorithm that is proposed gives to the best solutions of the population more exploration abilities while in the second version it gives to the worst solutions more exploration abilities. The two versions of the PMS-MOIVA are compared with the Parallel Multi-Start NSGA II algorithm. Considering the multiobjective problems that are solved, the first objective function corresponds to the optimization of the total travel time and the second objective function corresponds to the minimization of the fuel consumption of the vehicle taking into account the travel distance and the load of the vehicle either when the decision maker plans delivery or when he plans pick-up routes, respectively. A number of modified Vehicle Routing Problem instances and four different evaluation measures are used in order to measure the quality of the proposed algorithms. Considering the results, it is observed that the second version of the PMS-MOIVA produces a larger number of non-dominated solutions and more extended Pareto fronts in most of the instances but the first proposed version can produce Pareto fronts that dominate more to the fronts of the second version. Finally, from the comparison of the two PMS-MOIVAs with the PMS-NSGA II, it is observed that almost all the solutions of the PMS-MOIVA algorithms dominate to the solutions of the PMS-NSGA II.

Keywords: Influenza Virus Algorithm, NSGA II, VNS, GRASP

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Clonal Selection Algorithm for the Solution of the Multiobjective Route-based Fuel Consumption Multi-Depot Vehicle Routing Problem with Uniformly Distributed Customers

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ABSTRACT

In this paper, a Parallel Multi-Start Multiobjective Clonal Selection Algorithm (PMS-MOCSA) is proposed for the solution of Multiobjective Route based Fuel Consumption Multi-Depot Vehicle Routing Problems (MRFCMDVRPs). The problems are formulated with two competitive objective functions and are: the Multiobjective Symmetric and Asymmetric Delivery Route based Fuel Consumption Multi-Depot Vehicle Routing Problem (MSDRFCMDVRP and MADRFCMDVRP) and the Multiobjective Symmetric and Asymmetric Pick-up Route based Fuel Consumption Multi-Depot Vehicle Routing Problem (MSPRFCMDVRP and MAPRFCMDVRP). The first objective function is common for the delivery and the pick-up problems and is used for the minimization of the time needed to travel between two customers or a customer and the depot. The second objective function is used for the minimization of the Route based Fuel Consumption (RFC) taking into account real life route parameters in addition to the load and the traveled distance when the vehicle travels between two customers or a customer and the depot either in the case that the vehicle performs only deliveries or when the vehicle performs only pick-ups in its route, respectively. For all the problems we assume that the customers are uniformly distributed to the depots. The algorithm is compared with two other algorithms, the Parallel Multi-Start Non-dominated Sorting Differential Evolution (PMS-NSDE) and the Parallel Multi-Start Non-dominated Sorting Genetic Algorithm II (PMS-NSGA II). All the algorithms that are used have the same set of external iterations, the same way of creating the initial solutions and the same local search method. A number of modified Vehicle Routing Problem instances are used as there are no data sets of benchmark instances available for the solution of this kind of multiobjective VRP problems. Also, in order to measure the quality of the proposed algorithm four different evaluation measures are used. Considering the results, it is observed that the PMS-MOCSA performs better than the other algorithms considering the number of the solutions of the Pareto fronts and the Coverage measure.

Keywords: Clonal Selection Algorithm, NSGA II, NSDE, VNS

References: Iraklis-Dimitrios Psychas, Magdalene Marinaki, Yannis Marinakis and Athanasios Migdalas (2016) Non-dominated Sorting Differential Evolution Algorithm for the minimization of Route-based Fuel Consumption Multiobjective Vehicle Routing Problems, *Energy Systems*, DOI 10.1007/s12667-016-0209-5 (available on line).

Measuring public transport station quality using a node-place-experience model and BWM

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ABSTRACT

Compared to private transport, public transport is more desirable especially with respect to environmental and social issues. Still public transport can only attract people if it offers a high quality of service since it has the great drawback of not being door-to-door. Stations (or transit nodes) are critical to determine the quality of a public transport route. This quality is determined, among other factors, by the experience of travelers especially when transferring. However, the dominant model for classifying the quality of a transit node, the so-called node-place model, does not consider this important dimension (experience). In this study, we propose to add quality from a traveler's perspective to the node-place (NP) model (Bertolini, 1996) by adding the experience value. The new model is called node-place-experience (NPE) model. While the node and place values of a transit node can be identified based on some objective measures independent of the traveler's perception, the experience value is a perception-based construct composed of several criteria. A multi-criteria decision-aiding (MCDA) method can be used to evaluate this dimension. A case study in Rotterdam in the Netherlands is used to apply and illustrate our proposed model. Reviewing existing literature provided the criteria for the experience value. The weights of the criteria are obtained conducting a survey among 160 travelers as input for an MCDA method called Best Worst Method (BWM) (Rezaei, 2015a,b). Data for 32 transit nodes in Rotterdam was collected. Using the data for each transit node, and the weights obtained from the BWM, the experience value of each transit node is calculated. Normalizing the three values (node, place, experience) of each transit node, policy-makers are able to find improvement priorities. Comparing the results of NPE and NP models shows the new model provides more accurate results in what concerns the perception of the policy-makers and transport managers who are responsible for the transportation system in the case study city.

Keywords: transit node; node-place model; experience value; Best Worst Method (BWM)

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Reduce the semantic gap in content-based image retrieval with MCDA methods: An application in Cultural Heritage

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ABSTRACT

Content-based image retrieval (CBIR) is any technology that in principle helps to organize digital picture archives by their visual content [1]. The main problem is how to bridge the semantic gap between the low-level image features used and the semantic content of the images. A method to tackle this problem is Relevance feedback (RF) an interactive supervised learning technique [2]. In the MCDA framework a method for the elicitation of user preferences from relevance feedback is proposed based on relational Multi-Criteria Decision Analysis [3]. Our ongoing work proposes a method that combines local and global visual descriptors [4][5] of the image for modeling high-level criteria. Then, an interactive classification or ranking MCDA method is used to assess the user preferences in a small reference set of images. An application of the method is demonstrated on a dataset of cultural heritage images [6].

Keywords: content-based image retrieval, semantic gap, relevance feedback, MCDA.

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Multi-Objective Optimization of Rule Ensembles

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ABSTRACT

We present a methodology for constructing an ensemble of rule base classifiers characterized not only by a good accuracy of classification but also by a good quality of knowledge representation. The base classifiers forming the ensemble are composed of minimal sets of rules that cover training objects, while being relevant for their high support, low anti-support and high Bayesian confirmation measure. The population of base classifiers is evolving in course of a bi-objective optimization procedure that involves accuracy of classification and diversity of base classifiers. The final population constitutes an ensemble classifier enjoying some desirable properties, as shown in a computational experiment.

Keywords: Rule ensembles, Classification, Variable-consistency Dominance-based Rough Set Approach (VC-DRSA), Regularization

Robustness incensement into the additive value models estimated by UTA methods through the elimination of the criteria rank reversals

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ABSTRACT

The assessment of criteria' weights in multicriteria decision aid methods of value systems, and especially in the family of UTA methods, often leads to the assessment of preference models with low degree of robustness. One of the main undesirable situation in this cases of the infinitive set of estimated vectors of weights, bordered into the n-dimensional hyperpolyhedron, is the rank reversals of the criteria weights among different points of the hyperpolyhedron.

This research work presents a methodological frame, which aims to:

- a) Explain the nature of low robustness of the estimated preference models, utilising tomographical techniques, visual tools and specific indices for robustness measurement using the capabilities of RAVI system. Also, a set of indices (Priorities Reversal Indices) and visual techniques are used in order to picture the degree and the nature of the rank reversal of the criteria weights.
- b) Support the Decision Makers (DMs) to deeper understand his/her preferential structures and
- c) Acquire additional preference information by the DM as far as the priorities of the criteria is concerned so as to estimate a preferential model of higher robustness, through focused interactive feedbacks.

The above methodological approach is illustrated through a case study and the use of the special module of RAVI system for Robustness Analysis of the Estimated Preferential Models by UTA methods.

Keywords: Multicriteria Decision Aid, Preference Disaggregation, Robustness Analysis, Multicriteria Decision Support Systems

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Stepwise benchmarking with indirect preference elicitation

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ABSTRACT

Methods based on the indirect preference information are considered more user-friendly than approaches based on explicitly provided parameter values, because they require less cognitive effort from the DM at the stage of preference elicitation.

The aim of the paper is to use indirect preference elicitation as state of the art approach in MCDA community alongside the idea of disaggregation approach in order to create discretization method that would perfectly fit decision maker's preferences. This will be done through interactive selection of discretization outcome for each criteria by decision maker. The purpose of the proposed method is in line with benchmarking practice, where decision maker prefers discrete rather than continuous scale and thus proposed preprocessing method serves as an enhancement of ELECTRE MLO, method developed for purpose of benchmarking for public policies.

Psychometric studies have shown, the more scale steps in a questionnaire item the better, but with rapidly diminishing returns, whereas these studies have shown that having 5 or 7 steps is optimal. Similar idea will be applied in this paper, where decision maker can observe several outcomes of the proposed discretization method. This variation will effectively change number of steps and selection of appropriate scale will yield different outcome of the discretization for every criterion, thus acquiring true preference of the decision maker.

Keywords: stepwise benchmarking, ELECTRE, discretization.

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A comprehensive uncertainty analysis of the Analytic Hierarchy Process methodology in the context of environmental decision making

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ABSTRACT

This paper applies an explicit understanding of uncertainty with respect to the methodological properties of the Analytic Hierarchy Process (AHP). It embraces the three dimensions designation, categorisation and quantification that are used to analyse a hypothetical group decision making case located in the context of environmental decision making. To calculate the numerical impact of constructed uncertainty scenarios (USs) on the final ranking given by the AHP, a simulation experiment is conducted using R. It evaluates the impact of uncertainty within three variants of the hypothetical decision making case by calculating an “overall uncertainty” measure that indicate if and how often the inclusion of a specific US changes the rank of the best alternative given by the AHP. The simulation experiment is basically based on randomly generated pairwise comparison matrices and on data derived from literature. The results show that the absolute maximal impact caused by an US is approximately 0.03. With respect to a single US and the specific case characteristics, in about 50% of the simulated runs a rank reversal occurs. The geometric mean group aggregation method appears to be more sensitive to uncertainty than the weighted arithmetic mean group aggregation method. Similar shares of rank reversal over different USs within a single variant of the case raise the question to which uncertainty should be given prior attention in decision making practice.

Keywords: uncertainty scenarios, simulation experiment, overall uncertainty measure

References: unpublished

Calibrating the Bradley-Terry-Luce choice rule using MCDA

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ABSTRACT

Market simulations assist managers in new product design processes, providing estimations about a new concept's acceptance before its entrance to the market. The most critical part of market simulations is the choice model used for forecasting potential choice shares of a new offering based on consumer preferences. In this paper we propose a two-stage model for calibrating the Bradley-Terry-Luce choice rule in order to improve its accuracy on simulating consumers' choice process. First, we estimate a preference model for each individual or group of individuals (segments) that comprise a market with the use of UTASTAR. In the second stage, we fit BTL's choice rule to each individual (or market segment) with the use of three factors of the product utilities distribution: *range*, *kurtosis*, and *skewness*. We benchmark the model's performance against three popular choice models with the use of a Monte Carlo experiment with six factors. The proposed model displays the best predicting accuracy in all situations.

Keywords: Market simulation, Choice rules, UTASTAR