The Art of Supporting Decision-Making

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Abstract *The provision of decision support methods and strategies is of primary importance to guarantee justifiable decision-making processes. Many of the experts and practitioners in this area gathered from 3 to 7 August 2015 at Helmut-Schmidt University in Germany for the biennial conference of the International Society on Multiple Criteria Decision Making. This critical reflection collects the opinions and perspectives of eight leading scholars in the area of decision support, which were mostly video-recorded at this conference. The core findings of those interviews are summarised in this article, which focuses on (i) what Multiple Criteria Decision Making, Analysis and Aiding (MCDM/A) is, (ii) its main strengths and success factors, (iii) the recommended pathway to pursue a comprehensive understanding of MCDM/A; (iv) the main areas of application where MCDM/A is used; and (v) the recommended approaches to integrate MCDM/A in other research domains.*

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Introduction

Making informed decisions is a complex task as it usually involves multiple objectives to be achieved while respecting constraints defined by the context of the decision problem. This applies to our daily life when we are faced with the dilemma of what t-shirt or cell phone to buy as well as to much more challenging tasks such as the location of a nuclear reactor or the selection of the next economic policy for a country or region. One commonality that most real life decision-making challenges have, independently from their context, is that they involve a set of attributes that characterise them and which should be used to inform the decision process. The ubiquity of problems that are inherently based on multiple evaluation criteria led to a growing interest in the use of decision support strategies and tools to inform decision-makers (DMs), who can be a scientific officer, a company manager, a policy maker, a researcher or an investor. Ranking, classification, choice and optimisation systems are required to convey the information embedded in a set of

evaluation criteria/indicators for a certain pool of alternatives under evaluation (e.g. product, technology, policy, organisation), in order to support the DMs understanding how to tackle the problem at stake. These alternatives can be a limited set defined a priori, a group constructed in cooperation with the DMs or an infinite number, which are reduced using constraint functions according to decision variables.

To inform DMs appropriately, in compliance with their objectives, sound decision aiding techniques are required to provide transparent, traceable and robust decision recommendations. This is one of the main goals of the International Society on Multiple Criteria Decision Making (MCDM) (http://www.mcdmsociety.org), which is devoted to the development, test and application of methodologies to solve problems based on multiple criteria and support the management process. In order to advance its activities, the society organises a scientific conference every two years (http://www.mcdmsociety.org/content/international-conferences-mcdm) as well a summer school every three (jointly organised by the International Society on MCDM and the EURO Working Group on Multicriteria Decision Aiding: http://www.mcdmsociety.org/content/summer-schools-society). The conference is a fertile ground for exchange of ideas among researchers and academics at different stages in their careers, while the summer school is an ideal place for doctoral students and researchers who are entering the field of MCDM and can learn about the main methodologies and interact with some of the leading scholars in the area.

During the last edition of the conference, which was held in Hamburg on 3-7 August 2015, at Helmut-Schmidt University, the author of this article interviewed seven senior members of the society about their opinions on the role of Multiple Criteria Decision Making, Analysis and Aiding (MCDM/A) in their professional life. An additional expert was also included in these interviews during another scientific meeting, leading to an overall group of eight interviews (list of interviewees is provided in Appendix A). The acronym MCDM/A was necessary because the field of structured decision support with mathematical models is known with several names (e.g. making, analysis, aiding), which are aligned with the multiple schools of thought the researchers came from.

The goal of this work is to communicate the main insights obtained from these interviews, providing the perspectives of the experts on what MCDM/A means to them and the reasons for its success in a variety of real-life decision-making challenges.

Structure of the interviews

The interviews lasted between 4 and 9 minutes and had a simple structure, split in two parts. The first one was focused on the methodological aspects and asked the interviewees:

1. How would you define MCDM/A?
2. What are the main strengths and success factors of MCDM/A?
3. How is it possible to pursue a comprehensive understanding of this discipline?

The second part of the interview was oriented towards the application of MCDM/A, and was structured on these questions:

4. What are the application areas where MCDM/A is mainly applied?
5. What is the best approach to integrate MCDM/A in other research domains?

Findings of the interviews

This section provides the highlights of the answers given by the interviewees on each of the questions. They are based on personal elaboration of the recorded videos and try to covey the major lines of thought of the experts.

1. How would you define MCDM/A?

The common perspective is that MCDM/A is a discipline that helps DMs making better decisions through mathematical modelling. Three major distinct MCDM/A categories emerge. The first one is multi-objective optimisation. It has been developed to tackle decision-making problems where feasible alternatives are not explicitly known in advance and typically there is an infinite number, which are represented by decision variables restricted by constraint functions. In these cases alternatives have to be generated first, one or more objectives are defined and one or multiple compromise solutions are recommended, according to constraints that are defined a priory or interactively. The second category includes methods whose goal is the discovery of hidden preference models that DMs have in their mind. In this case the challenge for decision analysts lies in devising techniques to unveil such models. The third category stands on the philosophical perspective that the preference model has to be constructed and it does not necessarily exist a-priori. The resulting process is defined as decision aiding, which the analyst performs (ideally iteratively and interactively) in collaboration

with the DMs. It is centred on the idea that the person who is making the decision can learn about his or her problem and preferences and how they interact with it. It is an aiding tool to foster debate and learning in the process of forming an opinion about which will be the decision recommendation, in a way that can be understood by the DMs and explained to outside parties.

During the interviews an interesting remark emerged about the issue of validity of results of case studies employing MCDM/A. Most of the time there is no possibility of assessing whether the decision recommendation is valid by comparing it to an 'objective' measure, because MCDM/A methods usually convey integrated assessments for concepts/goals/objectives that do not have a 'true' holistic evaluation they can be compared with. Some examples are sustainability, risk, resilience, innovation, ecosystem services, wellbeing, and gender equality, which are all constructs that cannot be measured empirically. The important task of the analysts is rather to lead the decision process in the most transparent and intellectually honest manner, justifying the choices made to construct the models and increasing the interpretability of the resulting decision recommendations.

2. What are the main strengths and success factors of MCDM/A?

One of the main success factors of MCDM/A is its capacity of accounting for multiple assessment criteria, which can sometimes be even conflicting, and provide a decision recommendation in the form of a comprehensive evaluation of the alternatives or the set that satisfies the constraint functions. From a practical perspective, the success of MCDM/A is ascribable to the capability of developing decision support systems that satisfy most of the typologies of decision-making challenges in real-life problems, including evaluations in the form of ranking, classification and performance scores (see answers to question 4 for an overview of application areas). Furthermore, multi-objective optimisation allows solving additional types of problems, which are usually characterised by many alternatives, among which a set is recommended according to certain decision variables.

MCDM/A allows considering many objectives at the same time and it leads to more insightful decisions, because of the need of considering multiple consequences, effects and more participation of stakeholders (when they are included of course), where the affected people can have an explicit say and influence on the evaluation. This contribution is directly related to another key potential of MCDM/A, which is the enhancement of learning during the whole decision aiding process. For example, during the modelling stage there is a strong learning phase, where the interaction between the analysts and the DMs can lead the

latter to better understand the problem and identify criteria that were omitted at the start of the evaluation. In fact, the model construction requires the objectives of the DMs to be made explicit, which implies thinking and favours the emergence of a creative outcome.

3. How is it possible to pursue a comprehensive understanding of this discipline?

All the interviewees acknowledged that this is a notable challenge, mainly due to the multitude of methods that belong to the MCDM/A domain, which we can easily count in more than 50. However, the main issue does not seem to be the number of methods, but rather the rarity of places and events where students and researchers can learn about them in a comprehensive manner. There are however several solutions that exist to fill the gap of knowledge development in MCDM/A (see Appendices B-E for a detailed list): (i) attendance of training events with long lectures, case studies and fruitful discussions; (ii) participation in operational research societies, their conferences and development of research collaborations with scholars who (co)-developed decision support methodologies or are experts in the use of any of them; (iii) study books; and (iv) look for specific courses on decision analysis, decision science, decision aiding at mathematics, computer science and economics departments as well as business schools.

4. What are the application areas where MCDM/A is mainly applied?

There is a multitude of domains where MCDM/A has been and is currently used, the reason being that all decision-making problems require the interpretation, in an inclusive and traceable manner, of information that comes in different forms and shapes. MCDM/A has this integrative capacity as its main capability, which justifies the diverse application areas mentioned by the interviewees, summarised in Table 1.

Application area	Examples
Finance	Company performance; Market stability; Public debt management
Healthcare / Health management	Drugs development; Health technology assessment; Ranking of diseases; Cancer treatment
Infrastructure	Location planning (e.g. facilities, institutions, power plants)
Logistics / Transportation	Freight transportation; Scheduling means of transport (e.g. airplanes, buses, trains)
Manufacturing	Processing control; Product and process design; Production planning
Marketing	Product attractiveness
Systems	Understanding and management of energy, financial and human systems; Telecommunications
Sustainability	Energy planning; Environmental impact assessment; Evaluation of environmental, economic and social implications of products, organisations and policies; Management of water, fisheries, land, forests

Table 1: Application areas for MCDM/A mentioned by the interviewees (in alphabetic order)

5. What is the best approach to integrate MCDM/A in other research domains?

The best recipe to achieve this integration starts from MCDM/A scholars and practitioners, who should try to approach the application areas for these methods with a learning perspective clearly in mind. This means that they should learn the problems that are specific of the domain under consideration and develop, adapt and select the MCDM/A method(s) that best fit the challenge, and not vice-versa.

Another key characteristic for a successful integration is to ensure traceability and transparency during the decision support process, in order to allow those who do not have competencies in MCDM/A to understand the reasons why certain recommendations are provided. This allows avoiding the perception of decision support systems as 'black boxes', providing recommendations that are difficult to link to the input preference information expressed by the user. Three enlightening concepts emerged during the interviews, which nicely summarise the opinions reported above:

- The method has to be tailored to the problem and not the problem to the method;
- The choice of the method depends also on the kind of (preference) information the DM is willing and able to provide (and what kind of information (s)he wants to obtain);
- Humans are those who do the job, thus human contact is the key to integration of MCDM/A in application areas.

On the other hand, it would also be helpful if more courses in agricultural sciences, biology, business, chemistry, economics, engineering, management, politics and social sciences would be enhanced with basics on MCDM/A foundations and methods. This pedagogical choice would help framing the mind-set of university students who could be more supportive when possibilities for the development of decision support systems will appear as an option to solve their complex decision-making problems. Another pedagogical change which could help students approaching problems with an MCDM/A perspective consists in inviting the authors and publishers of Operations Research textbooks to include in the next editions of their volumes the possibility of having several conflicting objectives to be maximised instead of a single one only.

A further opportunity for extension and reinforcement of strong links between application areas and MCDM/A is to foster the organisation of operational research conferences whose themes are focused on such areas, which can help finding links between MCDM/A methods developers and application-focused experts.

Conclusions

The complexity of decision-making problems is increasing at a fast pace. The number of parameters that must be used to reach an informed decision is growing as well as the typology of stakeholders whose concerns need to be considered simultaneously. This is the reason why methods and strategies capable of providing decision support are receiving mounting interest both from researchers and practitioners. MCDM/A emerged as a premier set of methods and strategies to aid structured, transparent and intelligible decision-making and the reasons behind its success have been summarised in this article, which clusters the perspectives and opinions of eight well-known scholars in the area. What is more, the strategies to pursue a comprehensive understanding of MCDM/A are provided, with a focus on conferences, scientific societies, books and training courses. Lastly, the wide span of application areas that ranges from marketing to systems management shows the

flexibility in modelling as one of the main strengths of MCDM/A. Overall, in order to guarantee a fruitful integration of MCDM/A in the application areas, the recommendations from the experts include (i) a better understanding of the practical decision-making problems, (ii) higher attention to the interpretability of their decision support systems as well as to the suitability of preferences' elicitation strategies and (iii) integration of basic knowledge on MCDM/A foundations and methods in the university courses of the DMs of tomorrow, as part of degrees in agricultural sciences, biology, business, chemistry, economics, engineering, management, politics and social sciences.

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Appendices

A. **List of interviewees**

Interviewee (alphabetic order)	Affiliation
Professor Luis C. Dias	Faculty of Economics, University of Coimbra, Portugal
Professor Matthias Ehrgott	Department of Management Science, Management School, University of Lancaster, UK
Professor Salvatore Greco	Department of Economics and Business, University of Catania, Italy and Portsmouth Business School, University of Portsmouth, UK
Professor Murat Köksalan	Department of Industrial Engineering, Middle East Technical University, Ankara, Turkey
Professor Kaisa Miettinen	Department of Mathematical Information Technology, University of Jyväskylä, Finland
Professor Francisco Ruiz de la Rúa	Department of Applied Economics, School of Business, University of Málaga, Spain
Professor Roman Słowiński	Institute of Computing Science, Poznań University of Technology, Poland
Professor Theodor Stewart	Department of Statistical Sciences, University of Cape Town, South Africa

B. **Training events on MCDM/A**

1. International Society on MCDM summer school: http://www.mcdmsociety.org/content/summer-schools-society

2. Decision Deck Workshop: http://www.lgi.ecp.fr/~mousseau/D2Workshop/pmwiki-2.2.7/pmwiki.php

3. European Multiple Criteria Decision Aiding (MCDA) Spring School: http://www.laboratorioambiente.unipg.it/index.php?id=54

4. JRC Annual Training on Composite Indicators & Scoreboards, European Commission, Joint Research Centre, Ispra (IT): https://ec.europa.eu/jrc/en/event/conference/14th-jrc-annual-training-composite-indicators-and-scoreboards

C. **International operational research societies and working groups on MCDM/A**

1. International Society on MCDM: http://www.mcdmsociety.org

2. EURO Working Group on MCDA: http://www.cs.put.poznan.pl/ewgmcda/

3. The Association of European Operational Research Societies (EURO): https://www.euro-online.org/web/pages/1/home; Member societies of EURO: https://www.euro-online.org/web/pages/1457/current-member-societies

4. International Federation of Operational Research Societies (IFORS): http://ifors.org/web/; Member societies of IFORS: http://ifors.org/web/national-societies/

5. The Institute for Operations Research and the Management Sciences (INFORMS): https://www.informs.org

6. Red Ibero-Americana de Evaluación y Decisión Multicriterio (RED-M): http://www.redmsociety.org/

D. **Books on MCDM/A (from most recent)**

1. Greco, S., M. Ehrgott, and J. Figueira (2016), *Multiple Criteria Decision Analysis: State of the Art Surveys*, New York: Springer-Verlag

2. Bisdorff, R., L. Dias, V. Mousseau, M. Pirlot, and P. Meyer (2015), *Evaluation and Decision Models with Multiple Criteria. Case Studies*, Berlin: Springer-Verlag

3. Ishizaka, A., and P. Nemery (2013), *Multi-Criteria Decision Analysis: Methods and Software*, Chichester: Wiley

4. Linkov, I. and E. Moberg (2011). *Multi-Criteria Decision Analysis: Environmental Applications and Case Studies*, CRC Press

5. Branke, J., K. Deb, K. Miettinen, and R. Słowiński (2008), *Multiobjective Optimization: Interactive and Evolutionary Approaches*, Springer

6. Belton, V., and T. J. Stewart, (2002), *Multiple criteria decision analysis; an integrated approach*, Kluwer Academic Publisher

7. Miettinen, K. (1999), *Nonlinear Multiobjective Optimization*, New York: Springer

8. Steuer, R.E. (1986), *Multiple Criteria Optimization: Theory, Computation and Application*, New York: John Wiley & Sons

9. Yu, P.L. (1985), *Multiple Criteria Decision Making. Concepts, Techniques and Extensions*, New York: Plennum Press

10. Chankong, V., and Y. Y. Haimes (1983), *Multiobjective Decision Making Theory and Methodology*, Elsevier

11. Zeleny, M. (1982), *Multiple Criteria Decision Making*, New York: McGraw-Hill

12. Hwang, C. L., and A. S. M. Masud, (1979), *Multiple Objective Decision Making - Methods and Applications. A State-of-the-Art Survey*, Springer

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