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Comparison of multi-criteria decision analytical software for supporting environmental planning processes

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ABSTRACT

In this paper, we analyze 23 multi-criteria decision analysis software tools in terms of their applicability to support environmental planning processes. Our aim is to survey what kind of software is available, and compare the features they provide to meet the characteristics of environmental problems. Our focus is on useful or innovative features of the software from the viewpoint of supporting practitioners to systematically analyze and compare alternatives in environmental planning. The results can be utilized for selecting the most suitable software for supporting the needs of the environmental cases, but also for identifying good practices and innovative implementation solutions for software development.

1. Introduction

Multi-Criteria Decision Analysis (MCDA) is a general term for systematic approaches that can be used to support the analysis of multiple alternatives in complex problems involving multiple criteria (e.g., Belton and Stewart, 2002; Gregory et al., 2012). The process typically consists of the divergent and convergent phases (e.g., Franco and Montibeller, 2010). The divergent phase aims to enlarge the perspective by identifying all the relevant issues to be taken into account, whereas the convergent phase focuses on synthesizing this information for making concise and informed decisions. The problem is typically constructed into a tree-like hierarchy of criteria and alternatives. As an outcome, one gets overall values or a preference order of the alternatives, which reflect the evaluators' preferences regarding the criteria as well as the estimated performance of the alternatives with respect to each criterion (Keeney and Raiffa, 1976). For a comparison of different MCDA methods, see Belton and Stewart (2002) or Greco et al. (2016), for example.

MCDA has been increasingly applied to support environmental planning processes, in which MCDA can provide a transparent synthesis of a problem from different perspectives and a systematic evaluation of the alternatives (Kiker et al., 2005; Huang et al., 2011; Keisler and Linkov, 2014; Voinov et al., 2016). Carrying out the MCDA process in close collaboration with the stakeholders enhances social learning and enables a transparent inclusion of the public values and concerns in the process (Salo and Hämäläinen, 2010; Keisler and Linkov, 2014; Hamilton et al., 2015; Voinov et al., 2016). Consequently, these can contribute to increasing participants' trust in the process, as well as its quality.

Various multi-criteria software tools or decision support systems (DSS) have been developed to support the application of MCDA methods in practice. Besides computational support for implementing the methods, the tools typically provide various ways to support other phases in the process, such as construction of the model and analysis of the results (e.g., Liu and Stewart, 2004; French and Xu, 2005). For example, the graphical user interfaces offer various possibilities to visualize the process and the results, and consequently, to facilitate the illustrative, transparent, and understandable realization of MCDA (e.g., Reichert et al., 2013).

In this paper, we compare various MCDA tools in terms of their applicability to support systematic analysis and comparison of alternatives in environmental planning processes. Our motivation is that despite there being many earlier general-level comparisons of MCDA software available (e.g., Vassilev et al., 2005; Oleson, 2016; Weistroffer and Li, 2016), none of those explicitly focuses on the needs of environmental planning processes. Besides comparing the basic technical features of the tools, we analyze them in terms of their ability to meet the typical characteristics of environmental problems (e.g., Keeney, 1973; Mickwitz, 2003; Ascough et al., 2008; Maier et al., 2008), including:

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- the systemic and complex nature of the impacts and ill-defined nature of the problems,
- multiple stakeholders having different objectives,
- geographical distribution of the impacts, and
- uncertainties related to, e.g., the cause-effect relations of the impacts that can evolve over time.

We think that well-planned software support can provide considerable additional value for dealing with each of these characteristics. We discuss, for example, how the innovative software solutions can contribute to the practices of supporting environmental cases. The results are expected to be useful for practitioners in finding suitable software for the particular needs of their cases, as well as for developers of the new software in implementing new, innovative features.

Here, we group the possible users of MCDA methods and software in environmental cases into three types, based on their familiarity with MCDA and their levels of sophistication in the analysis:

1. Environmental experts who like to apply MCDA in their cases, even though they do not have prior education and experience of MCDA,
2. MCDA experts who act as MCDA facilitators in environmental cases, and need support for facilitation and visualization of the processes, and
3. MCDA experts who want to carry out sophisticated analyses on the cases.

We discuss the needs of the software for these three user groups in terms of methodological support for the user, ease of use, possibilities for various kinds of analyses, and visualization of the results.

Traditionally, users utilizing MCDA software have been those of “Group 2”, and the main focus of this analysis is on them. However, the increasing number of successful MCDA applications has also increased the interest of “Group 1” users to apply MCDA in their cases (e.g., Hämäläinen, 2015; Voinov et al., 2016). In this respect, today's easy-to-use software can even lower the threshold of using MCDA (Hämäläinen et al., 2010). However, this may also increase the risk of improper use of the methods, as there are a number of biases that can exist in preference modeling without fully understanding the method (e.g., Pohl, 2004; Montibeller and von Winterfeldt, 2015a; Franco and Hämäläinen, 2016). One way to promote the responsible and proper use of the methods is to implement such procedural solutions in the software that guide the user through the process. Thus, we also discuss the features the tools provide for “Group 1” users.

“Group 3” users may prefer to use spreadsheet tools like Excel or numerical calculation tools like Matlab or R for versatile analyses (e.g., Moeck et al., 2015; Guillaume et al., 2016). For them, and also for software developers, this comparison can provide inspiration for the elaboration of this process and the presentation of the results. In fact, some of the software tools in this analysis were developed with “Group 3” users in mind, and these could even be classified as programming languages rather than decision support tools.

This study was conducted as part of the IMPERIA project (IMPERIA, 2015) that focused on developing good practices for supporting the Environmental Impact Assessment (EIA) process. An earlier EIA-focused version of this comparison was published as an IMPERIA project report (Mustajoki and Marttunen, 2013), and it was reframed for this analysis to generally apply to all kinds of environmental planning. Our focus is on MCDA, but a general discussion about developing environmental software for supporting other decision support methodologies can be found, for example, in McIntosh et al. (2011).

This paper is constructed as follows. In Section 2, we describe the evaluation framework that was used to compare the software and the basics of the MCDA methods applied in the software. In Section 3, we present and compare the basic features provided by the software, and in Section 4, we discuss how well the solutions implemented in the software are suited for supporting environmental planning processes in particular. The concluding remarks are given in Section 5.

2. Evaluation framework

We evaluated the software in terms of fulfilling a set of various features describing needs in different phases of the process. Our focus was on the usefulness of the software to meet the characteristics of the environmental problems.

2.1. Selection of the software for the evaluation

There are numerous MCDA software tools available on the internet to be used online or to be downloaded. Our aim was not to analyze every single tool, but to get a versatile view of the possibilities to support environmental planning with MCDA. In order to find software for the analysis, we did a web search with various combinations of the keywords “MCDA”, “multi-criteria”, “multi-attribute”, “software”, and “decision support”. In addition, we searched through review or comparison articles of the software in international academic publications (French and Xu, 2005; Vassilev et al., 2005; Oleson, 2016; Weistroffer and Li, 2016) as well as link lists on web pages related to MCDA software (EWG-MCDA, 2016).

We only studied software that can be classified under the term *multiple attribute decision making* in the classification of Weistroffer et al. (2005). Thus, for example, software for *multiple objective decision making*, (e.g., *IND-Nimbus*, *FGM*), *sorting problems* (e.g., *IRIS*) and *portfolio analysis* (e.g., *HiPriority*) are excluded from this analysis (for a review of these, see Weistroffer and Li, 2016). A common denominator of the selected software is that they provide explicit support for eliciting the preferences of stakeholders as well as for combining these with the alternatives' performance data to get a preference order for the alternatives. Some software tools also provide *group decision support*, and of these we have only studied tools that explicitly support MCDA features. We mainly analyzed *generic software tools*, but the analysis also included a few *application-specific software tools* tailored for specific environmental applications. The aim was to study how MCDA software can been tailored to particular purposes. Of the methods, we focused on the software providing support for three commonly used MCDA method families, i.e., Multi-Attribute Value Theory (MAVT; Keeney and Raiffa, 1976), Analytic Hierarchy Process (AHP; Saaty, 1980), and outranking methods (Vincke, 1992; Greco et al., 2016).

Overall, we were able to identify dozens of different software tools that supported MCDA. Of these, we selected 23 for our final analysis based on the above-mentioned preconditions for the support of MCDA methodology, and on the availability of a demo or trial version of the software. We are aware that some tools may have still been omitted from this analysis, but for achieving our main objective of capturing ideas of the various ways to support environmental processes, we think that the set of analyzed software was large and versatile enough.

2.2. Methods supported by the software

MAVT is an MCDA method where the problem is structured into a form of a value tree that represents a hierarchical structure of the