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Review

Analysis of the potentials of multi criteria decision analysis methods to conduct sustainability assessment

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ABSTRACT

Sustainability assessments require the management of a wide variety of information types, parameters and uncertainties. Multi criteria decision analysis (MCDA) has been regarded as a suitable set of methods to perform sustainability evaluations as a result of its flexibility and the possibility of facilitating the dialogue between stakeholders, analysts and scientists. However, it has been reported that researchers do not usually properly define the reasons for choosing a certain MCDA method instead of another. Familiarity and affinity with a certain approach seem to be the drivers for the choice of a certain procedure. This review paper presents the performance of five MCDA methods (i.e. MAUT, AHP, PROMETHEE, ELECTRE and DRSA) in respect to ten crucial criteria that sustainability assessments tools should satisfy, among which are a life cycle perspective, thresholds and uncertainty management, software support and ease of use. The review shows that MAUT and AHP are fairly simple to understand and have good software support, but they are cognitively demanding for the decision makers, and can only embrace a weak sustainability perspective as trade-offs are the norm. Mixed information and uncertainty can be managed by all the methods, while robust results can only be obtained with MAUT. ELECTRE, PROMETHEE and DRSA are non-compensatory approaches which consent to use a strong sustainability concept, accept a variety of thresholds, but suffer from rank reversal. DRSA is less demanding in terms of preference elicitation, is very easy to understand and provides a straightforward set of decision rules expressed in the form of elementary "if ... then ..." conditions. Dedicated software is available for all the approaches with a medium to wide range of results capability representation. DRSA emerges as the easiest method, followed by AHP, PROMETHEE and MAUT, while ELECTRE is regarded as fairly difficult. Overall, the analysis has shown that most of the requirements are satisfied by the MCDA methods (although to different extents) with the exclusion of management of mixed data types and adoption of life cycle perspective which are covered by all the considered approaches.

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Abbreviations: MCDA, multi criteria decision analysis; DM(s), decision maker(s); MAUT, multi attribute utility theory; AHP, analytical hierarchy process; ELECTRE, elimination and choice expressing the reality; PROMETHEE, preference ranking organization method for enrichment of evaluations; DRSA, dominance-based rough set approach.

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1. Introduction

The literature about sustainability assessment is wide and steadily growing, with different interpretations and implementations of this concept available so far (Bond et al., 2012). On one side there are rather conceptual and holistic proposals based on sustainability principles (see for example WCED 1987; Gibson, 2006), which introduce frameworks to encompass and combine different values and perspectives, while one the other side there are more concrete and operational approaches that try to define and derive sustainability criteria/pillars to make the concept of sustainability operational (Omann 2004; Pope et al., 2004; Gibson, 2006; Cinelli et al., 2013a; Sala et al., 2013a). There are different attempts to perform this operationalization, ranging from two to seven pillars depending on the context of the analysis/evaluation to be performed (Gibson, 2006; Bond et al., 2012). One of the most common ones is the triple bottom line (TBL) approach, which is based on the environmental, economic and social pillars, having equal importance in the decision-making process (Pope et al., 2004; Gibson, 2006; Convertino et al., 2013; Subramanian et al., 2014; Tatham et al., 2014). This approach has been widely used as it fits properly with the professional figures and organizational bodies that are in charge of the assessment of each of the pillars (Gibson, 2006).

The objective of sustainability assessment (SA) can vary considerably, from a micro to a macro scale, meaning that the inclusion of various processes and mechanisms cannot always be taken into account with the same approaches (Cinelli et al., 2013b; Zamagni et al., 2009). This leads to the necessity to define clearly what the scope of the assessment is and what questions need to be answered, implying that different instruments should be used depending on each case (Sala et al., 2013b). Additionally, the spheres or pillars of sustainability considered can vary, which means that some studies can consider only environmental and economic aspects, others only the environmental ones and others environmental, economic and social together (Sala et al., 2013a).

SA has also the role of improving the decision aiding process, by (Bockstaller et al., 2008; Gasparatos et al., 2008):

- Integrating sustainability spheres and considering their interdependencies.
- Including intragenerational and intergenerational considerations.
- Supporting constructive interaction among stakeholders.
- Accounting for uncertainties and adopting a precautionary approach.
- Contributing to monitoring and communication of results.

Over the past decades a plethora of methodologies and tools were developed to perform sustainability assessment studies, focusing on different scopes (i.e. different pillars) and scales/objectives (i.e. micro, meso and macro), with some covering only a certain pillar and object of sustainability (e.g. life cycle assessment), and with others widening both (e.g. cost-benefit analysis, multi criteria decision analysis) (Singh et al., 2009; Zamagni et al., 2009). For example, life cycle assessment (LCA) is a product-oriented tool for the assessment of environmental implications, while multi criteria decision analysis (MCDA) is a set of methods that can be used to compare alternatives from a product level to a policy one, by covering one or more sustainability pillars (Munda, 2005; Epa, 2006).

Furthermore, Ness and coworkers (Ness et al., 2007) provide a categorization of sustainability assessment tools which includes (i) indicators which are non-integrated, (ii) product related assessments and (iii) integrated assessments. Non-integrated indicators support the decision-making processes by converting knowledge in manageable units of information (UN 2001). They can be defined as an “operational representation of an attribute of a system” (Gasparatos et al., 2008), which can be an environmental, economic or social state of the system under consideration. Some examples are the Environmental pressure indicators and the national indicators developed by United Nations Division for Sustainable Development (UN, 2001; Gasparatos et al., 2008). Product-related tools consider flows in relation to production and consumption of goods and services. An important distinction that can be introduced here and is applicable to all the tools for SA is the extend of the system tackled, in other words whether the method takes into account only direct impact of the target or is based on a life-cycle approach. Product energy analysis is an example of a tool covering only direct impacts, whereas LCA spans the whole life cycle stages of a product (De Ridder et al., 2007; Ness et al., 2007). Integrated assessment are all the approaches that try to handle the information from individual indicators in a comprehensive manner, by considering interrelations and interdependencies among them, accounting for the different importance that they might have, and adopting different degrees of aggregation. MCDA is one of this and it has been indicated as the appropriate set of tools to perform assessments of