The 6th International Conference on Life Cycle Management in Gothenburg 2013

USE OF MULTI CRITERIA DECISION ANALYSIS TO SUPPORT LIFE CYCLE SUSTAINABILITY ASSESSMENT: AN ANALYSIS OF THE APPROPRIATENESS OF THE AVAILABLE METHODS

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Keywords: multi-criteria-decision-analysis; sustainability assessment; data integration.

ABSTRACT

Main multi criteria decision analysis methods (i.e. MAUT, AHP, ELECTRE and PROMETHEE) were assessed with 10 criteria considered pivotal in sustainability assessments, from life cycle perspective and thresholds use to uncertainty management. It resulted that MAUT and AHP are fairly simple to use and have good software support, but can only uphold a weak sustainability perspective. Concerning ELECTRE and PROMETHEE, they can enforce strong sustainability concept, deal well with thresholds, support dynamic results re-evaluation, but suffer from rank reversal and are quite complex. Overall, the analysis has indicated that multi criteria decision analysis methods are appropriate for supporting life cycle sustainability assessment.

INTRODUCTION

Life Cycle Sustainability Assessment (LCSA) represents a set of methodologies/tools that can cover different spheres, scales and objectives of sustainability (i.e. micro, meso and macro) (Cinelli et al., 2013; Zamagni et al., 2009).

Multi criteria decision analysis (MCDA) is considered an appropriate set of methods for the "assessment of sustainability" (Gasparatos & Scolobig, 2012), and this study investigates how MCDA can contribute to LCSA, analyzing the main MCDA methods, namely multi attribute utility theory (MAUT), analytical hierarchy process (AHP), ELECTRE and PROMETHEE, on the basis of 10 criteria that they should satisfy to appropriately deal with problems concerning sustainable development.

MATERIALS AND METHODS

The analysis of the MCDA methods was performed with the following criteria derived and assessed from several sources (Antunes et al., 2012; Belton & Stewart, 2002; Benoit & Rousseaux, 2003; Buchholz, Rametsteiner, Volk, & Luzadis, 2009; Munda, 2005, 2008; Polatidis, Haralambopoulos, Munda, & Vreeker, 2006; Rowley, Peters, Lundie, & Moore, 2012; Sala, Farioli, & Zamagni, 2012; Teghem, Delhaye, & Kunsch, 1989): (i) inclusion of life cycle perspective; (ii) compensation degree among sustainability spheres; (iii) weights

expressed as trade-offs or importance coefficients; (iv) thresholds use to support preferences and analytical uncertainties management; (v) handling of qualitative and quantitative information; (vi) uncertainty treatment/sensitivity analysis; (vii) rankings robustness; (viii) software support and graphical representation; (ix) methods ease of use; and (x) learning dimension to support dynamic re-evaluation.

RESULTS

The results of the comparisons of the MCDA methods based on the 10 criteria are shown with the related references in Table 1 and they are briefly described below. 3 colors have been used to indicate the performance (i.e. green = good; orange = depends on the case; red = bad) of each group of methods in relation to each criterion on the basis of a sustainability-oriented evaluation perspective, specifically the strong one.

Firstly, all the MCDA methods analyzed can include a life cycle perspective.

MAUT and AHP score badly on compensation and weights as importance coefficients, since they assume a complete compensability among the criteria, whereas ELECTRE and PROMETHEE do not allow or limit such feature. ELECTRE and PROMETHEE can also handle effectively different thresholds, mixed information and uncertainty. Also AHP and MAUT score positively for the last two criteria, whereas they perform poorly on thresholds.

All the methods are supported by specific software that allow for medium/wide range of graphical results representation, except the ELECTRE ones whose graphics interface is poor.

AHP is considered as the easiest set of methods, followed by PROMETHEE and MAUT, while the ELECTRE ones are classified as fairly difficult.

Lastly, dynamic results re-evaluation is only possible in the case of the PROMETHEE methods, while MAUT is the only one which cannot be affected by rank reversals.

DISCUSSION

The analysis has shown that there is not a clear agreement among different authors concerning several criteria (see Table 1). Nonetheless, some considerations can be derived starting from the positive fact that all the methods can conceptually include all the life stages of a product.

MAUT and AHP can only use a weak sustainability perspective with trade-offs as the norm, whereas ELECTRE and PROMETHEE enforce a strong one, by limiting or abolishing the compensation among/within sustainability spheres.

All the methods can deal with mixed information and manage at different extents uncertain weights and criteria, while robust results can only be obtained with MAUT and rankings re-evaluation with PROMETHEE, leaving the others with a big disadvantage.

CONCLUSIONS

Several MCDA methods that can support LCSA are available, and in this paper, MAUT, AHP, ELECTRE and PROMETHEE were evaluated on the basis of 10 criteria crucial for

Evaluation criteria	MAUT	AHP	ELECTRE	PROMETHEE
Life cycle perspective	Possible[4]	Possible[4]	Possible[4]	Possible[4]
Compensation (i.e. weak vs strong sustainability)	Full[1,2,3,5,7,8,9,12]	Full[2,3,5,7,8,12]	Non possible[1,2,3,5,7,12] / Partial[1,2,8]	Partial[1,5,7,8] / Full[2]
Weights type	Trade-offs[3,7,8,9,10,11,12]	Trade-offs[3,7,8,12] / Importance coefficients[11]	Importance coefficients[3,7,8,11,12]	Importance coefficients[3,7,12] / Trade-offs[8]
Threshold values	Not possible[5,8] / Possible[6]	Not possible[5,6]	Possible[1,5,7,11,12]	Possible[1,5,6,7,10,12]
Qualitative and quantitative data	Possible[5,6,11]	Possible[5,6,11]	Possible[5,7,11]	Possible[1,5,7]
Uncertainty treatment/Sensi-tivity analysis	Possible[4,5,6,7,10,11]	Partially possible[5,6] / Possible[9]	Possible[4,5,7]	Possible[4,5,7,10] / Partially possible[6]
Robustness	No rank reversal is possible[5,8]	Rank reversal can occur[5,8]	Rank reversal can occur[5,8]	Rank reversal can occur[5,8]
Software support and graphical representation	Software available with wide range of graphical representation available[5,6,11]	Software available with wide some graphical representation available[5,6,9,11]	Software available, but with poor graphical interface[5]	Software available with wide range of graphical representation available[5,6]
Ease of use	High[5,6] / Low[7,8]	High[6] / Medium[5]	Low[5,7,8,11]	Medium[5,6,7,8]
Learning dimension based on software	Difficult[5,6]	Difficult[5,6]	Difficult[5]	Simple with scenario analysis[5,6]

Table 1: Comparisons of different MCDA methods ([1]: (Benoit & Rousseaux, 2003), [2]: (Teghem, et al., 1989), [3]: (Munda, 2005), [4]: (Belton & Stewart, 2002), [5]: (Antunes, et al., 2012), [6]: (Buchholz, et al., 2009), [7]: (Polatidis, et al., 2006), [8]: (Munda, 2008), [9]: (De Montis, De Toro, Droste-Franke, Omann, & Stagl, 2000), [10]: (Raju & Pillai, 1999), [11]: (De Montis, De Toro, Droste-Franke, Omann, & Stagl, 2005), [12]: (Rowley, et al., 2012))

such assessments. It emerged that all the methods can include mixed data and life cycle perspective. ELECTRE and PROMETHEE score better than MAUT and AHP in terms of enforcement of a strong sustainability approach, together with thresholds management. Nonetheless, they suffer from robustness, and partially for simplicity and software support. On the other hand, MAUT and AHP are mostly considered easier to use and their software support is wider, although dynamic re-evaluation potentials should be developed.

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