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Criteria Interaction Modelling In The Framework Of Lca Analysis

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Abstract

In this paper, we emphasize the possibility to aggregate evaluations by using different multi-criteria approaches and operators, actually more suitable for environmental problems. More precisely, values of different indicators, qualitative and quantitative, can be aggregate in a more flexible and efficient way, using operators not necessarily compensatory, allowing partial compensation and/or not transitive preferences, including also the very important possibility to model interactions among criteria. A single descriptor of multiple attributes, known as a composite indicator, can be used to reconcile apparently incommensurable criteria into a comparable basis, but the current aggregation and weighting practices in LCA are not sufficiently rigorous, because its methodological simplicity, usually being just weighted sums that implicitly require preference independence hypothesis and totally compensatory nature. We have explored different MCDA approaches in the literature that may be applied by LCA practitioners to enhance the technical credibility and also identify issues affecting the selection and implementation of a more appropriate aggregation approaches. In this direction, particularly attention can be devoted to some methods allowing the modelling of interaction, where suitable techniques can actually implemented in order to improve the validity of the results

Keywords: Life Cycle Impact Assessment, impact categories, MCDA, interactions, weighting.

Introduction

Production and consumption of goods and services are primary factors causing harmful effects on the environment. For this reason, the management of production and consumption is a key area in order to achieve sustainable development in our society. There is therefore a need for suitable decision-making tools to evaluate environmental options in all the production processes., In this field, life cycle assessment (LCA) appears to be a valuable method for assessing the environmental considerations of a product or service throughout its entire life cycle, including everything from raw material extraction, processing, transportation, manufacturing, distribution, use, re-use, maintenance and recycling to final disposal (Consoli et al. 1993). Life cycle assessment (LCA) is the term that is currently widely accepted for environmental assessment of products or processes on a holistic cradle-to-grave basis (Kooijman 1993); the International Standardization Organization is currently working on LCA methodologies with the aim of harmonising different methods and promoting further establishment (Strazza C. et al., 2010).

So, Life- Cycle assessment models are likely to become the future decision support tools and they include an inventory model and an assessment model (Del Borghi 2013) . The Life-Cycle Inventory model (LCI) provides a detailed account of all resource consumptions and emissions for an environmental system, as well as for any up-stream or down-stream activities associated with the impacts. The life-cycle impact assessment model (LCIA) translates and aggregates, according to fairly standardized methods, all of the detailed information provided by the LCI into the main resource consumption of concern and the main environmental impact categories (global warming, acidification, etc.). The significance of the aggregated data relative to each other and to all combined activities in society can usually be obtained by the weighted sum of normalized impacts caused by one average person. Weighting of normalized results can be made to identify the importance of environmental impacts or resource consumptions, but consensus on weighting factors has not yet been reached (Kirkeby 2007).

During the 1990s detailed contents were assigned to the steps of LCA on the basis of co-operation between investigators in several countries, especially in the Society of Environmental Toxicology and Chemistry (SETAC 2008) and the International Organization for Standardization (ISO). Life cycle assessment is documented in the form of ISO standards 14040-14044 (ISO 1997; ISO 2000a; ISO 2000b; ISO 2006a; ISO 2006b), giving instructions for LCA practitioners to conduct LCA applications according to “good practice”. Inventory data, environmental interventions representing a “cradle-to-grave” perspective, are the core of LCAs. However, from the point of view of a decision maker, the inventory results are usually not sufficient for making comparative better decisions. In comparative studies it may be found that alternative A is better than alternative B with respect to some points of view, but poorer in others. Life cycle impact assessment (LCIA) enables us to interpret the results of the inventory, but it is just the first step to draw the correct conclusions concerning improvement approaches (Saur et al. 1996). The consideration of environmental effects as a consequence of environmental interventions provides additional information, which is not covered by the inventory step. Several methods exist to establish weighting factors because weighting has always been a controversial issue; it can be difficult, in the context of developing an LCIA method, to select one method among others. A good weighting method must give certain common features, including transparency, simplicity in implementation, communicability and magnitude or capacity to assess environmental problems. Moreover, the weighing procedures have to take into consideration a certain number of issues including: the probability of the attribute to cause an undesirable consequence to the environment; the magnitude/severity of this consequence, possibly not reversible; the temporal aspect such as duration, time of occurrence, etc. This results in a proliferation of data gathering, storing and analysis techniques within the environmental assessment tools and MCDA methods are more relevant to these tasks. The use of uncertainty modelling formalisms and the building of decision support frameworks allowing the efficient interpretation of the assessment results and data in an uncertain environmental are greatly needed.

In this paper, first we outline a classification and assessment framework of the main multi-criteria decision analysis (MCDA) methods in the light of their ability to take into account the peculiar needs of LCIA (Benetto 2000). We shortly analyze different MCDA approaches to suggest the most appropriate method for aggregating different attributes values, underling the weighting issue of each one. This paper therefore aims to indicate the main guidelines representing a starting point in the development of a robust weighting method, which takes into consideration the importance of clearly identifying what part of the responses deals with subjectivity and objectivity in weighting assessment to provide the most relevant information during the decision-making process. In absolute terms, there is not recognized an ideal weighting method, so the proposed approach combines different weighting techniques and problems in a single weighting framework.

1. The LCIA Analysis

The LCA provides accurate and robust results by utilising the very detailed models developed in the inventory stage and this phase needs greater transparency and standardization of methods and calculations (Garrett P., 2013). LCIA is typically divided into five phases: selection of impact categories, classification, characterisation, normalisation and weighting. In the selection of impact categories (e.g. climate change and acidification), indicators for the categories and models to quantify the contributions of different environmental interventions to the impact categories are selected. The second phase, classification, is an assignment of the inventory data to some predefined impact categories. In the characterisation phase, the models make an aggregation of possible interventions within each impact category. Values of interventions are changed into impact category indicators resulting from characterisation factors. These factors measure the effect intensity of each single emission on the environmental problem at hand.

From a decision maker's perspective, impact category indicators are more manageable than interventions, but due to their proxy characteristics they are difficult to interpret. In order to obtain a more comprehensive view of impact category indicator results, some suitable normalisation can be conducted to better assess their overall environmental impact. Finally, the weighting phase relates the normalised magnitude of the indicator results with respect to the different impact categories to reference values, calculated on the basis of an inventory of a chosen reference system (Consoli et al. 1993, Wenzel et al. 1997, Finnveden et al. 1997).

Normalisation is needed in practice for comparative evaluations but it requires trade-offs between different category indicators, which are very difficult to evaluate. These trade-offs are determined as particular "weighting factors" (weights) in the weighting phase; we observe that these kind of weights depend also on the particular measurement scale of each indicator and therefore they are introduced in order to be able to obtain a final unique aggregated value (for example, the weighted sum) as an overall evaluation. As a consequence, the trade-offs do not give us direct information about the "intrinsic importance" of the corresponding indicators, since their values depend on the reference system actually chosen, including the ranges of the measurement scales. This means that if the trade off between categories A and B is equal to 3, the relative intrinsic importance of A is not three times the importance of B, but only that the "scale factor" to aggregate these factors in an additive value function is 3. For this reason, weighting is desirable or necessary in many LCA applications (e.g. Hansen 1999, Bengtsson 2000), although determination of weights is based on subjective value choices. Weights in fact are used with different meanings of "trade off " in functional approach or "coefficients of importance" in the case of non-compensatory methods (Minciardi et al. 2007). In this case, the inter-criteria information required is an evaluation of the relative importance between coalitions of criteria; such a concept of relative importance is often translated into numbers, called weights (for example in ELECTRE methods). In the case of compensatory methods (weighted sum), on the contrary, the weights have to be considered as scale factors and then their meaning is that of a trade-off between each pair of criteria (Minciardi et al. 2008).

In our opinion, the great attention devoted in LCIA to the weighting problems is related to the use of the weighted sum as usual, simple and efficient aggregation operator, accepted by the majority of authors, at least implicitly. But this operator, that should be applied only when all the data are homogeneous, although very easy to be understood, suffers from a lot of drawbacks. First of all, it is perfectly compensatory, which is a great advantage with respect to some characteristics, and can always compensate disadvantages, even if very huge, with respect to other points of view. In our opinion, this implicit hypothesis is very dangerous in the framework of environmental analysis, where it is often not possible to compensate (for example, with high financial cash flows) some very dangerous situations (concerning public health). Another weak point of the weighted sum is that this kind of aggregation operator can be applied only if there is preference independence among the considered impact indicators. This means that, if categories *a* and *c* have the same evaluations with respect to a subset of considered criteria, and categories *b* and *d* also have the same evaluations – but different from the evaluations of *a* and *c* - with respect the previous considered subset of criteria, and category *a* is preferred to category *b*, also *c* should be preferred to *d*, independently of their common evaluations with respect to the remaining criteria. This means that the weighted sum approach is not able to model any interaction among criteria, where this characteristic affects a lot of real environmental situations and should be taken into consideration (Matarazzo 2012).

Although there is an approximate consensus on the procedural framework of LCIA, the methods may vary in LCA applications. Different methods can of course produce different results. The results depend, among other things, on the coverage of impact categories, the chosen impact category indicators and the models chosen for characterisation factors. Furthermore, as observed before, a reference system used in normalisation can dramatically affect the interpretation and the results, also in the framework of the weighted sum operator. In practical application, in order to avoid some assessment difficulties and to simplify the implementation of well known approaches, "less is better" has been often applied in LCIA (Lo Giudice 2011). This approach assumes that all amounts of the same kinds of interventions lumped together cause harmful effects on the environment on the basis of their intrinsic hazard characteristics, regardless of where and when they take place, and only whether the amounts are above or below certain thresholds (White et al. 1995). Although the advantage of the "only-above-threshold" approach is clear, its implementation in practice has been developed only slowly due to the complexity of applying it on a life cycle scale.

In LCIA the values of environmental interventions assessed in the inventory analysis are interpreted on the basis of their potential contribution to the overall environmental impact. The term "potential contribution" indicates that the result of LCIA is not an absolute value, and that LCIA is a relative approach, part of a more complete analysis of environmental assessments. The idea is that comparative studies need more detailed data on temporal and spatial aspects than that required by absolute methods, such as environmental risk assessment. Weighting is a process which can take place within the different steps of LCIA and LCA interpretation to aggregate the results into a single score; LCIA is used to evaluate the significance of the environmental interventions contained in a life cycle.

Determination of weights has been a controversial issue in LCIA because of its subjectivity. For this reason, for example, the ISO provides no examples of weighting. Despite the weight assessment being necessary in a lot of aggregation operators, different approaches have been proposed in the specific literature in order to avoid excessive arbitrariness in this so difficult issue, but also taking appropriately into account the subjective preferences of the decision-maker. LCIA results for each process of the life cycle have then to be aggregated in order to get reliable conclusions and this aggregation framework has to minimize the information loss and the compensation between impacts and to reduce the amount of data in order to improve the intelligibility of results. The impact results of each scenario cannot be easily compared with each other and impacts cannot be aggregated as they represent very different realities.

2. Functional approaches

This method selects a suitable aggregation function, i.e. a real value function (utility or value function) associating to each alternative a real number, representing its degree of preference, that allows us to directly make comparisons and obtain the final recommendation.

The main features of this approach are the following: inter-criteria information as trade-off weights (substitution rates), usually constant; compensatory logic (only sometimes not perfectly compensatory). Formally, the utility function is expressed as $U(a) = U(g_1(a), g_2(a), ..., g_m(a)), \forall a \in A$, where U is a function of m variables, increasing in all its argument (marginal utilities. and the st of feasible alternatives.

4.1. Additive models

The simplest form of such a utility function is the additive representation, that is

$$U(a) = \sum_{j \in G} v_j(g_j(a)) ,$$

where, for each, $j \in G$, v_j is a non decreasing function and $v_j(g_j(a))$ is the marginal utility. But, as we said before, this kind of representation is based on the hypothesis of preference independence, that is no interaction among criteria, usually non realistic particularly in environmental impact analysis.

Very often, a particular case of utility function is considered, by the hypothesis $v_j(g_j(a)) = \lambda_j g_j(a)$, where $\lambda_j \geq 0$, for each $j \in G$; is the (constant) trade off weight, used also to normalize the evaluations on different criteria. Therefore, we obtain the weighted sum utility function,

$$U(a) = \sum_{j \in G} \lambda_j g_j(a) ,$$

That is one of the most elementary aggregation operators, as above recalled, that requires the elicitation of a set of trade-off weights. This very simple approach is used in a lot of real life applications, such as in LCIA.

2.2. Non additive models

There are also some non additive utility functions, for example in the form of multiplicative or polynomial functions. Apart from them, one of the most interesting approaches is given by the class of non-additive integrals, also called fuzzy integrals. In this approach, the main very interesting idea concerning weighting is that the intrinsic importance of criteria is represented giving a weight to each subset of criteria from ***G***. Then it is possible to explicitly represent the importance of each coalition of criteria, and therefore also their interactions.

3.3. The Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) structures the decision problem into levels which correspond to DM's understanding of the situation: objectives, criteria, sub-criteria and alternatives; by breaking the problem at hand into different levels, the DM can focus on smaller sets of decisions. This method (Saaty 2008) is based on four main axioms: given any alternatives, the DM is able to provide a pairwise comparison of these alternatives with respect to any criterion on a ratio scale, which is reciprocal; when comparing any two alternatives, the DM never judges one to be infinitely better than another for any criterion; one can formulate the decision problem as a hierarchy; all criteria and alternatives which impact one decision problem are represented in the hierarchy. After estimating the weights, the DM is also provided with a measure of the inconsistency of the given pairwise comparisons. It is important to note that the AHP does not require decision makers to be consistent in giving preference information, but rather provides a measure of inconsistency, as well as a method to reduce this measure if it is deemed to be too high. After generating a set of weights for each alternative and for any criterion, the overall priority of the alternative is computed by means of a linear, additive function. The AHP is a very widespread approach in many real-world applications and it explicitly deals with the issue of hierarchy in decision problems. AHP can be considered a particular case of multi-attribute value functions approach, thus being completely compensatory in nature. This implies that the weights derived in an AHP framework are always in the form of trade-offs and never of importance coefficients.

4. Relational approach

This approach is characterized by splitting the decision analysis in two steps. In the first one, we build up some outranking relations, making a direct comparison between each pair of alternatives with respect to each criterion, individually considered. The global outranking relations *aSb* means "*a* is as least as good as *b* with respect to all criteria from A". Therefore, in the second step, these relations are exploited in order to obtain the final recommendation. The main features of this approach are the following.

Building of crisp or fuzzy outranking relations and their exploitation; infra-criteria information by the introduction of suitable thresholds to take into consideration interval indifference and preference, incomparability and veto situations; inter-criteria information in the form of importance weights; logic usually locally non-compensatory. The outranking relation , *aSb* holds if and only if there are enough arguments to say that *a* is at least as good as *b*, while no reason to refute this statement exists (Roy 1985). The final recommendation depends on the global outranking relation, and not directly on the alternatives evaluations with respect to each considered criterion. The preference model of this approach is very rich, but it requires the elicitation of a lot of

parameters, including importance weights, that express the intrinsic relative importance of each criterion or coalition of criteria, that then do not depend on the different scales of measurement. These weights have a crucial role in the building of the outranking relations.
The most important outranking methods are the following.

4.1 ELECTRE methods

The family of ELECTRE methods (Roy 1995., Figueira, et al. 2005), is based on the concept of concordance and discordance analysis, and each one is devoted to solving specific decisional problems; ELECTRE I for choice problems, ELECTRE II and III for ranking problems, respectively building "nested" ranking (i.e. with different strength) and fuzzy outranking relations; ELECTRE IV that does not require elicitation of importance weights; ELECTRE TRI for sorting problems. The outranking relations are built taking into consideration the importance of criteria coalition (i.e. their weights) supporting the idea that *a* is at least as good as *b* (concordance test) and that there is no strong opposition to this sentence (non-discordance test). A problem specifically connected with the outranking approach is that it is necessary to assess a large number of ad hoc parameters, i.e. indifference and thresholds, concordance threshold, discordance thresholds and weights and this may cause loss of transparency and consistency in the model (Norese M.F., 2006).

4.2 PROMETHEE

In the PROMETHEE methods (Brans 1982), for each criterion $g_j \in G$ and for each pair of alternatives (a,b) a degree of preference $P_j(a,b) \in [0,1]$ is defined as a non decreasing function of the difference of evaluations $g_j(a)$ - $g_j(b)$. The shape of this function and the value of its parameters are chosen by the DM among some predefined types.

Using the notation k_j for the weight of criterion g_j, the global preference degree $\pi(a,b)$ is defined as

$$\pi(a,b) = \frac{\sum_{j \in \boldsymbol{F}} k_j \cdot P_j(a,b)}{\sum_{j \in \boldsymbol{F}} k_j} .$$

The final recommendation (ranking) is based on the concept of outgoing ϕ+ flow and ingoing flow ϕ^-, defined as following for each feasible alternative *a*:

$$\phi+(a) = \sum_{b \in \boldsymbol{A}} \pi(a,b)$$

$$\phi-(a) = \sum_{b \in \boldsymbol{A}} \pi(b,a) .$$

PROMETHEE I method gives us a partial preorder of feasible alternatives, (that means that incomparability between alternatives is allowed) as the intersection between the complete ascending preorder and complete descending preorder, built up respectively using the values of ϕ+(a) and ϕ-(a) (Brans and Vincke 1985).

PROMETHEE II method proposes the building of a complete preorder of feasible alternatives, taking into consideration the so called net flow ((Brans 1982, Oberschimidt J. et al., 2010):

$$\phi(a) = \phi^+(a)-\phi^-(a).$$

The PROMETHEE approach is based on a simple mathematical structure and is easy to use. In this model, preference intensity can be used, and the degree of compensability allowed is high. Moreover, weights cannot be considered as importance coefficients, but they should be derived as trade-offs. The possibility of rank reversals is high (Munda G.2008).

4.3 REGIME

REGIME Analysis is a method that considers pure ordinal information, and could be considered as the ordinal generalization of the concordance methods (Hinloopen and Nijkamp, 1986; Hinloopen, Nijkamp and Rietveld, 1983). The main idea is the concordance index Cil concerning the pair of feasible alternatives *a*i, *a*l :

$$\text{Cil} = \sum_{j \in \Gamma_{il}} w_j ,$$

where wj is the importance weight of criterion gj, j=1, 2,…,*m*, and □ il, is the subset of criteria for which ai is at least as good as al., The method considers only the sign of the difference Cil – Cli for each pair of alternatives, and not its value, since the data are ordinal. In this method, the first step is the construction of the so-called impact matrix, composed of the pairwise comparisons of alternatives, that is then suitably exploited. This method presents the advantage of taking into account ordinal information. It should be recalled that weights can also be simply ordinal in nature, and therefore from this point of view REGIME can be considered entirely consistent in its use of weights as importance coefficients. The only assumption required is that of a uniform distribution of the weights along the concordance region, that is not restrictive. However, when mixed information on criterion scores is present, the aggregation procedure becomes cumbersome. To deal with both qualitative and quantitative information, it is assumed that qualitative information is the representation of unknown quantitative information. Building on this assumption, a cardinalization scheme is applied and then all the ordinal information is transformed into quantitative. Besides considerations on the way, there is here a basic methodological problem with weights. In fact, if weights are connected to quantitative information and the intensity of preference concept is used, weights can only be trade-off and not importance coefficients.

4.4 NAIADE

NAIADE (Novel Approach to Imprecise Assessment and Decision Environments) (Munda 1995) is a discrete multi-criteria method whose impact matrix may include crisp, stochastic or fuzzy measurements of the performance of an alternative with respect to an evaluation criterion, thus it is very flexible for real world environmental applications. A peculiarity of NAIADE is the use of conflict analysis procedures to be integrated with the multi-criteria results. This method can give the following information: Ranking of the alternative according to the set of evaluation criteria; indications of the distance of the positions of the various interest groups; ranking of the alternatives according to actors' impacts or preferences. The whole NAIADE procedure can be divided into four main steps: pairwise comparison of alternatives according to each criterion; aggregation of all criteria; ranking of alternatives; social conflict analysis. This method presents many advantages: the possibility of taking into account various forms of mixed information in an equivalent way; the possibility of determining the degree of compensability allowed in the aggregation procedure; the explicit use of a conflict analysis procedure, thus distinguishing clearly the technical and social compromise solutions. However, this method suffers also from some serious limitations: the impossibility of using weights explicitly and, if they are used, they could only be trade-offs and never importance coefficients; the large number of ad hoc parameters needed for the elaboration of the multi-criteria impact matrix; the fact that qualitative information can be used only in the form of linguistic variables and can never be measured on a purely ordinal scale.

5. Interactive approach

It consists of a systematic exchange of information between DM and analyst about local preference evaluations of alternatives and about the consequent computation results, with the aim of searching for a solution (descriptive logic – MCDM), or for the comprehension of a coherent evolution of the decision process (constructive approach – MCDA). In the first step this approach requires a minimum number of inter-criteria information, such as trade-off weights, given by the DM.

The analyst provides a first alternative (or a first set of alternatives) to propose to DM, who, during the discussion phase, gives the analyst further information about his/her preferences. Therefore there is a new computation phase and so on. The procedure stops when the DM is satisfied by the alternative proposed, which is not always necessarily efficient.

A lot of interactive methods use the idea of a reference point, defined in the criteria space, and sometimes that particular of an ideal point, whose coordinates are usually the maximal values attainable by each criterion considered as a single one. There are two main categories of interactive methods: those that are based on the hypothesis of the existence of a utility function, implicit in the mind of DM, and methods that try to minimize a particular distance from a reference point. Among them we recall the Goal Programming and the STEM method (Benayoun,et al., 1971).Usually in this case some information about trade-off weights are explicitly or implicitly required, as well as the normalization of alternatives evaluations. Recently, very interesting approaches have been proposed in this framework, combining the advantages of interactive methods and genetic algorithms.

Conclusions

The interpretation of the LCA results in environmental problems and analyses should be actually aided by the application of MCDA methods, appropriate from the methodological point of view to the specific decision problem at hand. Decision analysis is a set of methods of systems analysis and operations research, going from the classical mathematical programming to the new MCDM and MCDA approaches, which should be extensively applied in supporting real life decisions in the presence of a number of conflicting points of view. In the LCA literature, decision analysis methods are often known and used, up to now, as tools for the weighting phase of LCIA, especially in the context of panel methods in which opinions about impact category weights are asked for from an individual person or a group of persons. However, the use of decision analysis tools has not been very common in LCIA applications.

This is partly due to the fact that LCA practitioners have been reluctant to use weightings, as a consequence of their subjectivity and difficulty in their assessment. But weighting is only an optional phase in the ISO standards due to its subjective results, and in the development of LCIA methodology during the recent years researchers have overall concentrated on the mandatory phases. Only very few analyses have been conducted using more sophisticated approaches, such as MCDA methods. Possibly, one of the main reasons for this behaviour is that only a few LCA researchers have enough information to use these kinds of decision analysis tools for weighting purposes in a context different from assessment of trade-offs.

Therefore, our main attention should be drawn not to the weighting problem in se, but to all decisional processes, with a clear idea of the different roles of all the actors (scientists, experts, decision-makers, stakeholders) involved in the process. Decision analysis is actually a process, with its own dynamic evolution, that has to be coherent with the preferences and the goals of the decision-maker. In order to support the decision-maker in his/her difficult activity, a multi-criteria approach could be very useful, but the particular method to be used must be correctly chosen and applied. This means, in particular, that the method we like to apply needs to be appropriate not only to the multi-criteria decision problem at hand (choice, ranking, classification, sorting), but also to the particular kind of data and information we have (cardinal, ordinal, qualitative, crisp, fuzzy, probabilistic,...).

Any MCDA method, on the other hand, as observed before, requires some peculiar preference information and technical parameters, among those very often weighting, in the form of trade-offs or importance coefficients. Only few, but very interesting approaches, do not require a priori this kind of information, that sometimes is given implicitly by the decision-maker, as in interactive approaches, or is obtained as output when we use preference information in the form of examples of decision, like in the dominance-based rough set approach. In any case, the choice of an MCDA method has to take into serious consideration the actual information DM can, wants and is able to give, avoiding forcing him/her to provide technical information required by the method, but that DM does not know or cannot give, often also too difficult or not understandable. It is the method that must be suitable and appropriate to the available information, not the information that has to be adapted or forced in order to be used in any case in an approach chosen a priori.

The interpretation of LCA results could be greatly improved by the use of suitable aggregation approaches based on MCDA proper methods, based on a functional or relational approach or on interaction between scientist and DM.

As a more general conclusion, we would suggest that uncertainty management and quantitative analysis has to be further addressed in the development and application of MCDA methods, because uncertainty is also a primordial factor in decision making, and not only in the environmental field.

Alternatives approaches to LCA modelling may also be useful, as well as some additional areas where further sensitivity and robustness analysis could improve presentation of results; MCDA methods allow very well for sensitivity analysis, a technique in which a variable is systematically modified to determine the impact on the outcome. In this case, we are particularly interested in modifying the weights assigned to various criteria. Of course, other standardisation of LCA studied should be improved, from a perspective of both transparency as well as comprehensiveness of LCA modelling.

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