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A method for choosing adapted life cycle assessment indicators as a driver of environmental learning: a French textile case study

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Abstract

Despite alefforts for a sustainable production system, many companies are still struggling to implement environmental aspects in their daily product development processes. Among the evaluation and improvement methods, life cycle assessment (LCA) is one of the most popular tools to achieve this goal. Up to date, LCA has been applied to many products, services, and industrial systems to evaluate their environmental impact aspects. However, there is a wide range of indicators available to be applied for LCA, and choosing an inappropriate indicator may lead the product designer to achieve wrong and weak results. Therefore, this paper proposes to overcome this difficulty by developing a method that can be used as a knowledge transfer to product designers and LCA practitioners in order to help them to make the most appropriate choice of LCA indicators. This method should have some characteristics, such as (a) to be adaptable to a given context and (b) to be dynamic, scalable, and easy to learn. The purpose of this paper is to present the Evaluation Method for Choosing Indicator (EMCI) developed to facilitate the learning process of LCA methods and to quickly select their most appropriate indicators. To validate the EMCI method, a case study on a French textile industry has been implemented. The focus was to evaluate how LCA indicators and methods were chosen to be integrated into the suitable eco-design LCA tool.

Introduction

The integration of eco-design into products and/or services is a collaborative process involving multidisciplinary skills and it is based on continuous environmental knowledge and learning improvement. In addition, it requires, among other things, changing attitudes, governance, new ways of management and organization, the involvement of players in the value chain, as well as at the core of the product development process (Johansson, 2002; Donnelly *et al.*, 2006).

In fact, companies are still unfamiliar with the environmental dimension (Bovea and Perz-Belis, 2012; Deutz *et al.*, 2013). Deutz *et al.* (2013) argue that there is still a gap between theory and operational implementation of eco-design in business even though publications related to eco-design tools and methods continue to rise (Rio *et al.*, 2013; Rossi *et al.*, 2016). In the literary review conducted by Rossi *et al.* (2016), it appears that despite the existence of a large variety of tools and methods available, companies are still having “difficulties in its implementation as well as in its practical and efficient use.”

Based on the literature, it seems that eco-design methods and tools are still needed for more improvements (Millet, 2003; Luttropp and Lagerstedt, 2006; Ramani *et al.*, 2010). Most of them are inadequate to attend to the needs of various industrial contexts. Tools and methods considered to be “universal” often require a lot of time and resources to be adapted to the needs of business and its users. These drawbacks may justify the difficulties faced by designers to implement these tools and methods in their daily work (Le Pochat *et al.*, 2007).

Lofthouse (2006) raises the fact that many product designers do not consider having the right tools adapted to their needs and that therefore they do not know how to drive an eco-design project. In fact, a study carried out by Rossi *et al.* (2016) also demonstrates the need to provide industry with tools and methods appropriate to their own context. In addition, they argue that these tools and methods must be applied within a collaborative work environment on which various actors of the design process may exchange their knowledge among themselves as well as provide suitable information along the entire value chain (Rossi *et al.*, 2016).

As a consequence, the first research question that motivates this research work is how to promote the dissemination of environmental knowledge for choosing adapted life cycle assessment (LCA) indicators across the entire value chain of an industry.

It is well known that the textile industry (target industry of this study) is largely responsible for the environmental impacts (Tukker *et al.*, 2006). Therefore, LCA could be an important tool to help this sector to evaluate the environmental impact of their products and process. However, its supply chain seems to be very complex. The reason for that is because this type of industry has a large variety of raw materials and processes used as well as a long sequence of many processing steps (Saxcé *et al.*, 2011). Each type of manufacturing processes requires different types of input, machinery used, specific treatment protocol, and processing time as well as different types of outputs and their treatment (e.g. water emissions or wastes). As a consequence, the impact indicators may vary according to the choice of raw materials and the processes used. In addition, the textile industry is geographically dispersed which also contributes to choose the most appropriate impact indicator (Saxcé *et al.*, 2011). Moreover, some environmental aspects such as regulations, market incentives (e.g., tax reduction), and customer demands may be considered "moderate" for the French textile industry when compared to other industrial sectors.

For these reasons, the selection of the most appropriate indicator turns even difficult. Therefore, the second question raised is how to provide a method for choosing LCA indicators applied to the needs of the French textile industry. As a consequence, there is a need to create a method which is able to help practitioners in the selection of impact categories for a particular application as well as their associated indicators. This method should be able to clarify the uncertainties (Laurin *et al.*, 2016), specifically those related to the textile industry. The aim of the paper is to enrich life cycle assessment (LCA) knowledge based on choosing the most appropriate indicators to an LCA savvy practitioner, on the context of the long-term perspective of eco-design.

The hypothesis of the paper is that by identifying the indicators adapted to a given context, it is believed that this could be used as a vector of continuous skills improvement among LCA practitioners involved in the production and service processes of a given economic sector (e.g., the textile industry).

The originality of this research is based on turning complex tools into more effective ones in such a way that they may be able to stimulate collaborative work and to exchange data in a simplified manner among savvy LCA practitioners who are closely related to the textile production chain.

This paper is divided into three major sections. The first section is dedicated to present a literature review on LCA. This section presents how LCA is structured, its drawbacks and limitations as well as the difficulties in choosing the appropriate LCA indicators, and also indicates the research objectives. The second section presents the Evaluation Method for Choosing Indicator (EMCI) as it may be built and be applied by the practitioner. In addition, the assumptions used to build the methodology are described. Finally, the case study will focus on the use of EMCI to choose the most suitable indicators to integrate them on an environmental assessment tool adapted to the specificities of the French textile industry.

LCA and its constraints

History of LCA

According to Guinée (2016) the first studies on LCAs date from the late 1960s and early 1970s. He also points out that studies were carried out by the Midwest Research Institute (MRI) for the Coca Cola Company in 1969 and in Europe by Sundström and by Basler and Hofman in 1971 and 1974, respectively. In addition, Guinée indicates that the period 1970–1990 comprised two decades of the conception of LCA with widely diverging approaches, terminologies, and results. He mentions that during the 1990s there was a remarkable growth of scientific and coordination activities worldwide reflecting on a great number of LCA guides and handbooks produced.

Furthermore, he also stresses that during the period of 1990–2000 there was convergence and harmonization of methods based on SETAC's coordination and ISO's standardization activities, providing a standardized framework and terminology, and platforms for debate and harmonization of LCA methods.

According to him, this helped LCA to become part of policy documents and legislation. It is also the period in which industrial ecology (IE) emerged, with life cycle thinking and LCA as one of its key tools.

Moreover, Guinée (2016) stresses that at the beginning of the twenty-first century there has been an ever-increasing attention to LCA resulting in new textbooks and its use as a tool for supporting policies and performance-based regulation (mainly on bioenergy). In addition, life cycle-based carbon footprint standards were established worldwide and LCA methods were elaborated in further detail. Furthermore, he points out that new approaches were proposed and/or developed such as consequential LCA, dynamic LCA, spatially differentiated LCA, environmental input–output-based LCA, life cycle costing, and social life cycle assessment. All of these recent developments have helped to broaden LCA from a simply environmental vision to a wider sustainable perspective.

Presentation of LCA

LCA is a methodology focused on the product (good or service) as well as the process that enables potential environmental impacts to be assessed over the full length of the product life cycle. The rules and requirements associated with LCA are defined by ISO Standards 14040 and 14044. The ISO Standard 14040 structure LCA into four essential stages: (1) goal and scope definition, (2) inventory analysis (LCI), (3) impact assessment [Life Cycle Impact Assessment (LCIA)], and (4) interpretation.

This paper is focused on stage 3, impact assessment, a crucial stage of the LCA, and it is when the assumptions made will directly affect areas of uncertainty and results, then influencing design decisions. The terminology employed in this paper is based on the *International Reference Life Cycle Data System (ILCD) Handbook* (European Commission, 2011).

The LCIA methodology designates a collection of individual characterization (or calculation) "models" or "methods" used in a combination to examine the different impact categories to which the methodology applies. A "method" is an individual characterization model, whereas the methodology is the collection of methods.

There are a great number of different methodologies used to carry out impact assessment such as CML (Guinée *et al.*, 2002), TRACI (Bare *et al.*, 2002), EDIP (Hauschild and Potting, 2005; Potting and Hauschild, 2005), ReCiPe (Goedkoop *et al.*, 2013), and LC-IMPACT (Curran *et al.*, 2011). Each one of them uses its own set of indicators that differ according to the measurement approach or the model of the environmental mechanism. In addition, the methods themselves are still under continuous development and improvement (Finnveden *et al.*, 2009).

As a result, there are a large number of methods currently in use, each one of them suggesting different indicators for each impact categories. Therefore, engineers, researchers, and designers who have little experience of using LCA have difficulties in choosing the most appropriate indicators that will enable them to better assess their products. Choosing an inappropriate indicator and/or method may lead them to an incomplete assessment and a decision which may be opposite to the initial environmental goals. For this reason, by designing a tool for a given context, it is important to choose the most appropriate indicators. As a consequence, this paper aims to facilitate the use of LCA in industry, in particular in the textile sector, suggesting a methodology that will allow the selection of characterization models of impact categories' indicators appropriate to the sector concerned.

From the operational point of view, the EMCI described in this work helps the user to select the most appropriate LCA indicators for their project. From the scientific point of view, the use of this method is used to enrich knowledge of the environmental expert.

EMCI is an interactive method in which the user is led to evolve the available tools according to their feedback. Its three stages are described so as to be usable by the user. Results were obtained by using EMCI to choose the appropriate indicators to integrate into the simplified environmental assessment software for the textile sector's (*Teksajo*) development.

Therefore, EMCI is a methodology that addresses everyone who is conducting an LCA, more precisely, the savvy practitioner or those who will be in charge of developing a customized tool to a sector or a particular context. Briefly, it is a tool for selecting customized LCA indicators and improves knowledge about the evolution of LCIA methods destined to the savvy practitioners.

Barriers for adopting LCA

Many barriers have been suggested for the implementation of LCA in practice. For instance, D'Incognito *et al.* (2015) suggest that organizational culture is the most relevant barrier to adopt LCA.

In addition, the literature review (Curran, 2013) also points out that it is still not clear what LCA can and cannot do, and how it fits within a strategic level approach to sustainability once it leaves much to interpretation by the practitioner.

Lack of readily available inventory data, uncertainty due to the variability of the inventory data, and the impact assessment indicators were also mentioned and all of them have a great impact on how the results of the LCA are used during the decision-making process within an organization (Curran, 2013).

Limitations of LCA

Finnveden has pointed out that no conclusions can be drawn from an LCA study concerning the overall preference from an environmental impact perspective of one choice over another because not all environmental aspects have been included. Therefore, the conclusions must be limited to the aspects studied (Finnveden, 2000).

Above all, Finnveden argues that it is not be possible to show that one product is environmentally preferable to another. As a consequence, no action will ever take place if the regulatory policy or international agreements require proving this. Finnveden finishes concluding that LCA is used as a "defensive" and "conservative" tool. This means that if a product, material, or policy is questionable, an LCA study may bring more confusion to the debate, once it is not possible to determine which one is preferable (Finnveden, 2000).

Testa *et al.* (2016) present the difference between practitioners and no-practitioners of LCA. They argue that, on average, these two groups of respondents believe that the difficulties are considered as more important than the benefits and that no adopters tend to overestimate the difficulties and underestimate the benefits associated with the implementation of LCA.

Difficulties in choosing the appropriate LCA indicators

Developed in the 1980s, LCA is an environmental assessment tool which has made improvements over the years. Its use is spreading internally within companies as an eco-design tool, as well at the institutional level, as a reference tool.

Thus, users of the LCA are not necessarily specialists. The development of a simplified version of LCA software, which is less complete but more accessible promotes the use of this tool by new practitioners. In addition, the ISO Standard 14040 guidance on selecting impact categories is insufficient for many applications (Laurin *et al.*, 2016).

Nowadays, there is an attempt to make LCA a more popular tool in order to allow a non-expert user to conduct a qualified assessment. This is the work publications and platform produced by the Joint Research Center (JRC) (http://eplca.jrc.ec.europa.eu/). In fact, this paper considers that there are four levels of LCA experts: (1) LCA expert who develops models, methods, indicators, and tools; (2) the Analyst, whose main activity is the LCA models (is a regular practitioner and user of the LCA); (3) the savvy experts who will perform LCAs to integrate result in a specific function and whom LCA is not the main activity (e.g., Ecodesigner, recycler); and (4) the non-expert beginner.

For savvy experts, some choices on LCA modeling are made based on the availability of LCIA method information, the time available to conduct the project, and the complexity of the LCIA methods themselves. Subjective choices can, therefore, be made based on so-called partial information and this can influence the results. The knowledge developed by multidisciplinary expertise at the level of the think tanks (SETAC, standardization, JRC, etc.) is insufficiently popularized to encourage their appropriation by these savvy practitioners.

This is the research area in which this research work arises. In fact, among the different steps of LCA, the user remains fairly guided in the selection of indicators (impact categories and calculation methods).

This step is important but complex. It is important because it is known that the appropriate choice of indicators and impacts categories affect the results (Dreyer *et al.*, 2003). This occurs because (a) the models used are different; (b) the characterization factors are different; (c) the substances considered are different; and (d) indicators (reference material and unit) are different. The kind of approach, midpoint, or endpoint does not lead to the same results (Bare *et al.*, 2000).

However, the understanding of the differences between these methods makes it difficult due to the complexity of their content. The scientific relevance of a method is difficult to estimate and recognition by the scientific community is not unanimous.

Moreover, since the creation of the LCA, evaluation methods have changed regularly. One can reference now more than 15 methodologies to assess the environmental impact based on the

LCA methodology as well as 20 impact categories (European Commission, 2010).

All of these factors contribute that the users choose their indicators based on their intuition which increases the risk of errors and adverse effects on the final results. It is necessary to drive the users in their reflection by informing and guiding them.

Our research work has been important even before the publication of the handbook of the JRC. In fact, it was observed that this handbook lacks a strong general chapter on the choice of indicators. In addition, the JRC publication does not present any special chapter related to one or more sectors of activity or type of study (with the exception of methodologies developed for one domain such as the Building Environmental Economic Sustainability – BEES (https://www.nist.gov/services-resources/software/bees) which is more related to the construction sector.

The methodology presented in this paper proposes to help savvy practitioners in their work of choosing the appropriate indicator based on two steps while stimulating continuous learning. Firstly, by the intermediation of a savvy practitioner who knows and understands the methodologies very well. In the second step, these savvy practitioners will be able to help to choose the most appropriate indicators for each one of their projects (depending on the specific context). The implementation of the method allows also to disseminate environmental knowledge to the stakeholders involved in each project by developing a common vision and language.

General presentation of the EMCI

The EMCI is intended to be used in the selection of indicators for conducting LCA studies or for the selection of indicators during the development of simplified implementation LCA tools (e.g. software). It is applied regardless of the objective of the assessment (e.g., adapted to a component, a product, a range of product, industry, and so on). For the purpose of this paper, all cases studies applying this methodology will be classified as a "project" or "LCA project."

Potential practitioners are those who are likely to choose indicators while carrying out an LCA or developing a simplified LCA tool.

Theoretical framework

Based on all indicators (from different methods, for each category impact), the user will make a selection of indicators adapted to its project following the three main stages of EMCI (Fig. 1). These are:

- Stage I: Assessment and screening of methods of calculation for all sector combined.

This stage I allows the most appropriate method of characterization for each impact category to be selected without reference to the context. This stage I implies:

- **a**: to become aware of the consensual indicators,
- **b**: to facilitate the knowledge transfer on methods by using the help of a table of information based on a pattern of methods.

- Stage II: specific analysis for the project.

The practitioners are guided to evaluate the context and analyse the recommendations of indicators tailored to their project. This stage II involves the following actions:

- **c**: technical characterization of the project using the project characterization sheet.

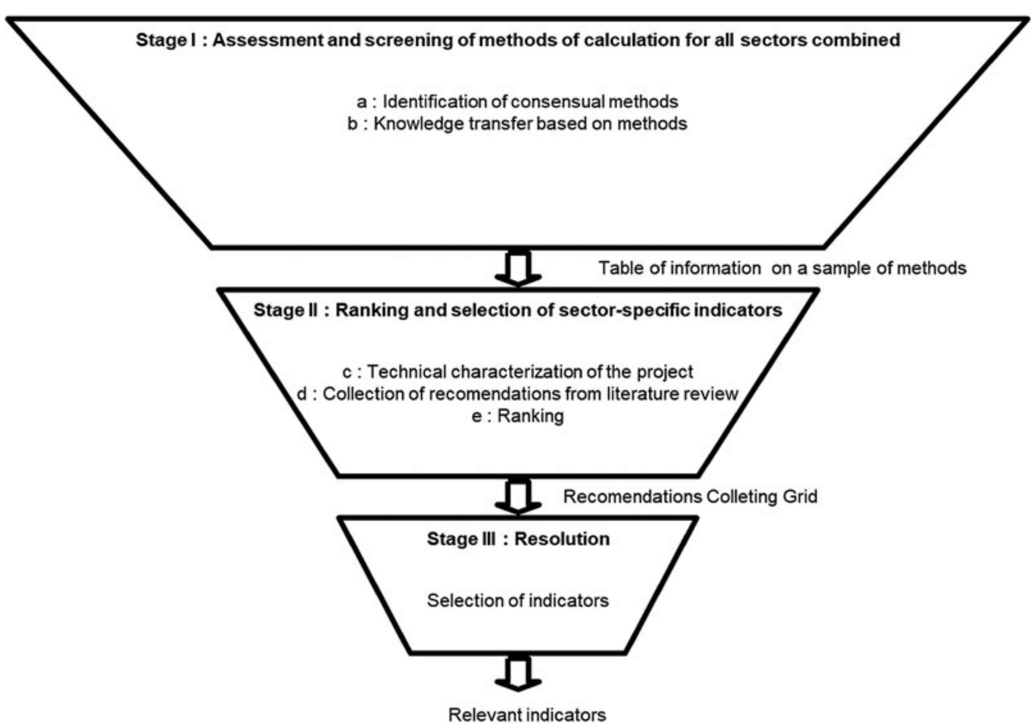


Fig. 1. EMCI diagram.

- **d**: collecting recommendations from a literature review. The literature review is based on the technical characterization of the project. It helps to identify and organize the recommendations in the collection sheet.
- **e**: ranking the recommendations collected using the help of a weighting tool.

• Stage III: resolution

The practitioners read the recommendations and choose the indicators using the expertise gained with the method.

EMCI is designed to be suitable for a large number of projects. Each study is unique. The user is led, in the second stage, to evolve the tools of the method to adapt to his project.

Detailed presentation of the method

• Stage I: assessment and screening of methods of calculation for all sectors combined

This first stage does not involve the selection of impact categories but aims to identify the best characterization models available for each impact category. This is a two-stage operation, as shown in Figure 1.

a. Identification of consensual methods

This action involves the selection of methods of calculation whose use in the relevant category is “consensus-based” and the scientific community does not currently envisage any alternatives. The most obvious example is the climate change indicator. The scientifically recognized reference method on this subject is the one published by the United Nations Environment Programme’s Intergovernmental Panel on Climate Change. It aims to evaluate the potential contribution of individual substances to the increase in the greenhouse effect using the GWP (global warming potential) index. The indicator used to assess ozone layer depletion is also consensual as far as the international scientific community is concerned. Most methodologies use the World Meteorological Organisation’s (WMO) model of ozone depletion potential (ODP).
So, there are two categories of impact for which indicators are consensus within the community of LCA and recommended internationally by the ILCD Handbook (European Commission, 2011).

- For the climate change, the evaluation model used is developed by the International Panel on Climate Change (IPCC) which provides the Global Warming Potential for 100 years (GWP100) from all types of greenhouse gases. Nowadays, this impact category will be chosen in the great majority of the cases.
- Concerning the depletion of the ozone layer, one will base the analysis on the model developed by the World Meteorological Organization. The characterization factors provided are the ODPs. This impact category is less likely to be susceptible to being chosen. It is based on the EMCI LCIA that the decision will be taken.

Assessment of “non-consensual methods”: The impact categories for which no consensual indicator has been identified are dealt with at this second stage. It involves comparing the characterization models with one another and assessing them on the basis of criteria listed below. In some impact categories, an indicator will have a significantly higher assessment and is liable to be recommended irrespective of the sector. In other impact categories, indicators with a significantly lower rating than the rest will be eliminated because they are not going to be recommended for any sector. The remaining indicators may, however, be suitable for one or more sectors and will be considered in the second stage.

b. Knowledge transfer based on methods

The practitioner acquires knowledge from table 1 of information with the recommendations of the handbook of the Joint Research Centre entitled “Recommendations for Life Cycle Impact Assessment in the European context” (European Commission, 2011). Table 1 of this report proposes a collection of methods which provide to the non-experienced practitioner technical information collected and interpreted by savvy practitioners. Those non-experienced practitioners who wish to get more details on this technical information may refer to the JRC Handbook (European Commission, 2011).

Firstly, for this stage, it was intended to guide the practitioner to the recommendations from the JRC. However, these were not yet available during the project which led us to the creation of a matrix. It turns out that this table will be a much more easy entry for the non-expert practitioner than using the JRC handbook whose recommendations are aimed primarily to the more experienced practitioner.

Initially, nine categories of impact were selected to form this table. They correspond to the categories of impact proposed by the JCR Handbook. The table excludes two categories: ionizing because its application is irrelevant for the textile industry and respiratory effects because there is no much information on it. In addition, categories such as climate change and ozone depletion have a model recognized internationally, which is used by all methodologies. Therefore, they were removed from this evaluation.

The selection of five methods of calculation allows us the comparison of a wide range of methods largely recognized (CML, TRACI, EDIP) with other newest methods (ReCiPe, USEtox). The geographical scope is also large (Europe, North America, and world). CML and USEtox have a global vision of the impacts. TRACI is specific to North America, while IDP and ReCiPe are more applicable to Europe.

This is not an exhaustive selection. Other methods widely used could also be incorporated in this table. That is the reason why an update of the table after the publication of the results from JRC may include more methods.

In order to format this table, a range of criteria was initially selected based on issues identified from an extended literature review. Then, discussions with savvy practitioners in LCA as well as non-expert practitioners and information available from methods of calculation were used to refine this selection. More precisely, these discussions were based on two questionnaires which were developed to conduct the discussion. The purpose of these surveys was, among other things, to identify the criteria that are used by these experts while selecting one or more impact assessment methods and impact categories when performing an LCA. The first questionnaire included three open-ended questions and it was sent to a small group of 15 experts from Quebec and France, targeted according to their LCA experience and knowledge. The second survey consisted of 14 questions (five open and nine closed). This questionnaire made it possible to obtain a much larger and international sample than the first questionnaire, given that it was deposited on the *LCA List* (mail list from PRé-consultant). A compilation of all the answers obtained for the two questionnaires allowed defining a list of recurrent criteria used by the LCA experts and practitioners when they choose a method (s) of impact assessment impacts or categories impact. This list served as the input to select the eight evaluation criteria for the table. Once the evaluation criteria were determined, they were forwarded to the experts who had demonstrated most interest when sending the questionnaire number one, in order to obtain their comments and validate the eight criteria.

As mentioned earlier, the recommendations on the utilization of models and JRC environmental assessment impact factors are the reference for the LCA (Hauschild *et al*., 2013). This is because they are based on collaborative work from international LCA experts, developers of methods who carried out a broad and structured vision which has been validated by industrialists and scientists. The results of this evaluation have been taken as a reference to update the information table in a synthetic manner. In addition, the practitioner is invited to consult this work to get more information on how to choose the most appropriate indicator for his/her application. However, there is a lack of methodology to allow this complex knowledge to be applied to particular contexts and also to a less expert practitioner.

For more information, this first stage is detailed on the report (Thériault, 2011).

The EMCI method is a complementary approach from the JRC studies. It proposes to make the interface between this work and non-experienced LCA practitioners. EMCI helps to guide and stimulate reflections from the practitioners. Note that the first published results are summarized in Hong *et al.* (2010).

- Stage II: Ranking and selection of sector-specific indicators.

This second stage, the ranking and selection of indicators, is a sector-specific approach to the problem. It allows the best indicator for the impact categories for which several potential indicators need to be identified at the end of stage I. More precisely, the second stage is supported by three main activities. A literature matrix is prepared for a particular sector. It uses information obtained from a literature review. The matrix uses diagnostic parameters to translate the constraints and requirements of the project into study conditions. The ranking allows the components of the literature matrix that satisfy the study conditions to be selected as the means of achieving a final result. The diagnostic parameters should be regarded as variables capable of having a finite number of values. They must be capable of representing those conditions and requirements of the project or study that are liable to influence the choice of impact indicators. A survey of a large sample of companies will be carried out in order to identify key parameters – for example, geographical location and type of product are two possible diagnostic parameters. For a given project or a study, each parameter will have a fixed value (e.g., "textile technique" and "Europe"). This set of values will constitute the study conditions for a given study.

c. Technical characterization of the project

In order to have a selection as relevant as possible, it is necessary to know well the study which is going to be carried out and identify the elements which are going to base the choice of indicators.

In order to carry out the study diagnosis, a pre-selection of seven criteria was taken: compliance with regulations, compliance with a label, communicate the results externally, levels of expertise of the future player/operator of the study, geographic scope, target sector, and main impacts generated by the sector/product.

They were considered as influence factors on the selection of indicators and impact categories in most studies. They allow practitioners to ask questions regarding the context of their study, objectives and recipients. They are given as a basis for the user who can choose other criteria.

The practitioner describes his project by completing and enriching the characterization matrix. This form allows the identification of the characteristics of the project which will give conditions to choose the indicators. In others words it is relevant to indicate the study conditions defined by each publication; in other words, the diagnostic parameter values were employed. The diagnostic parameter values are included in the table next to the indicators. It takes the form of a table. It is important to note that the user is allowed to add as many lines as possible to describe the project.

The matrix enables the user to translate the constraints and requirements of the study into a study condition compatible with the ranking. It takes the form of a multiple-choice questionnaire in which each question corresponds to a diagnostic parameter and each of the choices gives a value for the diagnostic parameter (Table 2).

Domain: It suggests different areas that are to be addressed in the project such as *communication of the study* or *context of the implementation of the study*. For instance, customer requirements can be added to these areas.

Criterion: It presents more accurately the criteria on which the project will be described for each area. For instance, in the context area: the *geographical zone* or in the communications area: *compliance with a label.*

Suggestion: In the pre-filled in lines, it gives some suggestions to the practitioner indicating how well he/she can reach the criterion.

Project characteristics: The user must include some characteristics of the project by establishing more details of each criterion chosen. For instance, the name of the label, describe the targets of the study, and so on.

This form is the basis of the collection matrix to be used in the remaining steps.

d. Collection of recommendations from the literature review

Based on the previous steps, the project is well defined which permits to effectively target the documents used in the literature review to collect recommendations on indicators.

In order to facilitate the resolution phase, the impact categories and indicators were separated because they can be considered in parallel. These recommendations are complementary.

The definition of project characteristics established in step ***c*** will allow conducting a literature review to collect recommendations regarding the choice of indicators to be collected in the collection matrix (Table 2).

It is composed of six principal columns:

Domain/Criterion/Characteristic of the project: The first three columns in the collection matrix are listed on the characteristic form.

Suggestion from savvy practitioners: To deliver, recommendations to make the literature review.

Recommendations collected in the literature review: To receive recommendations that the practitioner will find in the literature review. These recommendations can be generic or very specific guidelines. One column is dedicated to *recommendations on impact categories* chosen while others on *indicators (and methods).*

The practitioner searches in the literature review recommendations that will guide him to choose the indicators. These recommendations could be, for instance: "focus on indicators for air pollution" and "use the indicator of eutrophication ReCiPe method." Documents contained in the literature review will be defined by the practitioner. However, it includes standards, regulations, and texts on local and global policies, specific scientific publications some aspects to be diagnosed as well as LCA studies.

Only publications satisfying the specified study conditions are taken into consideration for scoring purposes. The scoring procedure involves tallying the number of times each indicator occurs in the bibliographic matrix. This allows the indicators that are used most frequently in the study conditions to be selected.

e. Ranking

The practitioner evaluates the importance and relevance of the recommendations related to his project. The practitioner also uses a weighting system on three levels to prioritize his recommendations. He attributes himself notes in the columns on the collection matrix (Table 2). This selection is not only based on the free subjective judgment of the practitioner. He also has to consider the criteria suggested by the method, as follows:

– *Level 1* is reserved for recommendations that are strictly and obligatorily as, for instance, regulations.
– *Level 2* is attributed to recommendations which are related to an important issue but it tolerates a slight drift if it conflicts with the recommendation from level 1.
– *Level 3* is applied to recommendations which are related to less important issues.

Ranking of recommendations was established on three levels as it allows quick and easy implementation. Moreover, it was not identified as any additional intermediate level. Deleting a level would make the ranking process simplistic and less effective. On the other hand, adding more levels may complicate the ranking process because the difference between them can become imperceptible. However, if the practitioner believes that his study needs an addition or suppression of levels, he can adapt the ranking system to his/her case.

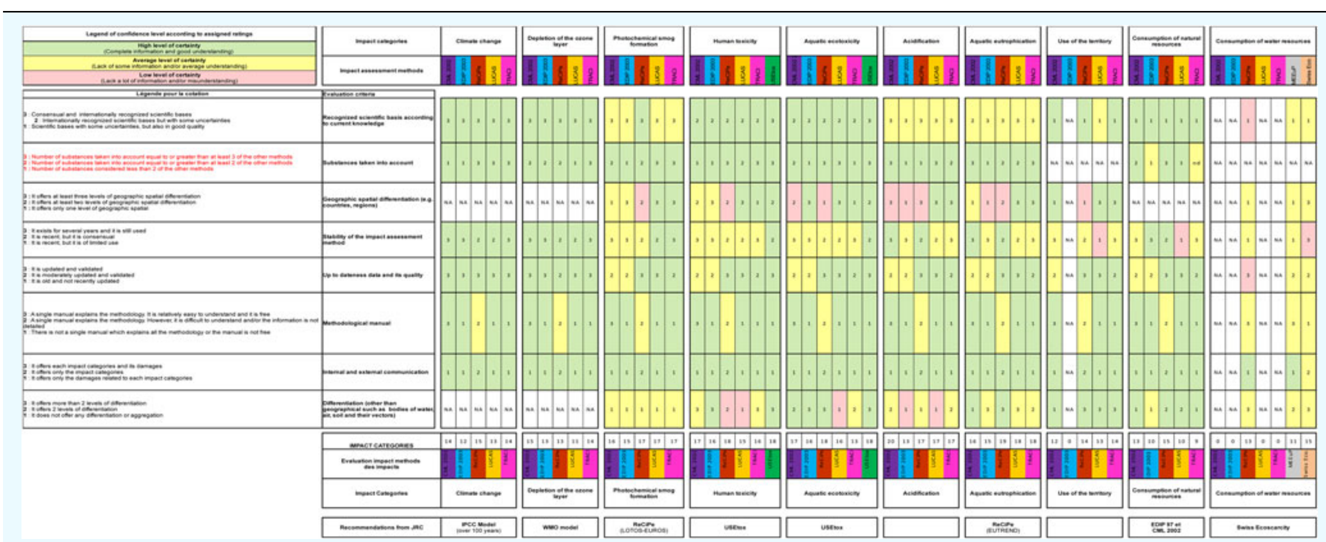
- Stage III: resolution

The resolution stage is deliberately guided summarily because each study is different. The practitioner develops his/her tools throughout EMCI. At this stage, the practitioner has all the relevant information he needs to take a decision. The different stages of the method allow the practitioner to enrich his knowledge on methods and indicators (through the structured analysis of methods, literature, and case studies), allowing him to make objective decisions and having a global vision to a given problem or specific use. The originality of this method lies in the ability of the practitioner to increment this knowledge and to be able to make reasoned choices and/or to exploit information that would make his choices more robust.

The practitioner begins this process by following the recommendations from level 1 and 2 before addressing the recommendations from level of 3. He bases his decisions on the matrix of LCIA methods from step "***b***" to make his final choice (Table 1). The user should not be limited to these methodologies on the information table to make his final choice. This means that the method stimulates a knowledge acquiring process. In other words, different stages of the method allow the user to enrich his knowledge on methods and indicators (either through the structured analysis of methods, literature, and/or case studies). This process also allows him to make objective decisions as well as to have a global vision to a given problem or specific use. Therefore, the originality of this method lies on the user's ability to increment his knowledge acquiring as well as to allow him to make thoughtful choices and/or to exploit information that would make his choices more reliable.

It is possible that there is a conflict for recommendations from the same level. For instance, one may have to decide between two

Table 1. Analysis grid



Legend of confidence level according to assigned ratings
High level of certainty (Complete information and good understanding)
Average level of certainty (Lack of some information and/or average understanding)
Low level of certainty (Lack a lot of information and/or misunderstanding)

Légende pour la cotation	Evaluation criteria
3 : Consensual and internationally recognized scientific bases 2 : Internationally recognized scientific bases but with some uncertainties 1 : Scientific bases with some uncertainties, but also in good quality	Recognized scientific basis according to current knowledge
3 : Number of substances taken into account equal to or greater than at least 3 of the other methods 2 : Number of substances taken into account equal to or greater than at least 2 of the other methods 1 : Number of substances considered less than 2 of the other methods	Substances taken into account
3 : It offers at least three levels of geographic spatial differentiation 2 : It offers at least two levels of geographic spatial differentiation 1 : It offers only one level of geographic spatial	Geographic spatial differentiation (e.g. countries, regions)
3 : It exists for several years and it is still used 2 : It is recent, but it is consensual 1 : It is recent, but it is of limited use	Stability of the impact assessment method
3 : It is updated and validated 2 : It is moderately updated and validated 1 : It is old and not recently updated	Up to dateness data and its quality
3 : A single manual explains the methodology. It is relatively easy to understand and it is free 2 : A single manual explains the methodology. However, it is difficult to understand and/or the information is not detailed 1 : There is not a single manual which explains all the methodology or the manual is not free	Methodological manual
3 : It offers each impact categories and its damages 2 : It offers only the impact categories 1 : It offers only the damages related to each impact categories	Internal and external communication
3 : It offers more than 2 levels of differentiation 2 : It offers 2 levels of differentiation 1 : It does not offer any differentiation or aggregation	Differentiation (other than geographical such as bodies of water, air, soil and their vectors)

Impact Categories	Evaluation impact methods des impacts	IMPACT CATEGORIES	Recommendations from JRC
Climate change	CML 2002, EDIP 2003, ReCiPe, LUCAS, TRACI	14, 12, 15, 13, 14	IPCC Model (over 100 years)
Depletion of the ozone layer	CML 2002, EDIP 2003, ReCiPe, LUCAS, TRACI	15, 13, 13, 11, 14	WMO model
Photochemical smog formation	CML 2002, EDIP 2003, ReCiPe, LUCAS, TRACI	16, 15, 17, 17, 17	ReCiPe (LOTOS-EUROS)
Human toxicity	CML 2002, EDIP 2003, ReCiPe, LUCAS, TRACI, USEtox	17, 16, 18, 15, 16, 18	USEtox
Aquatic ecotoxicity	CML 2002, EDIP 2003, ReCiPe, LUCAS, TRACI, USEtox	17, 16, 18, 16, 13, 18	USEtox
Acidification	CML 2002, EDIP 2003, ReCiPe, LUCAS, TRACI	20, 13, 17, 17, 17	
Aquatic eutrophication	CML 2002, EDIP 2003, ReCiPe, LUCAS, TRACI	16, 15, 19, 18, 18	ReCiPe (EUTREND)
Use of the territory	CML 2002, EDIP 2003, ReCiPe, LUCAS, TRACI	12, 0, 14, 13, 16	
Consumption of natural resources	CML 2002, EDIP 2003, ReCiPe, LUCAS, TRACI	13, 10, 15, 10, 9	EDIP 97 et CML 2002
Consumption of water resources	CML 2002, EDIP 2003, ReCiPe, LUCAS, TRACI, MEEuP, Swiss Eco	0, 0, 13, 0, 0, 11, 15	Swiss Ecoscarcity

different indicators. One is related to the "global warming" and other related to the "eutrophication." As "global warming" is obliged by law and ¨eutrophication¨ is demanded from the customers, the practitioner has to choose the "global warming." In this case, the practitioner should focus on one of the recommendations and abandon another. The practitioner will choose the recommendation that is most related to the criterion and/or to the area that seems to be the most important for the project. He must be aware that the criterion excluded will not be considered. This drift must be acceptable for the objectives of the project.

The resolution is during this last stage that the practitioner will make his final choice. He, in previous stages, has acquired some general knowledge on indicators. Now, he has got a better understanding of the project and could also identify its constraints to select the most appropriate indicator. As a consequence, he is now able to make the final selection.

Case study: choice of indicators to integrate into an eco-design tool for the French textile sector based on LCA

Context of the case study

The experiment was conducted as part of a collaborative project between the University of Technology of Troyes (UTT), TF Création (small textile company), and the French textile and clothing Institute (IFTH) from 2009 to 2012. The project was financially supported by the Champagne – Ardennes Regional Council which aims to develop an eco-design tool dedicated to the textile sector based on LCA, named *Teksajo*. This tool was designed primarily for non-experienced LCA practitioners. For this reason, the indicators are chosen previously and made available in the software. The implementation of the tool phase into the textile sector was conducted between 2013 and 2016.

The aim of the project was to propose an eco-design tool based on LCA. This tool is intended for all stakeholders (novice practitioners) who participate in the entire textile value chain.

The members of the project consisted of two LCA savvy practitioner from the UTT, one from the IFTH, the director of the company TF Création (initiated in LCA), and an IT developer. The functional specifications, the method of construction of the databases, and the methods of choice of the indicators (EMCI) have been developed and coordinated by the UTT. We will only focus on the implementation of the EMCI to choose the indicators.

Experimentation of the EMCI to define the specification of the eco-design tool

EMCI was implemented by a leading savvy practitioner but in strong and regular collaboration with the other two LCA savvy practitioners (UTT and IFTH). In this section, the use of the EMCI to identify the most appropriate indicators for the textile sector in order to integrate them into the tool under development will be presented. Thus, as the work contains a lot of information, this section will focus on the data that it is believed are relevant to show the potential of the method as well as these limitations. The case study is presented following the different phases of the methodology.

- Stage I: assessment and screening of methods of calculation for all sectors combined.

Reading the matrix of LCIA methods (Table 1) allows us to acquire knowledge from the indicators. Therefore, there is no particular outcome here. Is there a more collective improvement of skills between the savvy LCA practitioners.

- Stage II: Ranking and selection of sector-specific indicators.

c. Technical characterization of the project

The matrix (Table 2) is filled in according to the characteristic of the project.

– Geographic scope: it is all over France as well as Europe.
– To compliance with regulations: there is no specific regulation which applies to the tool or on the LCA that will be carried out with the textile tool.
– To compliance with a label: it is not expected that the tool will allow any specific labeling. However, it is expected that the results will be published under environmental labeling that will soon be introduced in France to all consumer products.
– To communicate the results externally: in the context of environmental labeling, it is expected that the results will be published.
– Level of expertise of the future practitioner of the study: the results obtained with the tool must be available to savvy practitioners as well as non-experience practitioners.

Table 2. Considered parameters

Domain	Criterion	Suggestion	Project characteristic
	compliance with regulations	Define if a regulation applies to the realization of LCA	
Communication	compliance with a label	Define if, as part of the project, label compliance is envisaged	
	communicate the results externally	Define the dissemination and communication of study results	
	Level of expertise of the future player/operator of the study	Define if the future reader/operator of the study has a level of analysis and understanding of indicators enabling him/her to process a lot of information	
Context of study	Geographic scope	Define areas of life cycles and distribution area under study	
	Target sector	Define the area in which falls the study or the area covered by the application developed	
	Main impacts generated by the sector/product	Identify the main areas affected by relying on studies and general knowledge of the sector	

– Target sector: the tool is exclusively dedicated to the textile sector.
– Main impacts generated by the sector/product: The textile industry is known to have a significant impact on the water usage presented in its manufacturing process.

d. Collecting recommendations from the literature review

In the context of the French environmental labeling, the working group "5" concerning the textile sector choose five indicators:

– the category of impact eutrophication
– the category of impacts on global warming
– the category of impact on water consumption
– the categories of impact representing all environmental sectors: water, air, soil, resources

In the context of the French environmental labeling, also the methodology working group develop a referential document (BPX 30 – 323: French Environmental footprint Guidance, (AFNOR, 2014) suggesting to choose:

– ReCiPe indicator for eutrophication
– ReCiPe or CML indicator for acidification
– USEtox indicator for ecotoxicity

Future user of the eco-design tool will be potentially beginners, it is best to limit the number of indicators to 6 maximum (defined by a survey with 11 potential users in the French textile industry).

The textile sector generates significant impacts on water (Al-Kdasi Idris *et al.*, 2004) so it is therefore preferable to focus on categories of impacts on water: eutrophication, ecotoxicity, and consumption. France and Europe, in general, has a particular interest in energy (Jamasb and Pollitt, 2005).

e. ranking

Compliant with French environmental labeling is one of the project's goals. The recommendations are therefore of level 1 with the exception of the number of the indicator. If these one are higher in the software *teksajo* due to the quality of the study, then the communication of the environmental display format can be changed.

The number of indicators related to the reader's experience allows some flexibility so that is a recommendation of level 2.

Regarding the main impacts of the sector, it is a recommendation of less importance, and it takes level 3 (Table 3).

• Stage III: resolution

The resolution begins with the recommendations of level 1. The eutrophication, global warming, and water consumption should be chosen. And the indicators to be used are IPCC 100 to climate change according to the consensus and ReCiPe for eutrophication according to the recommendation of level 1. For water consumption, ReCiPe is selected because it is the most recent.

The number of indicator may be six. Two of them are related to water and air. The recommendations' level 2 indicates an interest in energy where the use of the resource depletion category assesses impacts related to soil. CML is the method that is selected because it is best assessed in the evaluation table.

To complete the indicators on the water in compliance with the recommendation of level 3, the aquatic ecotoxicity impact category is chosen. USEtox is chosen on the recommendation associated with level 1.

The final impact category is chosen to complement global warming to assess the impacts on the air. Acidification is widely assessed in LCA studies for the textile sector. It is therefore chosen and evaluated by the ReCiPe indicator (recommendation level 1).

Discussion

Validation of the EMCI method as a driver of learning

Firstly, the case study shows that EMCI has significantly enriched knowledge LCA methods and indicators of the practitioners. Before launching the method, the three LCA practitioners had declared themselves to be moderately adept at choosing methods and indicators.

Two practitioners choose 5 on a scale out of 10 in terms of confidence on their knowledge of LCIA methods and indicators while one practitioner has chosen 6. It means that there is not a big difference between different practitioners

Following the collaborative use of the method, two practitioners considered that they were 9 on the same scale and one practitioner graded himself as 8.5. As a consequence, it is believed that all three practitioners gained confidence in their knowledge on LCA and now they incorporated expert groups on LCA at the national level. This allows showing a first validation of the method.

Secondly, the three practitioners declare to have enriched very importantly their knowledge of the environmental issues specific to the textile sector.

The use of EMCI proved to be simple and logical but remains long in terms of information processing, especially on the application part to a given sector. The limit of appropriation can also be an advantage because it allowed the practitioner to develop skills in the textile field.

The established method remains perfectible. EMCI as a learning method has been tested only in a case study with three practitioners. To consolidate the results, it would be necessary to test another field of experimentation. For this, within the UTT, the method will be used in a project in the cosmetics sector.

EMCI used to develop an eco-design tool

The method was used in the development of an eco-design tool based on LCA applied to the French textile industry. *Teksajo* allows calculating the environmental impact of various textile products.

Six indicators were identified using the EMCI method presented in this paper and built-in this collaborative tool where inventory data of the life cycle are also customized.

The company involved in this research work for 3 years was very participative and worked in a pro-active manner in this project, especially on the application of the EMCI on the textile sector. In addition, the company was responsible for disseminating the tool along with other companies with the help of the French textile union. The six indicators chosen were well accepted by this network. The company was also involved in discussions regarding the textile labeling platform for the choice of indicators. This participation allows us to suggest and to confront the indicators chosen by the EMCI approach at the French level.

Table 3. Illustration of ranking

Domain	Criterion	Project characteristic	Suggestion	Recommendations: summary of results and literature review			
				on impact categories	Score	on indicators	Note
	compliance with regulations	*no*	*Exclude indicators and categories of impacts which do not respect the recommendations of regulation*				
	…						
Communication	compliance with a label	*no*	*Exclude categories and indicators which do not meet the conditions of certification*				
	communicate the results externally	*yes, via environmental labeling*	*Comply with ISO 14040 and 14044*	*GT5 :*		*GT method:*	
				– Minimize the number of indicators (between 3 and 5)	2	*– eutrophication: ReCiPe*	1
				– category of impact category eutrophication	1	*– Acidification : ReCiPe or CML*	1
				– category of impact on global warming	1	*– ecotoxicity: USEtox*	1
				– category of impact on water consumption	1		
				– Evaluation representing all environmental sectors (water, air, soil, resources, etc.)	2		
	Level of expertise of the future player/operator of the study	*novice and expert*		*limit the number of indicators to a maximum of 6*	2		
	…						
Context of study	Geographic scope	*France*	*The impact categories, indicators, and bibliography must be related to the geographical area and the policy applied to it (effort on energy, on greenhouse gas emission).*	*– efforts on energy*	2		
	Target sector	*textile*	*Prioritize indicators for the main impacts generated by the sector*	*Prioritize impacts on water:*			
				– eutrophication	3		
				– ecotoxicity	3		
				– consumption	3		
				General knowledge of the sector: maritime less affected than freshwaters			
	Main impacts generated by the sector/product						
	…						

The EMCI approach was validated with two products: a conventional product (i.e. a product developed with any specific concern on the environment) and an environmentally friendly product. The results of the products were evaluated with the tool developed in the project (with appropriate indicators and a customized database) and also with Gabi and Simapro software. The results of the three tools were consistent, but certainly we reduce the uncertainties with the customized tool.

The great advantage of Tejsako is not the reliability of the software (even if the results show a solid scientific result of LCA), but mostly because it is used as a pretext for collaborative work which improves the learning process of eco-design within the textile sector.

The man–machine interface has been designed to ease appropriate the concepts such as the concept of the life cycle, life cycle modeling, transferring of environmental impacts in an environment, and especially a language and structure of the library only the specific textile area. The structure of tools is ready for use, but the practitioner can add data according to his needs or modify the structure by modifying the different modules.

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