EcoLogTex: a software tool supporting the design of sustainable supply chains for textiles

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ABSTRACT

This paper describes the design and the initial phases of the project *EcoLogTex* that aims to deliver a new methodology and a software tool to support the design of textile supply chains taking into account the impact on the environment as well as costs and time, while satisfying corporate social responsibility constraints. The key idea of *EcoLogTex* is to gather information on the environmental impacts of single steps in a supply chain in order to perform an*ex ante* life-cycle assessment which will produce indicators to be used in the design and choice of the supply chain to be implemented. In other words, the designers of clothing apparel will be able to select the composition, colours, styles of their garments taking into account not only the cost and time required for the production, but also the environmental impact, thus allowing a more conscious use of resources.

Categories and Subject Descriptors

Sustainability through ICT [**ICT and dematerialisation**]: ICT-supported life-cycle thinking

Keywords

Life Cycle Assessment, Supply Chain Design, Textiles, High-Fashion.

1. INTRODUCTION

Within the EU-25, clothing and textiles account for approximately 3-5 per cent of our environmental impacts [8], and globally this figure is even higher as Europe and the US have delocalised and outsourced most of the textile production, in an effort to reduce costs to the bare minimum. This has been possible at the expense of the quality of life of workers in developing countries, and of the environment, as risky and hazardous processes are subject to less stringent legislations.

Recently things have been slowly changing: some segments of the customers' market are switching to the so-called lifestyle of health and sustainability (LOHAS). Key to LOHAS are the respect of the environment and of the workers' conditions. While in the mid to long-term we expect that LOHAS will be widely adopted, at present only some brands and sectors can afford to enter the LOHAS market, especially the prestigious fashion industry that holds high commercial gains by benefitting from the first mover advantage.

Sustainability in supply chains is not easily measurable, as it comprises both quantitative economic aspects, and also qualitative and quantitative aspects (such as environmental friendliness and social equity compliance). Moreover, the evaluation of a supply chain must also embrace the direct and indirect manufacturing processes, which might have considerable impacts on the overall performance. Finally, even if a company has evaluated a supply chain for a selected product, the extrapolation of the results to other products or different supply chains must not be taken for granted at all.

Various projects address the task of assessing the sustainability of a supply chain. Eco Index ™ [7] is based on qualitative principles and management practices and is to be used as an educational tool. Considered Design [5] offers a tool employing a numeric scoring system. However, Considered Design is and input oriented method, meaning that the material types are rated according to their environmental performance. Although the rating of the materials is based on Life Cycle Assessment – at least in part – the tool does not reflect a LCA approach.This reduces the accuracy of the tool. Furthermore, Considered Design does not evaluate the entire product supply chain, including packaging or transportation but rather focus on preselected hot spots. Intertek also offers a tool that allows to compute the LCA of a supply chain [1] as well as the Vision 21project of The Cotton Foundation managed by Cotton Incorporated, Cotton Council International and The National Cotton Council, in the context of which PE Americas conducted an analysis on the supply chain of Levi's 501® jeans model.

We remark that all of these approaches start from an existing supply chain to measure its performance. When one

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leaves the supply chain designer free to choose among alternatives, in order to design a "best-compromise" supply chain the problem might rapidly become unwieldy, as the complexity of the supply chain grows. A simple chain made by only 10 steps, where there are at least two alternatives for each step, has a total of 2^{10} (1024) possible configurations, and this number can easily become larger for typical supply chains in the clothing sector, even for a simple garment such as a shirt.

Therefore, the supply chain manager needs a tool to (re-)evaluate supply chain options with respect to sustainability improvement potentials and to base improvement actions on a solid ground. The required data has to be obtained from the textile industry suppliers who, in exchange, are offered the possibility to benchmark their processes with other manufacturers in the same product and process category. As a result, the textile company will be able to provide its customers with reliable and transparent information on the sustainability performance of its products.

We identify the need for a new type of software product we named EcoLogTex that provides support in designing and implementing supply chains. The adoption and use of such a tool is expected to let a company:

1. Maintain and increase an edge on its competitors based on quality and environmental and social responsibility;

2. Provide consumers with accessible and transparent information on the provenance of its products

3. Be in a better position in order to face future cost internalisation of their carbon footprint.

4. Manage the increased complexity brought in by considering not only cost as the main objective to be minimised.

In this paper we present the main concept of EcoLogTex and we have therefore structured the presentation as follows: first we describe the ongoing project aims and objectives, then we therefore structure the architecture of the various components that make EcoLogTex: the benchmarker, the supply chain designer and the reporter. Finally we report on the current state of the implementation and we describe the next tasks and challenges we are facing.

2. THE PROJECT AIMS AND OBJECTIVES

This project aims to deliver a web-based software application, named EcoLogTex, for the"sustainable design" of the supply chain of textile and apparel companies. The key idea is to integrate Life Cycle Assessment (LCA) in each step of the supply chain in order to add the environmental perspective when designing an efficient supply chain. The Life Cycle Assessment methodology will allow specifying all the environmental impacts of the production and distribution processes related to the product distributed down to the shelf of a shop. As the uncertainty of LCA data is significantly higher than the one associated with traditional measures such as costing and timing, the software application will use a set of stochastic optimisation techniques in order to select the most efficient alternatives for the design of the supply chain.

The main components of EcoLogTeX are:

1. The *EcoLogTex benchmarker* is a web-based software application in which suppliers (of goods, of processes, of services) enter the relevant data for their products and services attracted by the gains in competitiveness as suppliers to the textile company and thus fill the data for a holistic supply chain evaluation. The supplier has two advantages in using the tool: first, it can qualify as a potential supplier for the textile company; second, it obtains a quick check of its "sustainability performance" in comparison to its competitors, leading to an even higher quality of their offer.

2. The *EcoLogTex supply chain designer* is a stand-alone software application for the design of sustainable supply chains. The tool can explore the potentially very complex current and alternative supply chain situations and identify the space for design alternatives, based on the background data from the ecoinvent database [6] but also specific supplier data from the EcoLogTex benchmarker. This allows for continuous improvements towards a sustainable supply chain.

3. The *EcoLogTex reporter* is a stand-alone software application for producing reports to be published on the company website regarding its supply chain sustainability. It uses the data provided by the suppliers and confirmed by an independent party (e.g. the ecoinvent database).

Also, we expect a positive side-effect of the project: as the use of the EcoLogTex benchmarker will spread, more anonymised data will be collected on each type of process and product. Non-governmental organisations can therefore benefit from this wealth of data. For instance, the ecoinvent database, which provides industry and research with life cycle inventory data required to assess processes with respect to their life cycle ecological impact is known as provider of the worldwide most comprehensive data base. However, as textile processes are not included in the database by now, the EcoLogTex project will contribute to the database considerably. In future, the data gathered will be serving companies in the textile sector in Switzerland and worldwide that want to implement a green supply chain for their products.

2.1 The benchmarker

The EcoLogTex benchmarker is a web-based software application in which suppliers (of goods, of processes, of services) enter the relevant data for their products and services. The supplier has two advantages in using the tool: first, it can qualify as a potential supplier for the textile company; second, it obtains a quick check of its *sustainability performance* in comparison to its competitors, leading to an even higher quality of their offer. At the same time, the benchmarker uses the data obtained from the suppliers to compute the environmental impact assessment indicators that will be used by the supply-chain designer to explore alternative production designs

The main features of the benchmarker are:

1. Quick and easy data entry on the basis of a user friendly on line questionnaire: specific user data is automatically complemented with generic background data.
2. Cradle-to-gate self-assessment: putting the ability to calculate and compare the upstream Life Cycle Impacts to every supplier participating in the supply chain of textiles and apparels.
3. Contribution assessment: showing which inputs matter most for each impact category.
4. Use and share real LCI data: use / share Life Cycle data of stakeholders upstream/downstream.

Information entered and processed by the benchmarker follows a flow defined in 1. The user enters all the available information on the specific processes she uses to deliver a given product or service, such as the amount of energy, the type of chemicals and their quantities, the water use and so on. This information is merged with the data extracted from ecoinvent especially where precise and readily available data cannot be provided by the supplier. An example could be the energy mix used by the supplier: in such a case the default value stored in EcoInvent for the specific country where the supplier's plant is located is used.

The environmental impacts of the user's process are obtained by combining the data with the selected impact assessment method and are integrated in the textile value chain for a calculation of the whole life cycle of the garment. The rest of the processes in the value chain are calculated based on either specific data of other suppliers or on default data (e.g. from ecoinvent).

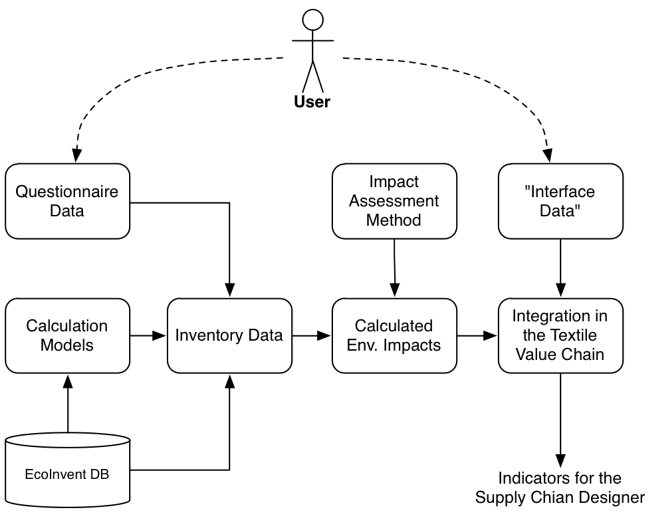

Figure 1: The information flow in the benchmarker

2.1.1 Questionnaires

The questionnaires were developed for all relevant processes along the value chain of the textile products, e.g. for cultivation of cotton or spinning of cotton fibres. To this aim the processes were studied in depth to include all relevant questions in the questionnaire. Furthermore, the questionnaires were tested on industrial partners to evaluate the completeness and the formulation of the questions. The information that the user has to fill in is either the direct flow (e.g. energy use) or parameters which help to calculate the inventory data (e.g. yield of the cotton field to allow the scaling of the flows to 1 kg cotton). The main categories of information gathered by the questionnaires are energy use, material and water requirements, emissions and waste.

2.1.2 Inventory data

The inventory data is the entity of the flows of energy and matter linked to an operation (dyeing, spinning or cultivation of cotton e.g.). These flows are necessary for the calculation of the environmental impacts of the operation. The inventory data is created based on the information given by the user (resp. the supplier in the textile chain), on calculation models and on the Ecoinvent database.

2.1.3 Inventory Modelling

The inventory modelling can be very resource intensive because, usually, only key factors of the agricultural and technical processes are known and not the environmental flows itself. For example, a farmer knows in detail type and amount of fertilizers he is applying and the respective yield of his cultivation but he does not know the amount of phosphate leaching to the groundwater or the diffusion rate of N_2O from his field to the atmosphere. Consequently, the EcoLogTex tool asks only for parameters which are known or at least can be determined by the operator.

The inventory data must contain following general information, which is called here "basic data":

1. Geographic information: electricity mixes e.g. depend on the location of the operation.
2. Information enabling to link the operation to the previous and following operations in order to build the value chain automatically "interface data".
3. Information to allocate the flows to the reference product, what product is linked to the next step in the value chain.

Data for 1. and 2. is collected using drop down lists to prevent ambiguous or not useable data. The allocation data includes:

- For data where the flows are proportional to the mass of the products, the total mass of the product type which enters the EcoLogTex value chain as well as the overall mass of the products in this operation is necessary.
- Where this relationship is not on a mass level, the turnover of the product type is used to allocate the flows to the reference product.
- Knowing the mass flow and cash flow per product or process within the same supplier the allocation could be more detailed and representative of the actual situation.

2.1.4 *Calculating the environmental impacts of a supplier*

The database of the tool contains:

1. questionnaires;
2. ecoinvent processes and elementary flows;
3. LCI results;
4. environmental impact calculated through the LCIA method's factors.

When completed, the inventory data is combined with the environmental assessment methods to calculate the environmental impacts of the operation/process. This means that all flows of the inventory are multiplied with the corresponding figures of the environmental assessment methods to obtain the overall environmental impacts of the process. The technology flows like fertilizer production can be multiplied with calculated results with the same environmental impact method from the ecoinvent database, whereas flows to or from nature are calculated directly with the environmental impact method. For example, the ecoinvent database is used to assess the greenhouse gas intensity of chemical production according to the IPCC 2007 method; for the methane emissions, the IPCC 2007 gives directly the CO_2-equivalent figure. The EcoLogTex tool uses the classification scheme of the ecoinvent database in order to classify and match both, the LCI exchanges and their associated impacts stored in an impact table. The impact table includes all required environmental impacts for all inventory flows available from ecoinvent classified into (i) exchanges from and to nature and (ii) technosphere processes. By linking the flows (e.g. electricity requirements) of the user with ecoinvent results from specific datasets (e.g. global warming potential results from grid electricity in a specific country), the database calculates the impacts of the user's operation.

2.2 The supply chain designer

The *EcoLogTex supply chain designer* is a stand-alone software application for the design of sustainable supply chains. The tool can explore the potentially very complex current and alternative supply chain situations and identify the space for design alternatives, based on the background data stored in the *Ecoinvent database* and from the *EcoLogTex benchmarker*. This allows for continuous improvements towards a sustainable supply chain. In detail, the *EcoLogTex supply chain designer* will be based on a mathematical programming model for the supply chain design problem with a multi-objective cost function covering environmental and social indicators together with economical ones. The tool will use techniques from stochastic and robust optimization to explore the complex combinatorial space defined by the model. Such a space covers all the possible feasible alternative choices to be taken in the logistic supply chain. The output of the tool will be represented by a set of supply chain solutions that constitute the Pareto front according to the weights assigned to the different indicators considered in the objectives of the optimization problem.

The tool will internally represent the supply chain problem as a directed multi-graph $G = (V, A)$, where V represents the set of all possible alternative resource sites, alternative processes@processing sites, warehouses and final destinations, and A is the set of the possible transportation alternatives between the sites (V). Models based on similar ideas can be found in [2], [3],[4]. In Figure 2, where a partial supply chain is presented, the factories, clews and sheep would be the set V, while arrows would be the set A. Notice that the final part of the supply chain is missing in the figure. It is also important to stress that in the figure there is not factory with alternative processes options: in such a case there would be overlapping factories at a same location.

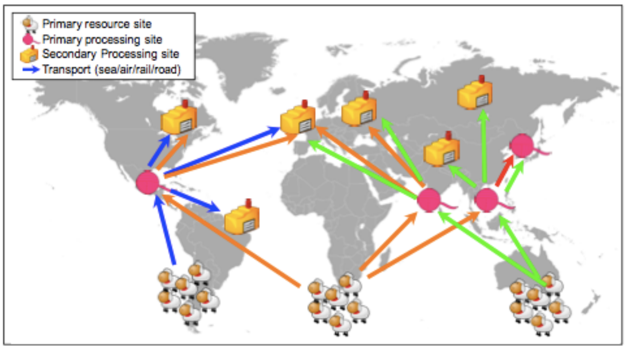

Figure 2: A partial supply chain.

Indicators covering both socio-environmental and economic parameters are associated with both nodes and arcs of G. According to these parameters the tool will build up a mathematical programming model and carry out the optimization process.

2.2.1 *Input*

In order to feed our model, we will require the following data:

- For each node $v \in V$, a socio-environmental indicator is required. It is a *score* about the operations at the site associated with the node v is. For some types of nodes, the indicator might be 0 (e.g. a warehouse).
- For each node $v \in V$, an economic indicator is required. It is the cost of the operations carried out on the goods at the site associated with the node v is.
- For each arc $a = (v, w) \in A$, a socio-environmental indicator is required. It is a *score* about the transportation between the sites associated with the nodes v and w.
- For each arc $a = (v, w) \in A$, an economical indicator is required. It is the cost of the transportation between the sites associated with the nodes v and w.
- Some weights measuring the importance of the different families of indicators. Changing these weights the user will be able to produce different solutions (e.g. more environmental-friendly, more economical).

2.2.2 Output

The tool will provide in output a set of supply chain alternatives that are Pareto optimal according to the input parameter. The decision maker will have the task to choose, among the alternative solutions provided by the tool, the one most suitable to her/his needs.

2.2.3 Comments

Notice that for a pair of nodes in V, there might actually be different alternative transportation options (rail, air1, air2, ship, etc). This means the graph G can actually be a multi-graph. In our model, indicators can be represented as numbers (e.g. 14), intervals of values (e.g. [14, 21]) or probabilistically (e.g. average 14.2, standard deviation 2.4) to represent uncertainty common to real processes. Some indicators can be aggregated, e.g. covering a set of connected nodes of G (sheep/clew). We will have to deal with missing/incomplete data

2.3 Conclusions and Recommendations

In this paper, we have described the aims of the EcoLogTex project, which is expected to deliver a set of tools for the analysis and design of supply chains in the textile sector from a sustainability point of view. The idea is to use LCIA to compute the environmental impact of the various processes and material flows in the supply chain related to a textile product and to use such impacts in the calculation of alternative designs for the implementation of the supply chain, integrating them with cost and time performance indicators. Thanks to this approach, it will be possible to run the sustainability assessment of a supply chain "ex-ante" rather than "ex-post", thus allowing textile companies to better focus their effort in the difficult task of maximising their environmental performance, while keeping the costs at a reasonable level. The EcoLogTex project is currently under way, and, as of writing this paper, we have laid out the database structure, started the implementation of the LCI flows and then of the assessment impact of the LCI flows. At the same time prototypical versions of the supply chain design tools are being implemented. It is therefore too early for us to be able to provide recommendations to our readers, but we have some expectations, which we believe are reasonable and well founded. In particular, we see the clear advantage of making as much information about LCA as possible available to all the participant in a supply chain. It is thanks to the ability of the supplier to compare his/her own performance against competitors that we can stimulate improvement and considerable reductions in the use of resources and in the impact on the environment. At the same time, we believe that the complexity of designing environmentally-friendly products considering all aspects of sustainability is a task of ever increasing difficulty that can be challenged only by the use of ICT tools such as the one we propose in this paper.

3. ACKNOWLEDGMENTS

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