LIFE CYCLE ASSESSMENT OF TEXTILE ORGANISATIONS

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Abstract

The environmental sustainability agenda has never been more relevant for textile companies, being a key driver for innovation and economic growth. In this paper, a novel decision-making process for the textile sector, exploiting the Organisational Life Cycle Assessment (O-LCA) methodology, is proposed. Such management system helps companies measure and control environmental performances, in order to recognise the hotspots that need to be managed for reducing the corporate environmental footprint, and at the same time, creating the business case for sustainability. Several operational tools were established to support this decision-making process. The tools were developed both by reviewing the specific literature and by conducting in-depth semi-structured interviews in six textile companies. Additionally, direct observation (e.g., plant tours) was also used as a data collection method. A case study of a spinning company discloses the potential benefits of this management system.

Keywords: *Organisational Life Cycle Assessment (O-LCA); Environmental sustainability; Textile sector; Decision-making process.*

Introduction

During the last two decades, the request of "green" textiles and garments, produced and distributed minimising the environmental impacts, has vigorously emerged from a wide range of stakeholders. Therefore, sustainability values, strategies and methodologies have become fundamental for textile and clothing companies to compete in the global market. In this paper, a decision-making process, based on the Organisational Life Cycle Assessment (O-LCA) methodology, is developed. In particular, specific guidance, methods and tools for the identification and the assessment of life cycle environmental impacts of a company are released, from the definition of the functional unit to the selection of the best environmental alternatives.

O-LCA is "a compilation and evaluation of the inputs, outputs and potential environmental impacts of the activities associated with the organisation adopting a life cycle perspective" (ISO, 2014). Such methodology meets several business requirements: i) identification of environmental criticalities along the entire supply chain; ii) monitoring and control of environmental performance; iii) support to decision-making; and iv) provision of information for sustainability communication (UNEP/SETAC, 2015). O-LCA helps organisations define their sustainability strategy and organise their operations, facilitating the change into more sustainable production configurations and consumption patterns, towards a circular economy. Even if the interest around O-LCA is rapidly increasing, complete and rigorous applications of O-LCA are not yet a common practice (Martínez-Blanco et al., 2015) and further research is necessary to understand how O-LCA can be implemented in textile companies.

The decision-making process - development and application

In order to support textile companies in implementing their commitment towards sustainability, a decision-making process, built on the technical framework for the O-LCA standardised by the International Standards Organization (ISO, 2014), is here proposed. The novel decision-making process was developed from a literature review, interviews and direct observation (e.g., plant tours); data was triangulated to increase its reliability.

In the remainder of this paper of this paper, each O-LCA phase is discussed with reference to the textile sector and, where appropriate, operational tools are established, in particular: i) Textile O-LCA scoping map; ii) Textile Inventory Matrix; and iii) Sustainable Textile Assessment Tool.

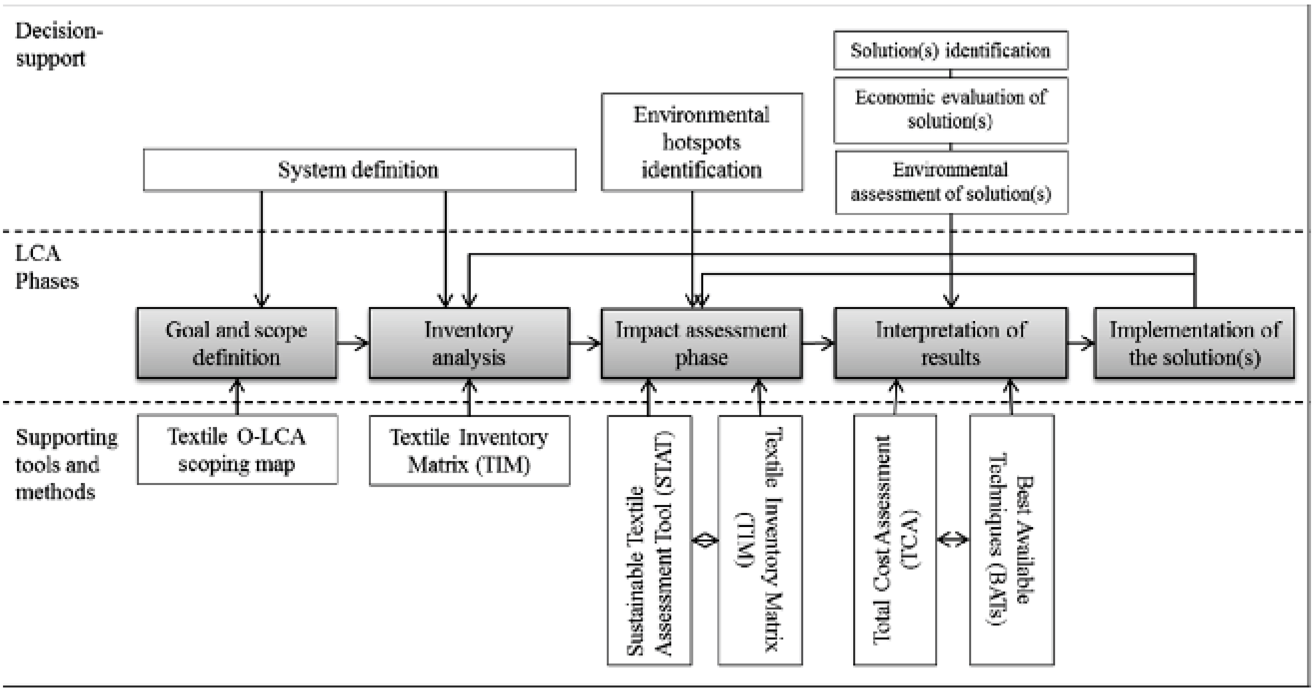

Fig. 1 The decision-making process

Phase 1: *Goal and scope definition*

Scoping phase defines the breadth, depth, and detail of the assessment in accordance with the specified goals. In particular, system boundaries define which are processes associated with the reporting organisation that need to be included in the study. In order to support textile companies in defining the boundaries of the analysis, 13 macro-processes were incorporated in the textile O-LCA scoping map: spinning, weaving, knitting, non-woven manufacturing, cutting, making, trimming, desizing, scouring, bleaching, dyeing, printing, and finishing.

Phase 2: *Inventory analysis*

Coherently with the goal and scope definition, during the inventory analysis phase, data are collected, systems are modelled, and Life Cycle Inventory (LCI) results are achieved. In particular, in an O-LCA the inventory should consist of all inputs (e.g., energy, water and materials) and outputs (e.g., environmental releases in the form of emissions to air, water and soil) associated with the direct activities included in the system boundary defined in Phase 1. Therefore, for each macro-process, both primary and support processes were defined and mapped. Primary processes are the activities involved in the physical creation of the product, while support processes allow the primary activities to take place. For each process, inputs and outputs were identified and coded. Additionally, supporting mechanical plants at the service of the production plant were considered (e.g., electrical, water, heating and cooling, pneumatic, lighting system, etc.) and inputs and outputs were identified. As a consequence, a comprehensive Textile Inventory Matrix (TIM) was developed. It contains 147 primary processes, 25 support processes, 11 mechanical plants, 242 inputs, 136 outputs and 105 resources. Table 1 shows the general structure of the TIM.

Table 1

The Textile Inventory Matrix - Macro-process # x

		Macro-process # x										
		Primary Processes (PPs)				*Support Processes (SPs)*				*Mechanical plants (MPs)*		
		PP1	PP2	...	PPm	SP1	SP2	...	SPn	MP1	...	MPo
Inputs	I1	x			x				x			
	I2				x		x					
	...											
Outputs	O1		x		x			x		x		x
	O2	x			x	x	x			x		x
	...											

Phase 3: *Impact assessment phase*

During the third phase, LCI results are used to estimate the importance of potential environmental impacts. Operationally, the inventory is firstly filled with "consumption data" for inputs and "produced quantities" for outputs. Then, inputs and outputs should be translated into environmental impacts by means of one of the existing impact assessment methods. In particular, two obligatory steps should be carried out: classification and characterization. Regarding the classification phase, the ReCiPe mid-point impact categories have been utilised (Schryver and Goedkoop, 2009) and have been linked to the inputs and outputs included in the TIM. The resulting tool, named Sustainable Textile Assessment Tool (STAT), can be used by textile companies to classify their inputs and outputs into reference impact categories, as illustrated in ***Table 2***.

Table 2

The Sustainable Textile Assessment Tool (STAT)

		Impact categories																	
		CC	*OD*	*POF*	*PMF*	*IR*	*TA*	*HT*	*TE*	*FE*	*ME*	*MD*	*FD*	*WD*	*FEu*	*MEu*	*ALO*	*ULO*	*NLT*
Inputs	I1	x		x															
	I2				x														
	...																		
	Ii		x			x				x	x		x	x					x
Outputs	O1																		
	O2	x	x		x		x				x				x			x	
	...																		
	Oo	x																	

Impact categories (Schryver and Goedkoop, 2009)

CC - Climate change	HT - Human toxicity	WD - Water depletion
OD - Ozone depletion	TE - Terrestrial ecotoxicity	FEu - Freshwater eutrophication
POF - Photochemical oxidant formation	FE - Freshwater ecotoxicity	MEu - Marine eutrophication
PMF - Particulate matter formation	ME - Marine ecotoxicity	ALO - Agricultural land occupation
IR - Ionising radiation	MD - Metal depletion	ULO - Urban land occupation
TA - Terrestrial acidification	FD - Fossil depletion	NLT - Natural land transformation

Characterisation methods, associating the used resource and/or emitted pollutant to selected characterisation/conversion factors, are applied. Environmental impact categories should be then normalised and weighted in order to identify the "hotspots", defined as the elements of the system that mostly contribute to the environmental burden. The goal of the normalisation step is to refer the impact scores to a common reference, enabling their comparison. In particular, LCA normalisation translates impact scores into the relative contributions of the organisation to a reference situation, intended as the environmental profile of an economic system that the organisation is part of. For our purpose, the European textile sector and the environmental impacts of textile production in the EU-27 have been considered as the reference economic system (Beton et al. 2011). After normalisation, the weighting step allows adjusting the normalised indicators to reflect the perceived relative importance of the different impact categories. Evidently, weighting requires determining values reflecting the respective importance of the impact categories, potentially considering several attributes. These judgements may be based on expert opinion, cultural/political viewpoints, or economic considerations.

Analysis the results from the impact assessment phase, the organisation gains insights into its current environmental impacts and reduction opportunities and can formulate strong arguments for effective actions, as discussed in the next phase.

Phase 4: *Interpretation of results*

Based on the results from the "Impact assessment" phase, a priority list can be created by ranking the weighted normalised indicators, thus identifying the most critical impact category. Then, since each impact category is linked to the TIM through the Sustainable Textile Assessment Tool (***Table 2***), it is possible to identify the environmental hotspots in terms of inputs, outputs and, consequently, processes. Such information can be used to define a set of solutions that potentially could decrease the environmental impact, focusing on the most critical elements identified. The identified solutions, aiming at mitigating the corporate environmental impacts, are then evaluated with financial tools, to assess their investment returns and economic impacts. The financial analysis must be able to capture all relevant and significant costs related to the alternatives, as prescribed by the Total Cost Assessment (TCA) method (Epstein, 1996). TCA is similar to traditional capital budgeting techniques except that it includes environmental expenditures and savings.

Once all the costs (and savings) associated with each solution are identified, financial tools for rating investments, familiar to many businesses, are then used to evaluate the economic added value of each option: Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period. Additionally, environmental savings are calculated to assess environmental gains of each solution.

Finally, by regularly collecting data and calculating the indicators defined in the Impact assessment phase, environmental performance could be monitored and controlled over time. It allows to assess the real benefits related to the introduction of an implemented solution, as well as to identify new hotspots and to propose new solutions, in accordance with a continuous improvement approach. Additionally, the TIM might be updated as a consequence of the implemented solution(s).

Empirical applications

Several empirical applications to textile companies have been carried to ensure model robustness and applicability in real contexts (Resta et al., 2016; Resta and Dotti, 2015; Resta et al., 2013). As demonstrated by all the pilot case studies, the solutions proposed and implemented have enabled significant both economic and environmental savings through a lower resource utilization. In this paper, the pilot case of a spinning company is described.

First of all, the processes and mechanical plants associated with the company's business were selected from the full TIM, and inputs and outputs were measured. Afterwards, the impact categories were calculated and then normalised and weighted. In particular, the weighting step was performed using the rank order centroid (ROC) technique (Barron and Barret, 1996). The Climate Change was identified as the most critical environmental impact category. Within this impact category, energy consumption was recognized as the most critical hotspot, since it was responsible for the major contribution to climate change. “Spinning” was the most critical process, mainly contributing to company's energy consumption. Among the available technical alternatives, the installation of high-efficiency motors was identified by a panel of experts as a potential solution able to decrease the energy consumption of the spinning process. The second critical process was the "Conditioning system (for spinning preparation)". In this case, the specialists focussed their attention on the Air Handling Unit (AHU), suggesting the installation of an inverter on the centrifugal fan. "Winding" was the third energy-consuming process. As for the spinning process, the solution proposed by the experts relates to the installation of high-efficiency motors on the winding machines. Additionally, a fourth option was selected: the substitution of neon lighting with LED technology. The four solutions were then compared in economic and environmental terms (***Figure 2***).

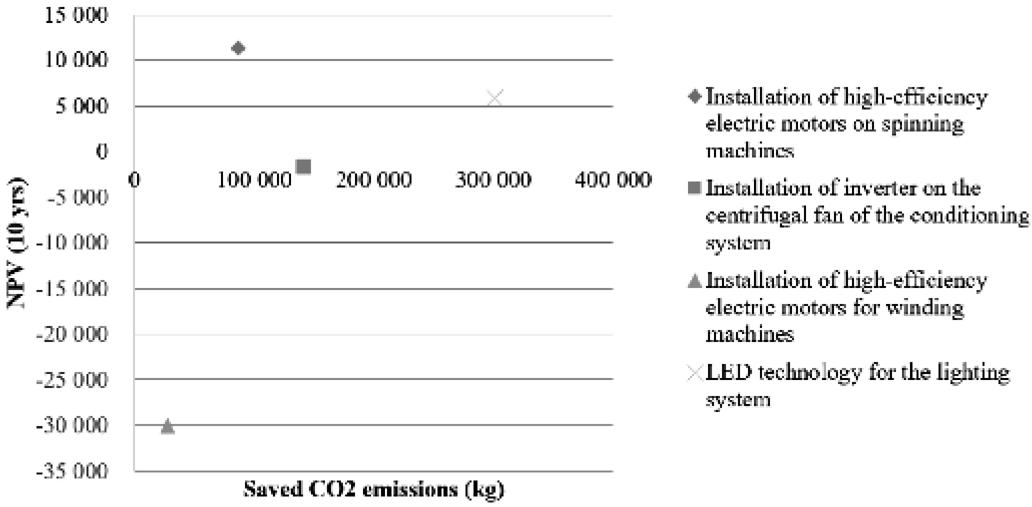

Figure 2 Economic and environmental evaluation of the proposed solutions

The best environmental and economic solution is the substitution of the neon lighting system with the LED technology, while the installation of high-efficiency electric motors on spinning machines is the second best solution. With the implementation of these two options, it is possible to save 388,402 kg of CO2 equivalent per year. Although the other two solutions (installation of inverter on the centrifugal fan of the conditioning system and installation of high-efficiency electric motors for winding machines) bring environmental savings, economic value is destroyed (negative NPV).

Conclusion

The decision-making process described in this paper provides textile companies with a management system able to: i) monitor and control environmental performances with a dynamic perspective, delivering the right information upon which to base decisions; ii) identify which activity and/or mechanical plant needs to be modified in order to reduce the environmental impact, enabling cost savings in both the short- and long-term, developing the business case for sustainability; iii) define strategies for sustainability; and iv) increase a sustainable image.

To conclude, this paper can be considered as a basis for further research. In particular, in order to overcome the limitations of this work, some possible directions can be pointed out. First, the social dimension should be included in the analysis. Secondly, goal and scope definition could be enlarged in order to cover the entire textile and clothing chain, from raw material growing and production, up to distribution and retailing of the final product to customers. Third, a Decision-Making Software (DMS) could be developed to support the analysis involved in decision-making processes.

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