A Decision Making Process for Sustainability in the Textile Sector

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Abstract. A growing number of textile companies are adopting sustainable principles as a way of distinguishing themselves from their competitors and gaining a competitive advantage. Life Cycle Assessment (LCA) is a predominant methodology for the systematic evaluation of the potential environmental impacts of a product or service system through all stages of its life cycle. However its influence and relevance for decision making is still limited since the important relationships between the economic and environmental performance are not properly addressed. In this paper, a new decision making process, exploiting the LCA methodology and combining economic and environmental aspects, is proposed.

Keywords: Life Cycle Management (LCM), Life Cycle Assessment (LCA), Sustainability, Textile, Decision making process

1 Introduction

The increasing concern about industrial pollution, waste problem, effects of global warming, and water scarcity has led to the need of approaches, methods, and tools for measuring and reducing the environmental impact of textile products and processes, from fiber sourcing to end product [1]. In particular, the negative impacts associated with this sector can be grouped in four main categories [2]: i) energy use in laundry, in the production of primary materials (especially man-made fibers), and in yarn manufacturing of natural fibers; ii) use of toxic chemicals which may harm human health and the environment; iii) release of chemicals in water – especially in wet pre-treatment, dyeing, finishing and laundry; and iv) solid waste arising from yarn manufacturing of natural fibers, making up, and disposal of products at the end of their life.

Despite the awareness of the relevance of this topic for the entire textile industry, the concept of environmental sustainability still must be assessed and transformed into business practices [3].

As argued by Waite [4], a life cycle thinking is one of the approaches that can support companies in making the textile industry more sustainable and less damaging to the environment, while at the same time remaining competitive. To this extent, the

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Life Cycle Assessment (LCA) [5] is one of the analytical methodologies that support the quantitative assessment of the environmental impacts of products, processes and services. Even though life cycle assessments currently available in the textile sector address numerous environmental issues, they do not properly consider the economic impacts of the decisions that, on the contrary, represent the main aim of private sector managers [6]. Hence, there is a need of investigating how LCA can be integrated with other management practices in order to encompass more aspects of the decision-making process.

In this paper, we develop a decision making process based on LCA that incorporates economic analyses, adopting a continuous improvement approach. This process helps the companies operating in the textile industry to measure, monitor and improve their performance in order to achieve, at the same time, economic and environmental advantages, both in the long- and short-term.

The remainder of the paper is organized as follows. Section 2 presents the theoretical background of the paper, focusing on Life Cycle Management (LCM) and LCA. Section 3 describes the development of a decision making process for the textile sector based on LCA, while Section 4 introduces an application to a real case. A discussion of the results precedes the final conclusions (Section 5).

2 Literature review

Life Cycle Management (LCM) is defined as "an integrated framework of concepts, techniques and procedures to address environmental, economic, technological and social aspects of products and organizations to achieve continuous environmental improvement from a life-cycle perspective" [7], from raw material extraction, through manufacturing, to consumption and finally to ultimate disposal [8].

Within this framework, Life Cycle Assessment (LCA) is one of the most prominent methodology [9] for the systematic evaluation of the potential environmental aspects of a product or service system through all stages of its life cycle. It can assist in [10]: i) identifying opportunities to improve the environmental performance of products at various points in their life cycle; ii) informing decision-makers in industry, government or non-governmental organizations (e.g., for the purposes of strategic planning, priority setting, and product or process design or redesign); iii) selecting relevant indicators of environmental performance; and iv) marketing (e.g., implementing an eco-labeling scheme, making an environmental claim, or producing an environmental product declaration).

Both the public sector and many business associations and industrial companies already use the life-cycle approach in the framework of sustainability. Within the textile sector, several LCA results were contributed from many areas like cotton growing, spinning, weaving and finishing, laundering and integrated life cycles, as analyzed by Nieminen et al. [11]. The key objective of these LCAs is to select the most appropriate strategies for a product or a process to reduce its environmental impacts [12]. Although environmental issues are important, it is crucial to consider in the decision-making process also business strategies and economic consequences, especially when considering private industry applications.

However, since LCA is a decision supporting methodological framework [5] rather than a decision making methodology, economic aspects of the decisions are within the scope of LCA methodology, and are not properly addressed by existing LCA tools. This traditional separation of life cycle environmental assessment from economic analysis has limited the influence and relevance of LCA for decision making, and left uncharacterized the important relationships and trade-offs between the economic and environmental performance [6]. Therefore, LCA results should be handled together with other criteria (e.g., economic aspects) in the decision-making process in order to utilize the outcomes in the final decision context [13].

In order to consider both environmental and economic aspects, a new decision making process based on a LCA approach, integrated with economic consideration, is proposed in this paper.

3 Development of the process

Through the identification of the critical elements in managing primary and support processes and facility infrastructures, combined with the definition of a set of indicators to measure and control environmental performances, the proposed decision making process aims at supporting a textile firm to: i) evaluate its environmental performance with a dynamic perspective; ii) identify "hotspots", that are activities and/or infrastructures that could be improved or changed in order to reduce environmental impact, save money in the short as well as in the long term; iii) drive investments for sustainability; and iv) increase a sustainable image. The proposed model, depicted in Figure 1, is built on the technical framework for the Life Cycle Assessment methodology that has been standardized by the International Standards Organization [14].

3.1 Goal and Scope Definition

Goal of the project is the integration of a traditional business model with sustainable principles to get environmental, economic and competitive benefits. By making the workplace healthier and working activities safer, also social sustainability can be obtained as a direct consequence. As for the system boundaries, the textile production chain as defined in [15] is addressed, including yarn, fabric and product manufacturing (spinning, weaving, knitting, cutting, making and trimming) as well as finishing processes (desizing, scouring, bleaching, dyeing, printing, printing and finishing).

3.2 Inventory analysis

Through the support of a panel of experts, from both academia and industry, 14 semi-structured interviews in 6 companies operating in the textile production chain were conducted. Each of the 14 interviews, carried out by two or three researchers, lasted between one and two hours and was recorded and subsequently transcribed. Informants included the Plant Manager, shop floor supervisors and workers, and representatives from Manufacturing and Quality function. Additionally, direct observation (e.g., plant tours) was also used as data collection method. As result, the main processes and facility features were identified. Both primary and support activities [16] were considered. Then, for each single process/facility feature, inputs (materials, water, and energy), outputs (environmental releases in the form of air emissions, water emissions or solid waste) and resources (including tools and equipment that support the processes execution) were identified and coded. The main result of this phase was a comprehensive textile inventory matrix, containing 152 inputs, 128 outputs and 64 resources.

3.3 Impact assessment phase

In accordance with the GRI standards [17] the environmental performance areas were identified, considering an operative as well as a strategic perspective: material consumption, energy consumption, water consumption, and waste production (operative areas); environmental protection expenses and innovation and training (strategic areas). Then, for each area, a set of Key Performance Indicators (KPIs) was proposed. They were used as a basis for a Sustainable Textile Scorecard, that enables managers to clarify their sustainable strategy and translate it into action. A performance target can also be defined for each KPI and used as a reference value to sustain continuous improvement. The strategic performance areas measure the innovation level and the culture for sustainability of the company, while the operative KPIs support the identification of the criticalities, as described in the follows.

Regarding the operative KPIs, a prioritization strategy was then needed to identify the “hotspots”, defined as the elements within the system that contribute most to the environmental impact. Consequently the different input/output values should be characterized into a common equivalence unit that can be compared and eventually summed to provide an overall impact. Among the impact categories defined by the ISO standard [14], the Global Warming was considered as the most representative. Hence, the characterization formula proposed by Heijungs et al. [18], and adapted by Forster et al. [19], was selected:

$$EI_s = GWP_s * Q_s \tag{1}$$

where EI_s is the environmental impact associated to substance s (input or output), $GWPs$ the global warming potential (characterization factor) for substance s calculated in terms of carbon dioxide (CO_2) equivalent, and Qs the quantity of substance s. Then, the operative KPIs can be assessed in terms of CO_2 emissions using the following formula:

$$EI_{KPI_i} = \sum_{s \in S_i} EI_s = \sum_{s \in S_i} GWP_s * Q_s \tag{2}$$

where S_i is the set of the substances that refer to the calculation of KPI_i.

3.4 Interpretation of results

Based on the results from the Inventory analysis and Impact assessment, a priority list can be then created by ranking the environmental criticality (in terms of CO_2 equivalent), thus identifying the most critical elements (process, input or output). Three different classes of solutions can be identified to decrease the environmental impact: i) facility structures and equipment; ii) organizational solutions; and iii) material supply management and waste disposal, including reuse, recycling and recovery.

Since the aim of this decision making process is to combine environmental and economic benefits, the identified solutions, potentially advantageous to mitigate the environmental impact, are then assessed with financial tools, to evaluate their investment returns and cash flow impact. In particular, the financial analysis must also capture all relevant and significant environmental costs related to the alternatives. Based on the Total Cost Assessment (TCA) method [20], the environmental costs on which the solution has an impact need to be identified and estimated. TCA is similar to traditional capital budgeting techniques except that it attempts to include all costs and benefits associated with each alternative, including environmental expenditures and savings. In accordance with Curkovica and Sroufe [21], four tiers of costs are considered: i) direct costs; ii) hidden costs; iii) contingent liability costs; and iv) less tangible costs. Once all the cost and savings that accompany each solution are identified, financial tools familiar to many businesses for rating each investment are then used to select the best option. By constantly collecting data and calculating the indicators defined in the Impact assessment phase, new critical indicators are identified and new solutions could be proposed by applying a continuous improvement approach.

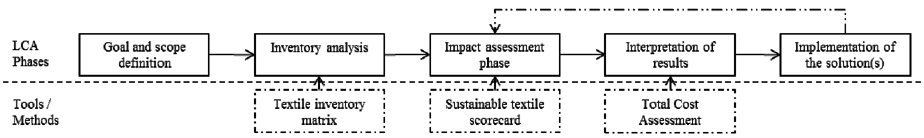

Fig. 1. The decision making process

4 An empirical application

In this section the application of the decision making process to an Italian textile company (hereafter referred to as TexCo) is presented. TexCo is specialized in finishing fabrics for a wide range of end uses and markets. The application of the model was limited to hospital cotton bed lines as they represent the most profitable market for the company. Data was collected through semi-structured interviews and several audits performed by the authors and their research groups. The gathered information was then discussed with a panel of experts, who supported the definition of the potential solutions to implement in order to reduce the company's impact on the environment.

Firstly, the processes and facility features associated to the company's business were selected from the comprehensive inventory matrix. For each process/facility feature, inputs, outputs and resources were measured. Afterwards the operative KPIs were assessed in terms of CO_2 emissions. The “Gas Consumption” KPI was recognized as the most critical, since it was responsible for the major contribution to CO_2 emissions. The inputs/outputs/resources, which were directly linked to gas consumption, were “Gas” (Input) and “Singeing machine”, “Desizing machine”, “Scouring machine”, “Mercerizing machine” and “Bleaching machine” (Resources). Consequently, the analysis was focused on five operative processes (Singeing, Desizing, Scouring, Mercerizing and Bleaching) and on one facility feature (Heating System), which were directly connected with the aforementioned input. Since 40% of the total gas consumption was imputable to bleaching process, the solutions proposed were addressed to improve its environmental sustainability. In particular, a panel of experts proposed the introduction of a peracid bleach for the bleaching process. The use of peracetic acid can accelerate the reaction rate and shorten bleaching time at relatively low temperature, which can reduce both the environmental burden and the production cost. Its applicability was tested through laboratory experiments, while its advantages were evaluated through environmental and economic analyses.

Basically, the technical solution under analysis is characterized by a lower operating temperature and, consequently, a lower gas consumption (from 0.125 Nm^3/kg to 0.077 Nm^3/kg). On the contrary, compared to a traditional bleaching process, this solution requires higher quantity of chemical composites (+ 2g/l of TAED, + 0.5 g/l of soda and +2.5 g/l of peroxide). Such technical specifications were directly obtained from the supplier of peracetic acid. No investments in new machines or technologies are required. Considering the four tiers of costs [21], the solution under analysis impacts on direct costs only. The best chemical formulation, characterised by the fulfilment of the required qualitative parameters at the lowest consumption of chemical substances, was defined through more than 30 experimental trials.

The cost analysis revealed savings for the bleaching costs (Table 1). Environmentally, equivalent CO_2 emissions savings of around 40% were gained.

Table 1. Economic and environmental costs and savings

	Additional costs (per kg of fabric)	Savings (per kg of fabric)	Costs or savings/year (*742.500 kg*)
Gas consumption		0,020208 €/kg	
Chemical composites - Soda - Peroxide - TAED	 0,00148 €/kg 0,00925 €/kg 0,00400€/kg	--- --- --- ---	
Total	0,01473 €/kg		4.067,4 €

Moreover, additional aspects were analysed to comprehensively quantify the environmental and economic implications of introducing this operational solution. As for cycle time, no significant improvements were registered. Regarding the waste production, the quantity of COD (Chemical Oxygen Demand) in the waste water from the peracid bleaching process decreased by 12% compared to the initial situation.

5 Conclusions

Sustainability is gaining more and more relevance on the manager's agenda since it can positively contribute to the firm's value creation process. The benefits are numerous and range from cost reduction, through risk management and business innovation, to revenue and brand value growth. In the textile sector, several companies are starting to pave the way towards sustainability through a number of different approaches.

In such a context, this paper proposes a decision making process to help textile companies in fulfilling environmental, economic and competitive benefits. The model, which has been built on the LCA methodology, supports the identification of opportunities for preventing pollution and for reducing resource consumption through a systematic analysis. Summarizing, the model provides a management system able to support managers to: i) monitor and evaluate its environmental performances with a dynamic perspective; ii) identify which activity and/or infrastructure needs to be improved or changed in order to reduce the environmental impact, enabling cost savings in both the short- and long-term; iii) define strategies for sustainability and foster the sustainable development of a company; and iv) increase a sustainable image. As demonstrated by the pilot case study that has been used to illustrate and analyse the applicability and consistency of the model, the solution proposed and implemented has enabled significant economic and environmental savings through a lower resource utilization.

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 are hereafter pointed out. First of all, the proposed Sustainable Textile Scorecard can be extended considering other relevant aspects and KPIs. Moreover, as shown in the empirical application, there could be solutions that entail a higher consumption of chemicals, whose environmental impact could go beyond the Global Warming category. Therefore, future investigations can be carried out to analyse the introduction of other additional impact categories which can be useful to represent environmental sustainability with a wider perspective. Finally, social costs are not included in the model, but could be considered as potential further extensions.

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