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SUSTAINABILITY RISK MANAGEMENT: THE ROLE OF LIFE CYCLE ASSESSMENT IN IMPROVING DECISION-MAKING ACTIVITIES

From Sustainable Development to Sustainability Risk Management

The term Sustainable Development, since its first appearance in the Bruntland Report (25), has gained widespread recognition, becoming a well-accepted strategy-focused task, both at government and industry level, acquiring, over time, strong connections with the Triple-Bottom-Line (TBL) dimension (simultaneous consideration of environmental, economic and social aspects). Focusing on the company level, sustainability goals are certainly part of the core business of firms whose objective is to enter the green/ethical product market, but it is also becoming an essential business task for other organizations that are not directly involved in green markets but are, in any case, more and more aware of the sustainability aspects of their activity. Indeed, the tendency to respect environmental and social principles can have positive results for the company's image and financial position; on the other hand, when ethics and the environment are ignored, organizations may face costs due to accidents, taxes, fines, legal expenses, damage reimbursements, negative publicity and reputational damage to such an extent that their finances can be totally ruined. Furthermore, companies are under increasing pressure from customers, consumers, employees and also from financial stakeholders to manage and report on their sustainability performance. This all goes to highlight the limitations of traditional economic theories, which have long qualified business in terms of its capacity to maximize profit, and the necessity of shifting toward more sustainable business (9). This means that businesses today have to fully integrate sustainability risk management into their strategies (26) and that the notion of competitive advantage is strongly connected to sustainable products, processes and systems. Risks arising from environmental problems or social discontent can be enormously costly and, in this context, sustainability assessment is necessary for managers, in order to select alternative projects before they are implemented and to avoid high-risk investments. So, in project decision-making, whether it be for a new product, technology and/or another kind of business activity, the main aim of companies is to evaluate these risks in order to reduce and manage them and improve business performances over time. Measuring economic risk, therefore, cannot be done without considering environmental and social risks because, nowadays, these are the risks that could cause serious financial problems. This is the core task of Sustainability Risk Management (SRM): a business strategy that involves the pursuit of balanced financial, environmental and social goals; it allows us to identify, evaluate, select and implement actions aimed at reducing risks and to choose the best alternatives from TBL points of view. “Environmental and social risk costs, which for years were externalized, are increasingly internalized to firms and they are evolving into one of the critical risk areas of the 21th century” (4). The concept of SRM is also closely tied to Corporate Sustainability Management (CSM): “a business approach that creates long-term shareholder value by embracing opportunities and managing risks derived from economic, environmental and social development” (6); “a values-laden umbrella concept which refers to the way in which the interface between business, society and the environment is managed” (24). Organizations should extend their strategies in order to understand and manage environmental and social impacts and select the new challenges of competitive advantages of the global market. The result is that many companies are focusing on sustainability, but doing it in very different ways; in any case, organizations that adopt TBL approaches for risk management need to evaluate these risks and thus need to manage proper data in order to reduce the uncertainty and understand the size of the risk the organization is subject to. While traditional financial analysis is not sufficient to evaluate these aspects, there are new analysis tools that should be added to traditional ones, because they allow us to calculate environmental and social dimensions and, in this way, could help improve the management of risks related to new projects. In fact, many different tools can be used by managers for dealing with sustainability risk, but within this great variety of tools, life cycle tools have a primary role. Indeed, sustainability awareness has widened strategic business vision, not only because the economic assessment of a project now also have to include environmental and social aspects, but also because of increased awareness of extended producer responsibility, which has led to a spread in the use of Life Cycle Thinking (LCT) approaches (22). This means that the producer is responsible for the economic, environmental and social impacts along the whole product chain, from suppliers to customers, users and end of life actors. The result is the necessity of taking into account the environmental, economic and social impacts of products in a life cycle perspective, finding a tool that allows us to overcome the limitations of gate-to-gate analysis and to achieve supply chain analysis. In this context, the most widely used life cycle based tool for decision-making, and the only internationally standardized environmental assessment method, is Life Cycle Assessment.

Using Life Cycle Assessment (LCA) to reduce risk

LCA is a well-established methodology based on the International standards of series ISO 14040. It is a method for the evaluation of the inputs (energy and materials), outputs (energy, materials, waste and products) and potential environmental impacts of a product, process or service throughout its life cycle, from extraction of natural resources to waste treatment (16; 17). ISO-LCA methodology consists of four parts: goal and scope definition (definition of the purpose of the study and of the functional unit); Life Cycle Inventory analysis (data collection for each unit process, included in the system boundaries, regarding all relevant inputs and outputs of energy and mass flow, as well as data on emissions to air, water and land; all the flows are in reference to the functional unit); Life Cycle Impact Assessment (evaluation of the potential environmental impacts such as global warming, acidification, eutrophication, etc.); interpretation (evaluation of findings to formulate improvement options and recommendations). Nowadays LCA is largely considered a product-related decision support tool because its usefulness is widely accepted and it constitutes a core part of the environmental information system by which the environmental performances of products, processes or projects can be controlled. At company level, during the introduction of a new technology or the launch of a new product, LCA must be seen as an addition to traditional financial assessment practices. Indeed, LCA can play a vital role in sustainability assessment because it represents scientifically valid support-data and a source of a great deal of qualitative and quantitative information which, when adequately interpreted, helps managers to identify the best ways to improve the use of energy and resources associated with certain products or services, while also providing a detailed and global picture of the strengths and weaknesses of the system considered (9). This information helps risk managers to implement methods of reducing the risks associated with a new project. For ex., thanks to the LCA of a product, firms can calculate its potential environmental impact and also the phase which is subjected to the highest environmental risks, determining where most efforts must be made to minimize environmental impacts. It also helps identify opportunities for avoiding pollution and gaining competitive advantages, choosing among various projects, comparing the energy needs of various solutions and designing new products. However, LCA relates only to the environmental aspect, so, in order to completely cover the TBL dimensions, it is often developed and expanded, taking into account economic and social considerations typically evaluated with other specific economic and socially oriented assessment methods. In (14) the extension of the environmental LCA to address economic and social aspects was already seen as one of the possible future developments of this tool.

Life Cycle Sustainability Analysis

There are several broadening LCA approaches in literature mainly oriented to the integration of economic aspects, but integration of social aspects is also quite frequent; these approaches have different application levels (macro, meso and micro analysis) and use different methodologies: a complete and interesting analysis of the various options for broadening and deepening the LCA approaches is presented in (18) and (23). Furthermore, there is a wide range of approaches and case studies on sustainability assessment with many different names and methodologies. On the other hand, consideration of both economic and social aspects in the LCA model is less common, maybe because of the greater complexity or the relative infancy of the life cycle issue, even though the first experience of LCA including TBL impact assessment appeared as early as 1987 in the book "Produktlinienanalyse" published by Volksblatt Kolner Verlag; moreover, the need to consider the three pillars of sustainability was already recognized and discussed at the 1th SETAC Europe LCA Symposium 1991 (20). Leaving aside these early experiences, attention was later concentrated on integration approaches based on the LCA methodology standardized by the International Organization for Standardization. A literature review of studies containing TBL assessment methods using the ISO-LCA as a common tool is presented in table1.

Table 1

ISO-LCA-based TBL approaches: a literature review*

References	TBL approach	References	TBL approach
Weidema, 2006	Life Cycle Assessment Cost-Benefit Analysis Social indicators	Abeysundara et al., 2009a Abeysundara et al., 2009b	Life Cycle Assessment Economic score Social score
Grießhammer et al., 2007	Life Cycle Assessment Life Cycle Costing Social Life Cycle Assessment Benefit Analysis	Colodel et al., 2009	Life Cycle Assessment Life Cycle Costing Life Cycle Working Environment
Albrecht et al, 2007	Life Cycle Assessment Life Cycle Costing Life Cycle Working Environment	UNEP/SETAC, 2009	Life Cycle Assessment Life Cycle Costing Social Life Cycle Assessment
Saling et al., 2007	Life Cycle Assessment Total cost of Ownership Societal Indicators	Heijungs et al., 2010	Life Cycle Assessment Micro/macro models for environmental, economic and social analysis
Kloepffer, 2008	Life Cycle Assessment Life Cycle Costing Social Life Cycle Assessment	Finkbeiner et al., 2010	Life Cycle Assessment Life Cycle Costing Social Life Cycle Assessment
Zamagni et al., 2009	Life Cycle Assessment Life Cycle Costing Social Life Cycle Assessment	Guineè et al., 2011	Life Cycle Assessment Life Cycle Costing Social Life Cycle Assessment

* Grey literature or other published papers not in English could be missing.

In Weidema (28) the integration of economic and social aspects in LCA is presented using an integrated approach of LCA and Cost-Benefit Analysis (CBA), where social issues are also included. CBA is a well-established analytical method for assessing the costs and benefits of a project, presenting the results in monetary terms. As the connection between LCA and CBA is well described in previous literature, in this paper the author concentrates on a description of how social aspects can be integrated into LCA: six damage categories under the general heading of human life and well-being are identified, making proposals for indicators, units of measurement and a first estimate of global normalization values, then a procedure is proposed to convert all LCA impacts (included the social ones) into the QALY (Quality Adjusted Life Years)[1]. The author finally proposes that human well-being measured in QALYs may provide a single-score alternative to direct monetarisation, establishing a conversion rate between the LCA single-score in QALYs and the CBA single score in monetary units.

In Grießhammer (10) the PROSA (Product Sustainability Assessment) is presented. The PROSA is a method for the strategic analysis and evaluation of products and services with the goal of identifying system innovation and options for action towards sustainable development; it assesses and evaluates sustainability opportunities and risks of future projects. PROSA provides the opportunity to carry out analysis with stand-alone tools or with integrated frameworks and it presents an integrated framework called ProfitS (Products Fit to Sustainability) for the quantitative evaluation of the impacts of the three dimensions and the outcome can be aggregated and expressed, if necessary, as one index. The tools integrated are Benefit Analysis (based on consumer research and aimed at identifying consumer groups and their needs and utility demands), LCA, Life Cycle Costing and Social Life Cycle Assessment.

Life Cycle Costing (LCC) is a technique that allows the evaluation of all costs associated with a product/process including all internal and external costs incurred throughout its entire life. One of the strong issues related to LCC is if and how external costs are to be included; there is, in fact, no consensus on how to monetarize environmental damage in a consistent way (12). LCC could be fully incorporated with LCA, but there is still no standard for it (even if various Codes of Practice exist), so costs included in the study may significantly vary depending on the goal and scope of the analysis. A recent SETAC Working Group has developed a methodology for Environmental LCC in order to give it more coherence with LCA. Environmental LCC is defined as "an assessment of all costs associated with the life cycle of a product that are directly covered by any one or more of the actors in the product life cycle with complementary inclusion of externalities that are anticipated to be internalized in the decision-relevant future" (15).

Social Life Cycle Assessment (S-LCA) is an assessment technique of the social aspects of products and their potential positive and negative impacts along their life cycle. Social impacts are strongly influenced by local conditions, so the relevant impacts may differ from company to company in the product chain but also from product or industry sector. For this reason social impact categories are divided into (7; 19): obligatory (e.g. discrimination, child labour, forced labour and freedom of association) based on universal declarations and conventions, that represent the minimum predetermined requirements for conducting responsible business; and optional (e.g. physical working conditions, minimum wage, development

[1] QALY is a unit of measurement that represents the morbidity of diseases on a scale between 0 and 1 (0 = death and 1 = full health).

support towards local society) which represent a set of categories that may vary depending on the local conditions in which the company operates.

In Albrecht (3), an integrated framework combining environmental, economic, technical and social aspects is applied in the R&S-stage of a product with the aim of obtaining a decision support for the optimization of the production of peptides. In this framework, TBL dimensions are evaluated using LCA, LCC and Life Cycle Working Environment (LCWE) without the trade off among TBL scores. LCWE is a methodology that measures the work-related social effects of processes and products in working seconds considering the following social aspects: Qualified Working Time (duration of work, qualification profile of work, training), Health & Safety of Working Time (lethal and non-lethal accidents, heaviness of work) and Humanity of Working Time (child labour, forced labour, right to organize in trade unions). LCWE is sometimes preferred to S-LCA because it is more consistent with LCA and LCC methodology and it allows us to consider only indicators that fit the LCA framework, bypassing the problem of the lack of international consensus on which social indicators to provide to describe the whole social profile of a product and how to manage them in an LCA-consistent way.

In Saling (21) the social aspect was added to the BASF Eco-Efficiency analysis, creating a new tool called SEEbalance®. The environmental impact is evaluated with LCA, the economic dimension is assured by calculating the Total Cost of Ownership (which includes all the costs incurred in manufacturing or using a product) and the social impact is measured with societal indicators: employees, international community, future generations, consumers, and local & national community. This tool allows us to understand the position of a product according to TBL dimensions and the results are used to support decision-making in the areas of marketing, R&D, strategy and political issues.

In Kloepffer (20) a state-of-the art in LCSA is presented. The author furthermore presents two options for including LCC and S-LCA in LCA, considering the following formula LCSA=LCA+LCC+SLCA. The first option is to consider three separate life cycle assessments with consistent system boundaries; the second one is to design a new LCA with only one inventory followed by up to three impact assessments. The author also highlights that the central problem of LCSA is how to relate social indicators to the functional unit of the system and how to restrict the great number of social indicators in order to better manage them.

In Abeysundara (1; 2) a matrix that helps decision-makers in the construction sector to select sustainable building materials is presented. The matrix combines TBL scores in which: LCA was used to determine environmental scores; economic scores are based on market prices and affordability of material (LCC of an element = cost of materials at production + Cost of materials used for repairs and maintenance – Market price of materials at the end of life of the element); social scores take into account thermal comfort, interior aesthetics, ability to construct quickly, strength and durability from responses of selected stakeholders. The conclusions of the studies show that the matrix is very useful in selecting materials for sustainable buildings in Sri Lanka where the case studies belong.

In Zamagni (27) the CALCAS project is presented. It is the EU 6th Framework Coordination Action for innovation in Life-Cycle Analysis for Sustainability aimed at identifying research lines on how to increase the efficacy of sustainability decision making, through further development of the ISO-LCA into LCSA. The whole project presents a road map for LCSA that could be used from lower to higher level of analysis (micro, meso and macro) and that includes several methods, including LCA, LCC and S-LCA; which methods are used in specific cases will depend on the actual analysis needs.

In Colodel (5) a comparison between adipic acid from renewable resources and adipic acid from crude oil was performed using an integration among LCA, LCC and LCWE. In the study, the authors showed that with this approach it is possible to improve all three pillars of sustainability in parallel, identifying realistic productive options. This framework does not include the trade off among TBL scores.

UNEP/SETAC (23) presents guidelines that explain how S-LCA may complete environmental LCA and LCC. In particular, it shows the differences and the communalities among LCA, LCC and S-LCA, goes into details regarding the methodology of an S-LCA (intended here as a social and socio-economic LCA) and finally provides an adequate technical framework for an S-LCA from which a larger group of stakeholders can undertake to move towards a sustainability LCA.

In Heijungs (13) a framework built on the ISO LCA model and offers the possibility of including various environmental, economic and social aspects, separating empirical knowledge (technical and engineering models, physical models, environmental models, micro, meso and macro models, cultural and institutional models), normative positions (ethical and societal values at micro/macro level) and trans-disciplinary integration (LCA, integrated micro and macro models). This conceptual framework allows us to move from micro questions on specific products, via meso questions on life styles, up to macro questions in which the entire social structure is part of the analysis.

In Finkbeiner (8) a state-of-the-art of the environmental, economic and social dimension of LCSA is presented, still considering the conceptual formula LCSA = LCA + LCC + SLCA. Furthermore, the authors present previous experiences of graphical evaluation of LCSA (the Life Cycle Sustainability Assessment Triangle[2] and the Life Cycle Sustainability Dashboard[3]).

In Guineè (11) the aim of the paper is to give an overview of the past, present and future of LCA. The authors, envisage for LCA a future development in LCSA, specifying that it is a trans-disciplinary integration framework of models rather than a model in itself. "LCSA

[2] For details see Hofstetter P. et al.: *The Mixing Triangle: Correlation and Graphical Decision Support for LCA-based Comparisons*, "J. Ind. Ecol." 1999, 3, 97–115.

[3] For details see Traverso, M. et al.: *Life Cycle Sustainability Dashboard*, Proceedings of the 4th Int. Conference on Life Cycle Management, Cape Town, South Africa, 6–9 Sept. 2009.

works with a plethora of disciplinary models and guides selecting the proper ones, given a specific sustainability question. Structuring, selecting, and making the plethora of disciplinary models practically available in relation to different types of life cycle sustainability questions is the main challenge" (11). The authors specify that LCSA can be performed at product, meso, or economy level. Product-oriented analysis could use models such as LCA, hybrid IO-LCA (combination of LCA and Environmental Input Output Analysis), LCC and SLCA. The authors conclude stating that LCA will be elaborated in many directions over the next decade, but the 2nd decade of the 21st century will be the decade of LCSA.

Conclusions

Sustainability is an opportunity for proactive companies to differentiate themselves as leaders in the industry, in the environment and in society, ensuring long-term business success (26), but sustainability assessment is necessary to support decision-making by providing data covering TBL aspects connected to new products/processes or projects in general. In fact, the analysis presented here shows us that, in recent years, there has been rapidly growing attention to an integrated methodological framework for sustainability assessment and, in this context, LCA based tools could be of great importance. Life cycle-based studies could be a valid support for decision-making in the examination of all the possible options available to reduce or eliminate risks, in the choice of which option should be taken by evaluating feasibility, efficiency, costs, benefits, unintentional consequences and social and cultural impacts related to each choice. The various alternatives and options found to reduce risks can be evaluated with ISO-LCA-based TBL approaches to determine and evaluate where and how to intervene in order to manage risk. The most important environmental critical points are shown up and companies can therefore choose their intervention priorities. In particular, the adoption of LCT methods such as LCA, LCC, and S-LCA, despite the methodological problems linked to their possible integration, could represent a solid base for decision makers who need a combination of financial, environmental and social product-oriented performance assessments, because it enables organizations to integrate sustainability orientation into their decision making activities and enhance their competitiveness, while minimizing business risk. Furthermore, the decision maker can decide what level of aggregation is more appropriate for his decision process and could continually adjust the framework to changes in stakeholders' needs and the real sustainability goals that a company aims to reach. The regular use of such a framework can enable managers to reach and continually maintain the defined sustainability goals connected to a product and process. Furthermore, the systematic use of the sustainable framework can assist companies in editing their sustainability reports. Thus, in the near future, LCA developments are needed in order to broaden the method into an LCSA capable of providing more reliable sustainability information to decision makers.

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Summary

Sustainability Risk Management involves the pursuit of balanced financial, environmental and social goals, in order to identify and implement actions aimed at reducing risks. While traditional financial analysis is not sufficient to evaluate these aspects, there are new analysis tools that should be added to traditional ones. In recent years, there has been rapidly growing attention to an integrated methodological framework for sustainability assessment and, in this context, LCA based tools could be of great importance. The paper presents a literature review of Life Cycle Sustainability Assessment.