Proposal of a Framework for Assessing Environmental Performance of Supply Chains

C. Silva, L.M.D.F. Ferreira and S.G. Azevedo

Abstract Companies need to excel in many areas to achieve a competitive advantage. Supply Chain Management is critical for company's overall performance, while its operations can lead to a significant impact on the environment. It is therefore crucial that organizations measure the environmental performance of their supply chains in order to define strategies that contribute to minimize the negative impact of their operations. This paper aims to suggest a framework for the assessment of environmental performance of an upstream supply chain integrating Analytic Hierarchy Process with a modified Balanced Scorecard.

Keywords Environmental performance · Supply chain management · Composite index

1 Introduction

Organizations are increasingly aware and concerned with the environmental and social impact of their business activities. The focus on supply chains is a forward step into a broader adoption and development of sustainability. Supply chain managers must address a complex assortment of factors that include the product and

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the process on both the upstream and downstream of the supply chain (Vachon and Klassen 2006).

Environmental impact of business activities has become an important issue in the last years due to the growing public awareness of environmental, and the introduction of environmental legislations and regulations mainly in developed countries (Lau 2011).

However, in recent years, more and more companies are introducing and integrating environmental issues into SCM processes by auditing and assessing suppliers on environmental performance metrics (Handfield et al. 2005). In this way they seek to ensure that they have effective tools not only for measuring environmental performance of their suppliers but also for carrying out action plans to improve their performance (Olugu et al. 2011).

The literature shows that most models for evaluating environmental performance focus on the evaluation of the organization itself (Dias-Sardinha and Reijnders 2001) and that the data used is reported by the companies in their environmental reporting (Colicchia et al. 2011). Therefore, the main objective of this article is to propose a framework for the assessment of environmental performance of an upstream supply chain.

The article is divided into five sections. This section seeks to provide an introduction to the topic in question and define the objective of the study: the definition of a model for evaluating the environmental performance of the supply chain. The second section presents a literature review. Section 3 presents a model for evaluating the environmental performance of a supply chain is proposed. Finally, the main conclusions of the study are drawn in Sect. 4.

2 Literature Review

The concept of Supply Chain Management (SCM) was born and brought a new facet to company management in the 1980s. SCM has gained a strategic relevance as a source of competitive advantage (Fine 1998).

The integration of issues related to sustainability in the legislation encourages companies to change the way they operate (Webster and Mitra 2007). These changes require not only the management of new concepts, such as the reverse supply chain, or green purchasing, but also a clear change in existing practices and concepts creating new management and production systems. It has become essential to include the management of by-products and to consider the life cycle of the product in SCM.

For any activity that has strategic implications, such as the management of the supply chain, it is essential to make performance reviews. Although many papers have been published on the topic of assessment of environmental performance within organizations, the emphasis on the evaluation of environmental performance of the supply chain has been relatively limited (Azevedo et al. 2011).

In a supply chain, a significant number of actors influence not only the costs but also the associated environmental impacts. Suppliers, producers, consumers, logistics providers, as well as suppliers of services are the main players. All these players perform most activities that impact business and the environment. Thus, it is necessary to create models that makes possible to assess the environmental performance of the supply chain, promoting also the monitoring of indicators that support decision-making and management (Olugu et al. 2011; Shaw et al. 2010).

Several attempts have been done to develop environmental supply chain performance measures. Azevedo et al. (2011) suggest a model to identify the influence of several green practices on supply chain performance. Nevertheless, the proposed model does not allow to quantitatively assess the environmental performance of a given supply chain. Braithwaite and knivett (2008) propose a model to evaluate supply chains carbon footprint. The model resulting map can be used by the supply chain parties to identify carbon emissions reduction potential and discuss SC re-design to improve it environmental performance. El Saadany et al. (2011), based on an extensive literature review, propose and categorize a set of environmental quality measures. Then, these performance measures, both quantitative and qualitative are aggregated into an environmental quality model which can be used to assess a supply chain environmental performance.

The use of composite indicators is an innovative approach to evaluate sustainable development. Computing aggregate values is a common method used for constructing indices. Indices, which can be either simple or weighted, are very useful in focusing attention and, often in simplifying the problem. Such an approach allows the evaluation of a multitude of aspects which can be deciphered into a single comparable index.

There are also some advances in measuring the environmental performance of companies and their respective upstream supply chain. Azevedo et al. (2013) suggest an "Ecosilient Index" to assess the greenness and resilience of automotive companies and the corresponding supply chain. Tsoulfas and Pappis (2008) propose a set of environmental performance indicators and multi-criteria decision-making methodologies to measure the extent to which environmental principles are fulfilled along the supply chain. Schmidt and Schwegler (2008) also study environmental performance, proposing the concept of cumulative ecointensity to help calculate a score which includes not only a company's direct effects, but also the negative indirect effects in upstream and downstream processes along its supply and waste disposal chain. Hutchins and Sutherland (2008) argue that the company's social performance can be determined by social indicators aggregated into one single weighted measure. They proposed a variety of indicators of corporate social responsibility that are aggregated into a single social sustainability metric for a company. To expand the measure to the supply chain context, value-weighted social sustainability is considered to include both the impact of the company and the social impact of its suppliers.

In the next section we propose just such a framework, describing an integrated approach to assess the level of environmental performance in both individual companies and their corresponding upstream supply chain.

3 Proposal a Framework for Environmental Assessment

In order to address the lack of structured systems for monitoring the environmental performance of the supply chains, the following framework is suggested. The proposed framework is based on the logic of the Balanced Scorecard to assess the environmental performance of the supply chain, while using ISO 14031 and the GRI guidelines to suggest the indicators.

The steps that make up the proposed framework are displayed in the Fig. 1.

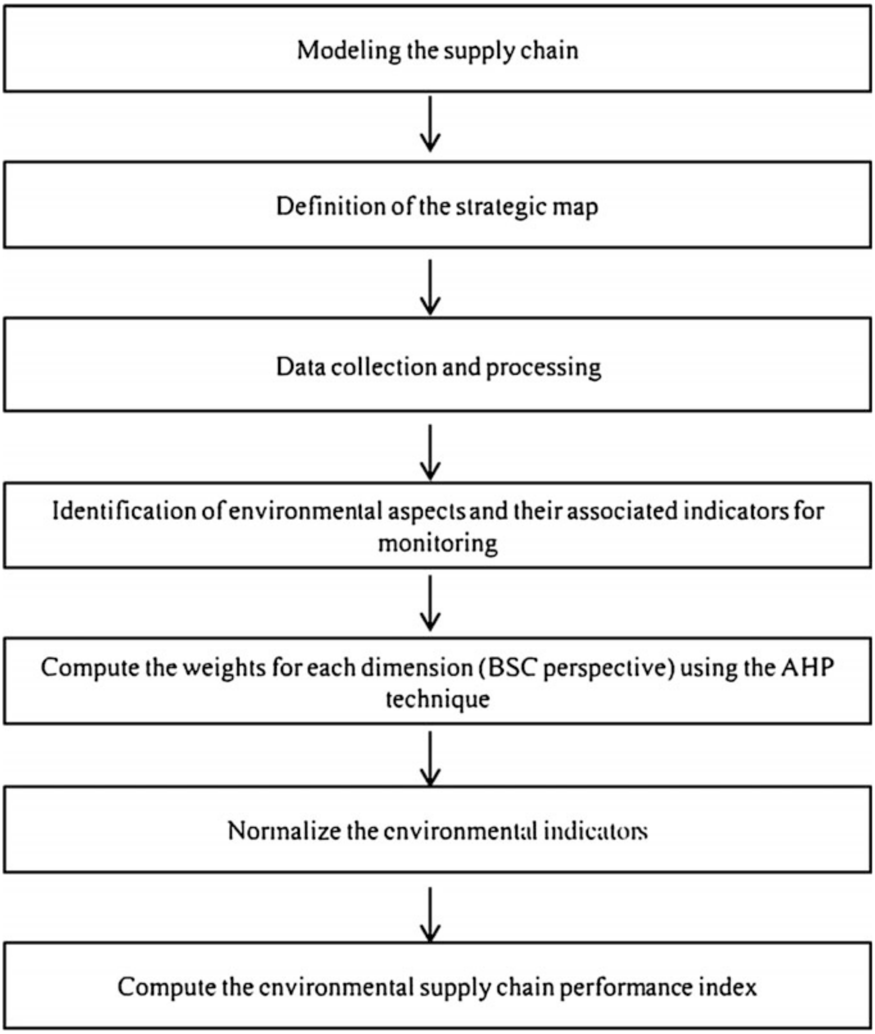

Fig. 1 Framework for evaluating the environmental performance of supply chains

There now follows a description of the different phases of the framework.

Step 1 *Modeling the supply chain.*
The project must start with the study of the supply chain in order to understand its flows, stakeholders and particularities.

Step 2 *Definition of the strategic map for the supply chain.*
The initial formulation of the BSC depicts the strategy of the company distributed over four perspectives. To develop a BSC it is advisable to draw-up a strategic map. The definition of the strategic map should take into account the strategies of the business, SCM and environmental management. In order to facilitate the management of the indicators and avoid introducing additional complexity to both the company's general performance evaluation system and the system to be created, a specific and adapted BSC to monitor the evolution of the environmental performance of the supply chain is suggested.

Step 3 *Data collection and processing.*
The instrument used for collecting the necessary data for performing this framework is a questionnaire to be sent to all first-tier suppliers. This mailing should be performed annually, to make possible that the evolution of the indicators could be monitored and compared across several years. This option represents a simple and effective way to collect the data necessary to evaluate the environmental performance of the supply chains and to incorporate it into the standard procedures associated to the supplier evaluation by most of the companies.

Step 4 *Identification of environmental aspects and their associated indicators for monitoring.*
The chosen indicators should be appropriate to each organization and should be related to the strategic objectives of the organization. The indicators should follow three criteria: measurability, data availability and the indicators should be related to the supply chain type. In this research the indicators for each perspective were selected from the Global Report Initiative (GRI) and ISO guidelines. After selecting the indicators it is necessary to create a calculation method to transform collected data into values that can be compared and analyzed.
In this study the chosen scenario for the application of the suggested framework is to analyze the environmental performance of the supply chain for a given project. Each project is associated to a particular Original Equipment Manufacturer (OEM), whose lifespan is known and where there is no sharing of components between different products that the company produces. However, in some cases the same supplier may provide components for different projects. The indicators are calculated by supplier using Eq. 1.

$$IS_i = (Ind.) \times (ShareS_i) \tag{1}$$

where

IS_i	represents the indicator under study for supplier S_i
Ind.	represents the data for the indicator under study as reported by the supplier S_i
$ShareS_i$	is the percentage of the supplier's total business volume as represented by the purchases made.

This last value is a proxy for developing the model. If for example, the volume of sales of the supplier S_i to the organization under study would be half of its total business, $ShareS_i$ will be 50 %. Ideally, the percentage would be calculated considering the contribution to the impact associated with the respective indicator of the components produced by the supplier to the company. For indicators in percentages the shares are not considered, as is the case with the following indicators: costs, other air emissions, waste water, hazardous waste, compliance with legal and customer requirements, the number of hours of training and certifications held. The indicators that record absolute numbers also do not need shares. In both cases the values of the indicator must be equal to the value reported by the supplier: IS_i = Ind.

Thus we obtain weighted indicators for different processes/business of the supplier. It is only of interest to consider the portion related to the processes associated to the manufacture/acquisition of the considered project. This suggested approach is similar to the method proposed by Hutchins and Sutherland (2008), that is based in the input-output modeling technique, to characterize the social sustainability of a given supply chain. The indicators for each project are calculated using Eq. 2:

$$IP_y = \sum_{i=1}^{m} \frac{IS_i \times SharePS_i}{m} \tag{2}$$

where

IP_y	represents the indicator for the project y
IS_i	represents the indicator under study for supplier S_i (previously calculated)
$SharePS_i$	it is the percentage of sales that the part or component represents for supplier S_i. This percentage is important because a supplier can provide more than one part/component for the same project. If supplier S_i provides only one part/component, then the $SharePS_i$ will be 100 %
m	is the total number of parts produced in the project y

Step 5 *Compute the weights for each dimension using the AHP technique.*
Analytical Hierarchy Process (AHP) is a helpful tool for dealing with complex decision making, and helps to set priorities and make the best decision possible. AHP contributes to the rationalization of the entire decision process. Additionally, the AHP integrates a practical technique for examining the consistency of the decision maker's evaluations, therefore reducing the bias in the decision making process.
An AHP hierarchy model is used to compute the weights for the four dimensions/perspectives of the BSC model. The goal is located at Level 1. Level 2 of the hierarchy contains the four dimensions/perspectives of the BSC. Level 3 contains the sub-criteria/indicators for evaluating each dimensions/perspectives (see Fig. 2). After building the hierarchy a team of evaluators is formed to assign the pair-wise comparisons to the Level 2 used in the AHP hierarchy. A nine-point scale is used. The weights of level 3 sub-criteria will not be computed using AHP pair-wise comparisons (because the possible number of pair-wise comparisons to perform would be very high). In this case we will assume that each sub-criterion will have the same weight. For example, if we have 5 indicators for one of the perspectives each will weight 20 %.

Step 6 *Normalize the sustainability indicators*
The main difficulty in aggregating indicators into the environmental performance supply chain index is because indicators may be expressed in different units. To normalize the indicators, the following procedure will be used:

$$I^{+}_{N,ij} = \frac{I^{+}_{A,ij} - I^{+}_{\min,ij}}{I^{+}_{\max,ij} - I^{+}_{\min,ij}} \tag{3}$$

$$I^{-}_{N,ij} = 1 - \frac{I^{-}_{A,ij} - I^{-}_{\min,ij}}{I^{+}_{\max,ij} - I^{+}_{\min,ij}} \tag{4}$$

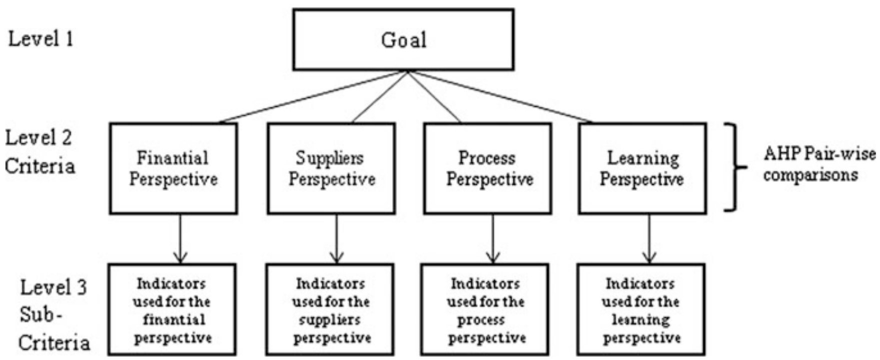

Fig. 2 AHP Model for analysis of the perspectives

where $I^{+}_{N,ij}$ is the normalized indicator i (with positive impact) from group of indicators j and $I^{-}_{N,ij}$ is the normalized indicator i (with negative impact) from the group of indicators j. In this way, it is possible to integrate different kinds of quantities with different units of measurement. One of the advantages of the proposed normalization method is a clear compatibility among different indicators, since all indicators are normalized.

Step 7 *Compute the environmental supply chain performance index*

At this stage the focus of the study is placed on the development of a methodology for deciding on which of the projects would be most advantageous in terms of the environmental performance of its upstream supply chain. Because each indicator has different units, not comparable with each other and also have a different importance an environmental performance index is proposed.

Using Eq. 5 the environmental supply chain performance index is computed:

$$Env\_Perf\_Index\_SC = \sum_i \sum_j W_i \times W_{ij} \times I_{ij} \tag{5}$$

where:

Env_Perf_Index_SC	represents the score of the environmental performance index for the supply chain of a product
W_i	represents the weight of the *i*th perspective of the BSC (calculated through the AHP judgments)
W_{ij}	it is the weight of the *j*th subcriteria of the *i*th perspective of the BSC
I_{ij}	it is the normalized score for the *j*th environmental element of the *i*th perspective of the BSC

The follow-up phase for the index is carried out jointly by the Purchasing and Environmental Management departments. In the event of deviations from the targets established, an action plan should be carry on considering the principles of the continuous improvement cycle, present in the PDCA cycle.

4 Conclusions

The starting point of this study was the need to develop a framework to support the evaluation of the environmental performance of an upstream supply chain.

The evaluation process consists of the development of a framework for the assessment of the environmental performance of an upstream supply chain, based on the four perspectives used in the BSC. A group of relevant environmental indicators for each perspective is identified considering the GRI and the ISO 14031 indicators. The model represents an effective tool for decision making support.

One of the difficulties is related to the correct application of this framework, relying on a deep understanding of the environmental impacts of the upstream supply chain. It can also be noted that the level of complexity of the supply chain can be a determining factor for the successful application of the proposed framework, due to the difficulties involved to collecting the data. As previously noted, there are several paths open to future development of the model. The next phase may include the application of this model to different industry sectors. This could contribute for enhancing the usefulness of the framework in a wider and more encompassing way.

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