An environmental balanced scorecard for supply chain performance measurement (Env_BSC_4_SCPM)

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An Environmental Balanced Scorecard for Supply Chain Performance Measurement (Env_BSC_4_SCPM)

1. Introduction

Organizations are increasingly aware and concerned with the environmental and social impact of their business activities (Winter and Knemeyer, 2013 Gold et al., 2010; Carter and Easton, 2011; Yu and Tang, 2011).

The focus on supply chains is a step towards the broader adoption and development of sustainability, since the supply chain considers the product from initial processing of raw materials to delivery until the customer. However, this demands for the integration of issues and flows that extend beyond the core of supply chain management: product design, manufacturing by-products, product life extension, product end-of-life, and recovery processes at end-of-life (Linton *et al.*, 2007).

Supply chain managers must address a complex assortment of factors that include the product and 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 growing public awareness of environmental, and the introduction of environmental legislations and regulations mainly in developed countries (Lau, 2011). Srivastava (2007) argues that "*much research is needed to support the evolution in business practice towards greening along the entire supply chain*".

To address these stakeholders' concerns, manufacturers have adopted different strategies that focus on internal operations (Vachon and Klassen, 2006). However, in recent years, more and more companies are introducing and integrating environmental issues into supply chain management 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 to help choose them for new projects/products or for carrying out action plans to improve their performance (Naini *et al.*, 2011; Olugu et al., 2011).

However, traditionally the performance measurement of supply chain has been oriented around cost, time and accuracy criteria (Gopal and Thakkar, 2012; Thakkar *et al.*, 2009; Bhagwat and Sharma, 2007; Hervani *et al.*, 2005; Gunasekaran *et al.*, 2004; Gunasekaran *et al.*, 2001).

Hervani *et al.*, (2005) argue that there are difficulties in measuring performance within organizations and even more difficulties come up in inter-organizational environmental performance measurement. The authors point out the following reasons for the lack of systems to measure performance across organizations: non-standardized data, poor technological integration, geographical and cultural differences, differences in organizational policy, lack of agreed upon metrics, or poor understanding of the need for inter-organizational performance measurement.

Performance measurement in supply chains is difficult for additional reasons, especially when looking at numerous tiers within a supply chain (Lehtinen and Ahola, 2010; Hervani *et al.*, 2005; Gunasekaran *et al.*, 2004). Overcoming these barriers is not a small issue, but the long-term sustainability (environmental and otherwise) and competitiveness of organizations relies on successful implementation of performance measurement systems (Olugu *et al.*, 2011; Hervani *et al.*, 2005).

Shaw *et al.*, (2010) conducted an extensive literature review on this issue and concluded that environmental supply chain performance measurement is "*relatively under-researched in supply chain and environmental management literature*". The authors proposed a framework, which integrates the Balanced Scorecard (BSC), Global Reporting Initiative (GRI) and ISO 14031 frameworks, and will enable organizations to effectively manage and benchmark (internally and externally) their environmental supply chain performance. However, that framework was not tested and the authors argue that more research is required in the field to supply direction for practitioners.

The literature shows that most models for evaluating environmental performance focus on the evaluation of the organization itself (Tóth, 2003; Dias-Sardinha and Reijnders, 2001) and the data used is reported by the companies in their environmental reporting (Colicchia *et al.*, 2011).Thus, the main objective of this paper is to propose a model for evaluate the environmental performance of supply chains. The contribution of this study relies on the development and application of a model for the evaluation of the environmental performance of the upstream supply chain using data collected from the first tier suppliers and in this sense this work extends the work of Shaw *et al.*, (2010). As far as we know, this is the first time that a model which incorporates environmental performance indicators, based on GRI and ISO 14031, within the BSC framework is tested with data collected from a case study company.

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: to propose a model for evaluating the environmental performance of the supply chain. The second section presents a literature review on supply chain management and sustainability, evaluation models for environmental performance measurement. Section 3 presents a model for evaluating the environmental performance of a supply chain. In the fourth section the proposed model is applied in an automotive industry company case study. Finally, the main conclusions of the study are drawn in section 5.

2. Literature review

This review is structured as follows. A brief review on supply chain management and it relationship to sustainability is presented in section 2.1 before literature on models for supply chain environmental performance management is reviewed.

2.1 Supply chain management and sustainability

The concept of Supply Chain Management was born and brought a new facet to company management in the 1980s (Luque and López, 2009). Supply chain management is the coordination and management of a complex network of activities involved in delivering a finished product to the end-user or customer. It is a vital business function and the process includes sourcing raw materials and parts, manufacturing and assembling products, storage, order entry and tracking, distribution through the various channels and finally delivery to the customer (Hervani *et al.*, 2005).

Handfield and Nichols (1999) argued that manufacturers must not only manage their own organizations but also be involved in the management of the network of upstream and downstream firms. Supply chain management has gained a strategic relevance as a source of competitive advantage (Fine, 1998; Christopher, 1992) and managing value on supply chains has become critical for company survival and growth. Practitioners and researchers should focus not only on individual companies, but also on the value chains that supply chains and their various links represent, including the range of suppliers, the firms that produce the final product and distributors and customers. For an improvement in the supply chain management, it is crucial to have a good planning, organization and control of the activities across the supply chain (Christopher, 1998).

The focus on the supply chain enables the development of topics related to sustainability, as the supply chain encompasses the different stages ranging from the initial processing of raw materials to delivery to the end customer (Stonebraker *et al.*, 2009; Vasileiou and Morris, 2006). It can be argued that the sustainability opens a window of opportunity for improving the performance of organizations even though it may require short-term investments (Corbett and Klassen, 2006).

A focus on supply chains is a step towards the broader adoption and development of sustainability, since the supply chain considers the product from initial processing of raw materials to delivery to the customer (Linton *et al.*, 2007). Furthermore, sustainability introduces the interaction between economic, social and environmental issues (Carter and Easton, 2011; Gold *et al.*, 2010; Seuring and Muller, 2008).

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 supply chain management. The total cost should include the effects of resource depletion and the generation of by-products that are not captured or used (pollutants and waste). It is therefore essential to investigate the operational implications and how organizations can incorporate sustainability issues into their management practices (Fandel and Stammen, 2004; Jiménez and Lorente, 2001) and create competitive advantage (Markley and Davis, 2007).

2.2 Evaluation models for supply chain environmental performance measurement

For any activity that has strategic implications, such as the management of the supply chain, it is essential to make performance reviews. According to Chan (2003), performance evaluation describes the return of information from activities related to strategic objectives and reflects the need for improvement in areas of poor performance. Although many papers have been published on the assessment of environmental performance within organizations, the emphasis on the evaluation of environmental performance of the supply chain (especially between organizations), has been relatively limited (Azevedo *et al.*, 2011; Gunasekaran *et al.* 2004).

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 services suppliers are the main players. All these players perform most activities that impact business and the environment. Thus, it is necessary to create models that make possible to assess the environmental performance of the supply chain, promoting also the monitoring of indicators that support decision-making and management (Dey and Cheffi, 2012; Naini, 2011; Shaw *et al.*, 2010; Olugu *et al.*, 2001).

Shaw *et al.*, (2010) performed an extensive literature review and concluded that there has "*only been limited research into incorporating environmental measure or metrics into the bank of supply chain performance measures*". The authors proposed a framework, that integrates the ISO 14031, GRI and BSC frameworks, which will enable organizations to effectively manage and benchmark (internally and externally) their environmental supply chain performance.

ISO 14301 is an international standard from the ISO 14000 family that describes a process for measuring environmental performance. It is designed to help organizations in achieving ISO 14001 certification. This standard provides benefits to organizations independent of whether or not they have implemented environmental management systems (EMS) (Morhardt *et al.*, 2002). In applying this standard, an organization should evaluate its performance against its environmental policy, its objectives, goals and other criteria established as part of a management system. The process described in the standard is based on the Plan-Do-Check-Act (PDCA) business process improvement model (Figure 1).

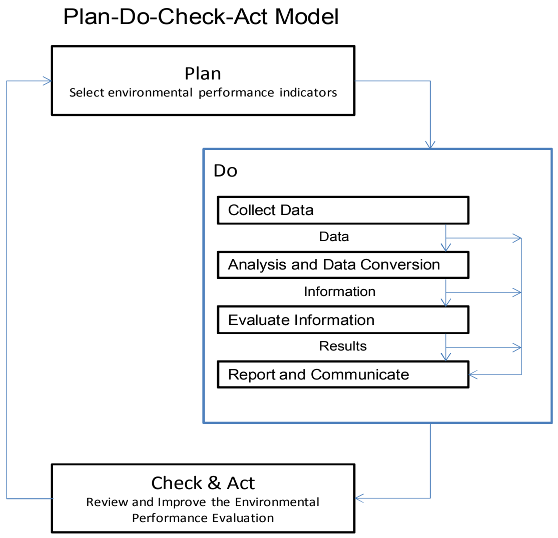


Figure 1 – Continuous improvement model for the environmental performance evaluation system (Source: Adapted from Hervani *et al.,* (2005, p. 343))

The number of companies that adopt EMS to provide guidance on mitigating their impact on the environment has been increasing (Griffith and Bhutto, 2009). In fact, the EMS provides an organized, systematic, and coherent scheme to properly address the environmental questions in organizations. Its main purpose is to improve environmental performance (Perotto *et al*., 2008). The implementation of an EMS allows: the synthesis and communication of information, the identification of priority areas for intervention and provides a measure of the distance to the targets set. An organization that has implemented an EMS can thus assess environmental performance against its environmental policy, objectives, targets and other environmental performance criteria.

A decisive phase in environmental performance evaluation is the development and/or selection of indicators. The indicators will support the organization in the quantification and communication of its environmental assessment. Particularly, the indicators allow summarizing and classifying the environmental information, providing an immediate picture of the environmental situation of the organization. These should be defined for those environmental impacts that the organization has direct influence over, as a result of its operations, management, activities, products or services. These values are essential, since they will represent a benchmark and set reference for future assessments of environmental performance. In turn, this information will also be useful for decision making and to ensure a better alignment of the objectives and environmental targets to the strategies and policies of the organization (Campos and Melo, 2008).

Studies conducted on the use of indicators to measure performance in EMS have highlighted the relevance of using performance indicators related to strategic objectives. The indicators provide a measurement of the degree of success in the implementation of a strategy comparing it to a defined objective. A key issue in the development of environmental performance indicators is the ability to make comparisons within and between organizations. There is the possibility that this data can be used to make environmental decisions, involving various organizations. However, the possibility of inter-organization comparisons assumes a set of shared standards, in terms of the techniques employed, including the indicators and the time span used. Only in this way it will be possible to carry out environmental benchmarking in a more credible and continuous way.

However, the implementation of an EMS does not guarantee by itself the improvement of the performance of an organization (Chen, 2004). The results of evaluating environmental performance should be periodically reviewed so as to identify opportunities for improving it. The emphasis for improvement can be centered on improving data quality, increasing analytical and evaluative capacity, or developing new indicators, as such encouraging a change in the remit of the program or a rearrangement of resources.

Some frameworks exist to evaluate the environmental performance of individual companies and supply chains. The GRI is an international agreement, created in 1997, with the mission of drawing up and disseminating the directives for writing sustainability reports. These reports are produced by organizations wishing to communicate their economic, environmental and social performance to different stakeholders. The GRI directives recommend that the sustainability report should contain, among others, a section covering environmental performance indicators related to consumption (for example, raw materials, energy or water), and production (for example, emissions, effluent, and waste) (GRI, 2002). Moreover, these indicators should take into account the performance related to biodiversity, environmental compliance and other relevant information, such as spending on the surrounding environment and the impacts of products and services.

The Balanced Scorecard (BSC) is a framework that was developed by Kaplan and Norton (1992). The BSC is a system for strategic management that uses, in a balanced way, financial and non-financial indicators while establishing cause and effect relationships between those indicators. The main objectives of the BSC are: to clarify and translate the vision and strategy; to communicate and associate objectives and strategic measures; to plan, establish goals and align strategic initiatives; to improve the feedback and the strategic learning.

The initial formulation of the BSC depicts the strategy of the company distributed over four perspectives: financial, client, internal processes, and learning and innovation (Figure 2). These perspectives are interlinked by cause-effect relationships. The general direction of causality moves from the learning and innovation perspective towards the financial perspective. That is, the organizational capabilities of the organization enable improvements in its processes which, in turn, satisfies more clients and, as such, leads to better financial performance.

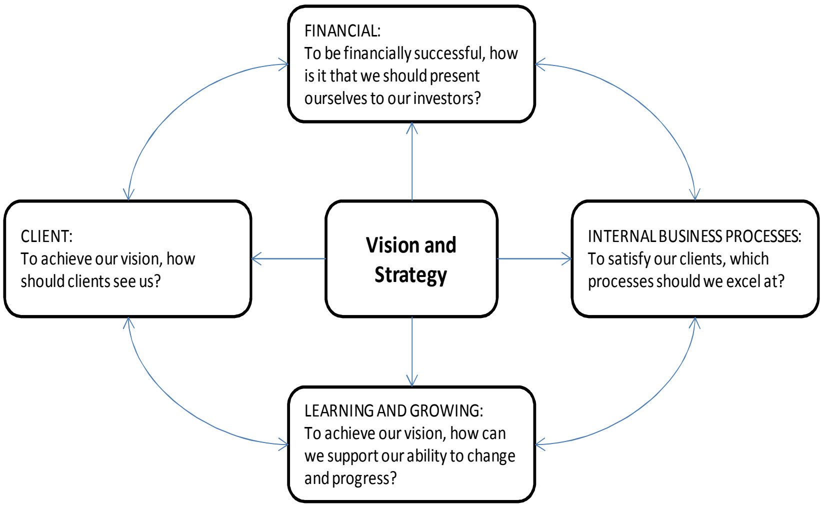


Figure 2 – Viewpoints of the BSC (adapted from Kaplan and Norton, 1992)

Several authors have pointed out limitations to the use of the BSC (Bhagwat and Sharma, 2007). The following criticisms are noteworthy: the efficiency of the BSC can be limited by "*interpretation effects*", in implementing the strategy, priority may be given to the use of financial indicators rather than non-financial indicators, some stakeholders are not accounted for and the formulation of the BSC can depend on the relative power of the various groups involved.

Despite those limitations the BSC's characteristics have lead a number of researchers to see potential for applying this new methodology to environmental management (Hsu *et al.*, 2011; Hsu and Liu, 2010; Shaw *et al.*, 2010; Länsiluoto and Järvenpää, 2008; Hervani *et al.*, 2005; Figge *et al.*, 2002; Epstein and Wisner, 2001; Johnson, 1998). In this process, environmental management benefits from the advantages of using the BSC. At the same time, the BSC as a system of strategic management becomes more complete by incorporating the treatment of the relevant strategic aspects of environmental management.

The literature regarding the inclusion of environmental management into the BSC points to four options (Dias-Sardinha *et al.*, 2002): 1) the distribution of environmental indicators over the four traditional perspectives of the BSC; 2) the creation of a fifth perspective for environmental management: 3) the inclusion of environmental indicators only for the perspective of internal processes; 4) the treatment of the environmental management department as a specific unit, with the construction of a specific BSC.

Comparing the ISO 14031, GRI and BSC frameworks it can be concluded that they are generally compatible with each other, sharing a set of principles and common data. The three frameworks suggest the use of indicators. The definitions of ISO 14031 and the GRI are more specific in relation to the use of environmental performance indicators. The BSC is a methodology that can be adapted to environmental management and there are already several authors which have described how this adaptation can be possible. The BSC, echoing ISO 14031, defines a generic methodology for implementing a strategy, leading the organization itself to subsequently define the indicators that should be used.

By not specifying any indicator from the outset, ISO 14031 and the BSC become broader and more robust methodologies. However, this fact may also increase the subjectivity of the results, making it difficult to compare the indicators between companies, projects or supply chains. From the analysis of the different frameworks it is clear that none is able to effectively define a way to assess the environmental performance of a supply chain. Thus, it seems appropriate to opt for a combination of methods, taking advantage of what each has to offer.

Several attempts have been done to develop environmental supply chain performance measures. Based on a cross-case analysis Azevedo *et al.* (2011) suggest a model to identify the influence of several green practices on supply chain performance. The authors conclude that there is a positive relationship between green practices implementation and: 1) supply chain operational performance, considering “customer satisfaction” and “quality”; 2) supply chain environmental performance, considering “reduction in business waste”; 3) supply chain economic performance, considering “efficiency”, “reduction in costs” and “reduction in environmental costs”. The authors conclude that the proposed model can help managers in deciding which green supply chain practices should be adopted to improve their environment, economic and operational 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 is composed by three steps: 1) developing a supply chain map, representing each of the three types of event which can occur – inventory, material conversion and transport; 2) collect and normalize data on energy consumption and emissions; and 3) representing in the map the accumulation of carbon footprint along the supply chain. The model is tested in a wine supply chain, considering activities from growing of grapes to wine distribution. 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. The authors did not discuss which green practices should be considered to reduce the supply chain carbon footprint and their model only consider energy consumption and emissions, ignoring other important supply chains performance metrics.

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 in an environmental quality model which can be used to assess a supply chain environmental performance. The proposed model is tested in a two level supply chain in which demand depends on the environmental quality of the system and the associated costs. The model can be used to evaluate the evolution of total profit, price and demand when changing the environmental quality value.

Hervani *et al.* (2005) propose a balanced scorecard-type framework to implement and measure environmental and social performance of a company. Their model consider approximately 60 environmental performance indicators which have been pointed out as a drawback to it implementation (Shaw *et al*., 2010). In fact, there is no rule to the right number of measures to include in the BSC but, as stated by Epstein and Weisner (2001), too many performance indicators can distract from pursuing a focused strategy. Shaw *et al.* (2010) refer that a complete scorecard should contain three to six measures in each perspective.

Shaw et al (2010) present a comprehensive literature review on environmental supply chain performance measures and they propose a green supply chain performance measurement framework. This framework consists in incorporating a fifth environmental perspective in the company balanced scorecard. The authors refer that the GRI and ISO 14031 are good starting points to decide which performance indicators should be incorporated into the BSC. The paper ends with some research questions like: “is the BSC the most appropriate framework for supply chain performance measures?” or “How can existing ISO 14031 and GRI environmental performance indicators be used in the BSC framework?”. The authors also refer the need to test the proposed framework.

In this sense, the model presented in this paper, described in the following sections, can be considered an extension of the research presented in Shaw *et al.* (2010) however with a different level of specificity since it focus on the upstream of the supply chain and being empirically tested with data from a convenience case study.

The proposed model relies on the BSC approach and use the GRI and ISO 14031 to define the performance indicators to be used. Unlike Shaw *et al.* (2010), 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, it was decided to opt for the development of a specific and adapted BSC to monitor the evolution of the environmental performance of the supply chain.

3. The proposed model to assess the environmental performance of the supply chains

According to Cohen (2004), the definition of an appropriate set of metrics allows the performance of the activities in the supply chain to be evaluated, contributing to the diagnosis of problems and improvement in the decision making processes. The ultimate goal of the assessment of environmental performance is to ensure that industrial activities move towards sustainability in an acceptable manner to both society and the environment (Linton *et al.*, 2007).

The benchmarking of sustainability practices requires intra and inter-organizational practices with a set of environmental and business performance outcomes (Hong *et al.*, 2012). In practice indicators evaluating environmental performance may be used either by stakeholders outside the company (as in the case of the supply chain), or internally by the company (at a departmental level), in order to establish a process for reducing the environmental impacts of their products and processes. However, such benchmarking has not been adequately explored (Yang et al., 2011; Soni and Kodali, 2010).

In order to address the lack of structured systems for monitoring the environmental performance of the supply chains, the model described below was developed. Although the proposed model is supposed to be independent of the general company BSC, it forms a natural part of the management system, linking up with the various systems and giving decision making signals to the top management, as well as logistics, purchasing and environmental managers.

The proposed model, named the Environmental Balanced Scorecard for Supply Chain Performance Measurement (Env_BSC_4_SCPM), is based on the logic of the BSC to evaluate the environmental performance of the supply chain, while using ISO 14031 and the GRI to define the indicators.

The model is displayed in Figure 3. The phases that make up the proposed model are: 1) Modelling the supply chain process and identification of the strategic business unit; 2) Definition of the strategic map; 3) Identification of environmental aspects and their associated indicators for monitoring; 4) Collection of the data necessary for enabling Env_BSC_4_SCPM; 5) Data processing and implementation of Env_BSC_4_SCPM, including monitoring and a PDCA Cycle.

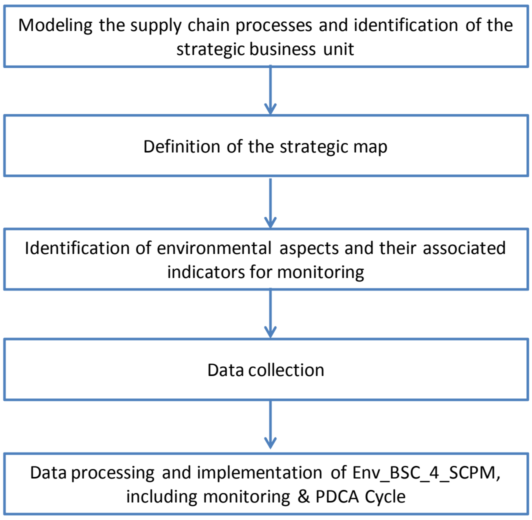


Figure 3: Model of the Environmental Balanced Scorecard for Supply Chain Performance Measurement - Env_BSC_4_SCPM

There now follows a description of the different phases suggested for the model.

Phase 1 - Modeling the supply chain process and identification of the strategic business unit

The project must start with the study of the supply chain in order to understand its flows, stakeholders and particularities. After modeling the supply chain, the boundaries of the business unit are defined for the application of Env_BSC_4_SCPM.

Phase 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. These perspectives are interlinked by cause-effect relationships. The general direction of causality moves from the learning and innovation perspective towards the financial perspective. That is, the organizational capabilities of the organization enable improvements in its processes which, in turn, contribute for suppliers' satisfaction and consequently lead to better financial performance. To develop a BSC it is suggested to draw-up a strategic map to clarify the relationships between critical elements of the BSC and shows the adopted perspectives.

The definition of the strategic map for building Env_BSC_4_SCPM should take into account the strategies of the business, supply chain management 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, it was decided to develop a specific BSC to monitor the evolution of the environmental performance of the supply chain.

Phase 3 - Identification of environmental aspects and their associated indicators for monitoring

In this study the option is to analyze the environmental performance of the supply chain for a given project *y*. Each project *y* 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 rare cases the same supplier may provide components for different projects.

The indicator *i* for project *y* is calculated in three steps, described below and illustrated with an example.

Step 1: Indicator *i* for supplier *j*

The indicator *i* is calculated for supplier *j* of the project *y* using Equation 1.

$$\mathit{Ind\_Supplier\_ij} = (\mathit{Raw\_data\_Ind\_ij}) \times (\mathit{Share\_Supplier\_i}) \qquad (Eq.\ 1)$$

where,

Ind_Supplier_ij – Indicator *i* for supplier *j.*

Raw_data_Ind_ij – Data for the indicator *i* as reported by the supplier *j.*

Share_Supplier_i = Total sales of supplier *j* (in monetary units – m.u.) to the company / total sales of supplier *j* (in m.u.)

Let us suppose that supplier *j* as an annual total sales volume of 100 m.u. Supplier *j* sales two different components for the company: component *a* used in project *y* and component *b* used in project *z*. Sales of component *a* represent 6 m.u. and sales of component *b* represent 4 m.u. Suppose that indicator *i*, as reported by supplier *j* is 1000 units. Then *Ind_Supplier_ij* will be $1000 \times \left({}^{10}\!/_{100} \right) = 100$.

The calculation of the indicators *Ind_Supplier_ij* is based on two important assumptions pertaining to the variable *Share_Supplier_i*. Assumption 1 (Eq. 1): The sales volume of supplier *i* to the organization under study as a proportion of the supplier's total sales volume is a reasonable proxy for the production volume proportion during the period in which the environmental resource is consumed. Assumption 2 (Eq. 1): The component supplied by supplier *j* consumes the environmental resource in equal proportion to the other products produced by that supplier during this period based on units of production.

It is important to note that these assumptions would be violated in two cases: a) if the supplier's production volume mix of products is very different from their sales volume mix OR; b) if the component provided to the organization under study consumed the environmental resource at a greater or lesser rate than the other products produced by the supplier during this same period.

We obtain weighted indicators for different processes/business of the supplier. It is only of interest to consider the portion related to the processes involved in the manufacture/acquisition for the project *under analysis*. The adopted approach here 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.

Step 2: Indicator *i* for supplier *j* to project *y*

The indicator *i* for supplier *j* associated to project *y* is calculated using equation 2.

$$Ind\_Supplier\_Project\_ijy = Ind\_Supplier\_ij \times Share\_Comp\_Supplier\_jy \qquad (Eq.\ 2)$$

Where

Ind_Supplier_Project_ijy – is the indicator *i* for supplier *j* associated to project *y*.

Share_Comp_Supplier_jy = sales of supplier *j* (in m.u.) corresponding to the supply of the component to project *y* / Total sales of supplier *j* (in m.u.) to the company.

Thus, considering the example presented in step 1, for component *a*, the *Ind_supplier_project_ijy* will be $100 \times \left({}^{6}\!/_{10} \right) = 60$.

In the case of the indicators that report to "Total number of environmental accidents" or "Number of complaints, fines or sanctions levied for environmental reasons" we do not use shares. In both cases the values of the indicator must be equal to the sum of value reported by the supplier.

For indicators in percentages the shares are not considered, as is the case with the following indicators: 1) percentage of total costs and investments relating to environmental protection; 2) the degree of compliance with legislation or customer requirements in the specific environmental area of the sector; 3) percentage of first tier suppliers with environmental certificates; 4) percentage of first tier that use returnable packaging; 5) percentage of waste generated per thousand product units; 6) dangerous waste generated as a percentage of total waste; 7) percentage of other significant atmospheric emissions; 8) Percentage of waste water. For indicators reported in percentages we calculate the average of the indicators reported by the suppliers involved in the project.

Step 3: Indicator *i* for project *y*

In this last step the indicator *i* for project *y* is calculated considering all it suppliers using equation 3.

$$Ind\_Project\_iy = \sum_{s=1}^{n} \frac{Ind\_Supplier\_Project\_ijy}{m} \qquad \text{(Eq. 3)}$$

where:

Ind_Project_iy – Indicator i for project y.

Ind_Supplier_Project_ijy – is the indicator i for supplier j associated to project y (previously calculated).

n - Number of suppliers involved in the production of the project y.

m – Total products y manufactured by the company.

Let us continue with the example presented in the previous steps. Suppose that supplier *k* sales component *a* used in project *y*. As we have seen previously the indicator *i* for supplier *j* corresponding to project *y* is 60. Suppose that project *y* uses a second component, supplied by supplier *k*, and the indicator *i* for supplier *k* corresponding to project *y* is 40. Finally suppose that the company manufacture 100 products *y*. Then the indicator *i* for project *y* will simply be (60+40)/100 = 1.

Phase 4 – Collection of data for the Env_BSC_4_SCPM

The instrument used for collecting the necessary data for enabling Env_BSC_4_SCPM is a mail questionnaire to be sent annually to all first-tier suppliers, which will allow the analysis of the evolution of the indicators to be monitored and their comparison with previous years. This option represents a simple and effective way to collect the information necessary to evaluate the environmental performance of the supply chain to the extent that it can be incorporated into the standard procedures that are presently implemented for supplier evaluation in most of the certified companies.

Phase 5 – Data processing and implementation of Env_BSC_4_SCPM, including monitoring - PDCA Cycle

The question of which project has the best environmental performance cannot be directly answered. This is because each indicator has different units, not comparable with each other and also of different importance. At this stage, the focus of the study was not placed on the development of a methodology for deciding which of the projects would be most advantageous in terms of the environmental performance of their supply chain.

Analysis of the results for the various indicators is focused on the study of each result individually. The objective is to separately improve each of the indicators rather than the result set for a given project. This analysis, through the use of multicriteria models, could be considered as an evolution of this model.

The follow-up phase for these indicators is carried out jointly by the Purchasing and Environmental Management departments. In the event that there exist deviations from the targets established, an action plan should be put into place in accordance with the principles of the continuous improvement cycle, present in the PDCA cycle.

4. Application of the model in a case study company

Besides the research level of analysis proposed in the suggested model is the SC however, for convenience reason and to capture the application of the proposed model, the unit of analysis used in this study is the individual company and corresponding first-tier suppliers. The selection criteria for choosing the company for the case study were: i) relevance to the Portuguese automotive supply chain; ii) the company belongs to a large automotive group; iii) willingness to collaborate with the study; and iv) geographical proximity to ensure the right conditions for the research team.

4.1 Methodology

Since the main objective of this research is to propose a model for assessing the environmental performance of a supply chain based on the principle of balanced scorecard, a convenient case study from the Portuguese automotive supply chain (SC) was used to illustrate its application in a real situation.

In the automotive industry there is an uneven power balance among supply chain members. The automaker has huge power, controlling the entire production cycle from the product design to product manufacturing and parts sourcing, and in some cases the suppliers' processes. Typically, in this supply chain there are a limited number of suppliers for components and parts, and the control of the automaker can extend to second tier-suppliers (the first tier-suppliers can only purchase components and materials from some approved suppliers). Therefore, the environmental concern of the automaker is extended to his suppliers, stimulating the adoption of EMS and the improvement of environmental performance by suppliers (Naini et al, 2011; Olugu et al., 2011). In this context, it is important to analyze if there are differences in the environmental indicators among different partners belonging to the same supply chain.

The automotive industry employs a management logic which is based on project management. With this in mind, this work seeks to compare different projects in terms of the environmental performance of their supply chains. The projects in question correspond to different products for different car models. Thus the indicators relating to the different suppliers are taken into account, whilst also considering the number of parts for the project in question.

The case study selection was also made on the basis of "planned opportunism", which is to say there was an anticipation of gaining access to secondary data (Pettigrew, 1990). Case selection is often opportunistic, given that it is frequently difficult to find suitable case studies that allow insight into the research topic, and those that can be pursued often emerge from existing contacts a researcher has with an industry (Seuring, 2005).

To limit expert bias in the study results, data related to personal judgment of the automotive company's managers were obtained through semi-structured interviews (Yin, 2003; Saunders et al., 2003). The visits made to the company made it possible to collect the necessary information to illustrate the application of the proposed model. Other sources of evidence, such as industry databases, newspaper clippings and company web sites, were used to corroborate and augment evidence.

A case study approach is developed in the following section to illustrate the application of the proposed Env_BSC_4_SCPM model as developed above.

4.2 Case study profile

In 2012 the Portuguese auto components industry sold 79.6% of its production to foreign markets, with a strategic role in the economy representing 4.4% of the country's Gross Domestic Product (AFIA, 2012). The company selected as case study has around 400 employees. The main activity is the manufacture of components for the automotive industry, including sets of mechanical and electronic locks, steering wheel locks and external door handles.

The company has some of the major OEMs among its main clients. Its turnover in 2012 was around 84.4 million euros with purchases representing about 60% of this value. The current number of suppliers is 136 and they are located mainly in Spain and Germany. The company is certified according to the following standards: ISO / TS 16949, ISO 14001 and OHSAS 18001.

The company has an evaluation system for its management indicators based on the BSC. Some of the indicators already monitored are relevant for monitoring the environmental performance of the supply chain. However, there is no logical or strategic bond between them so that they can be used as a useful management tool for improving environmental performance in the company supply chain. Here it is worth remembering that the choice was made to develop a specific BSC, independent of the existing one, to facilitate its management and avoid excessive complexity in its usage.

In order to develop and test the Env_BSC_4_SCPM model it was necessary to work together with the company to collect the necessary data related to the company ongoing projects . To this end a multidisciplinary team was assembled, coordinated by the head of the environmental group, with elements of management as well as the engineering, logistics, quality, purchasing and production departments. This team met several times to review the environmental aspects associated with the supply chain, to develop the strategic map of the supply chain and to delineate the Env_BSC_4_SCPM.

4.3 Application of the proposed model

Here the proposed model is applied to measure the environmental performance of two major projects/products currently underway at the company.

Phase 1 – Modeling the supply chain process and identification of the strategic business unit

The case study only takes account of the first-tier suppliers, due to difficulties associated to data collecting for the other elements in the supply chain (tiers 2, 3, n). The company has a total of 136 suppliers located mainly in Spain and Germany.

Phase 2 – Definition of the strategic map for the supply chain

Before defining the indicators to be monitored, the strategic map was created (Figure 4). This was obtained as a result of a number of meetings held by the multidisciplinary team and based itself on the mission and values of the company.

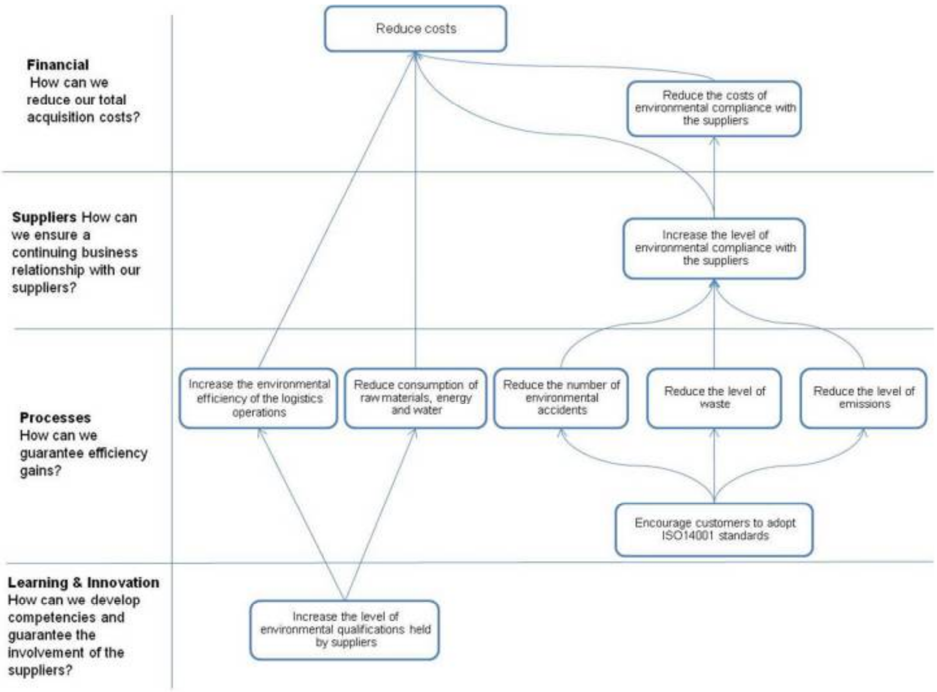
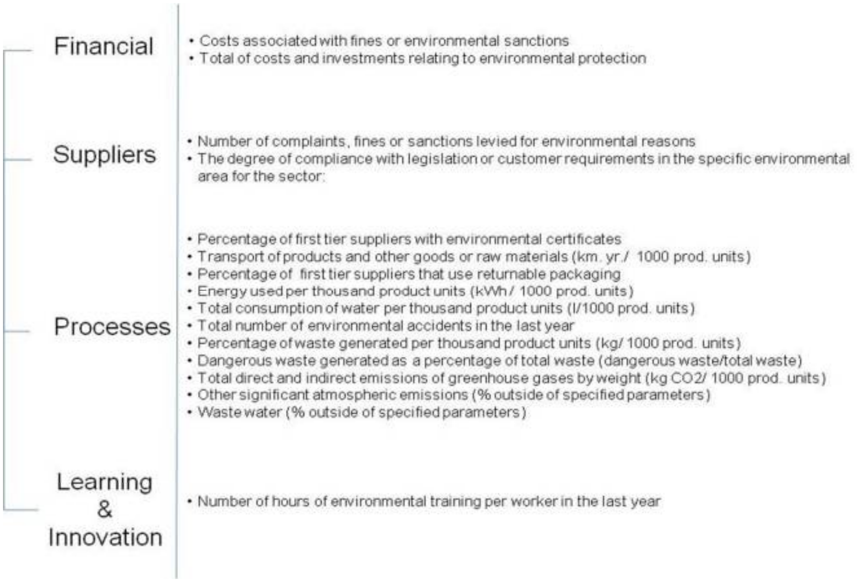


Figure 4 – Strategic map

Phase 3 – Identification of environmental aspects and their associated indicators for monitoring

The indicators were defined by drawing on the GRI and ISO 14031 as well as the reality of the company in question. In this way the indicators presented in Figure 5 were obtained.



- Costs associated with fines or environmental sanctions
- Total of costs and investments relating to environmental protection

- Number of complaints, fines or sanctions levied for environmental reasons
- The degree of compliance with legislation or customer requirements in the specific environmental area for the sector;

- Percentage of first tier suppliers with environmental certificates
- Transport of products and other goods or raw materials (km. yr./ 1000 prod. units)
- Percentage of first tier suppliers that use returnable packaging
- Energy used per thousand product units (kWh / 1000 prod. units)
- Total consumption of water per thousand product units (l/1000 prod. units)
- Total number of environmental accidents in the last year
- Percentage of waste generated per thousand product units (kg/ 1000 prod. units)
- Dangerous waste generated as a percentage of total waste (dangerous waste/total waste)
- Total direct and indirect emissions of greenhouse gases by weight (kg CO2/ 1000 prod. units)
- Other significant atmospheric emissions (% outside of specified parameters)
- Waste water (% outside of specified parameters)

- Number of hours of environmental training per worker in the last year

Figure 5 – Suggested indicators for applying the Env_BSC_4_SCPM to the case study company

The number of performance indicators used in the model is limited to 16, avoiding too many metrics to measure and compare, making environmental benchmarking difficult. The performance indicators have been chosen accordingly to our case study company specificities but, in our opinion, they are sufficiently generic to be adapted to other companies.

Phase 4 – Collection of data for the Env_BSC_4_SCPM

Out of a total of 136 companies that supply the case study company, 105 companies replied to the questionnaire within the prescribed time limit, representing a response rate of 77%. ISO 9001 or ISO/TS 16949 are prerequisites for becoming a supplier of the case study company. All of the suppliers have at least one environmental certification. The company already has 45% of its suppliers ISO 14001 certified, while that number will show a tendency to rise given that the evaluation procedure for suppliers penalizes those that are not ISO 14001 certified.

The largest numbers of observations for the indicator for Total waste / Raw materials occur in the ranges 0%-1% and 10%-20%, with no observations for the range 70%-100%. Dangerous waste as a proportion of total waste is most frequently reported to be in the range of 1%-5%, with 30% of the responses. It is worth noting that a significant number (15% of suppliers) indicated the 50%-70% range, which is indicative of the complex nature of the manufactured products and the materials involved.

Data on water consumption show that around 30% of suppliers have average levels of annual water consumption in the 1,000-5,000 m^3 range. The data collected is displayed in figure 6.

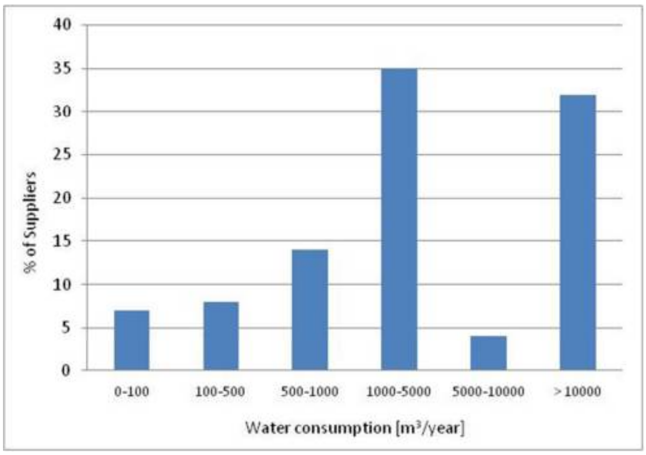


Figure 6 – Data on water consumption of suppliers [m^3/year]

The data collected on management of effluents show that 5.6% of suppliers that produce and analyze waste water have problems with their waste water output.

Data on atmospheric emissions shows that the majority of the suppliers have CO_2 emissions under 100 tons/yr. or between 500-1000 tons/year (Figure 7). The measurements of atmospheric emissions also show that only 5% of the suppliers had results that were in breach of the specified levels.

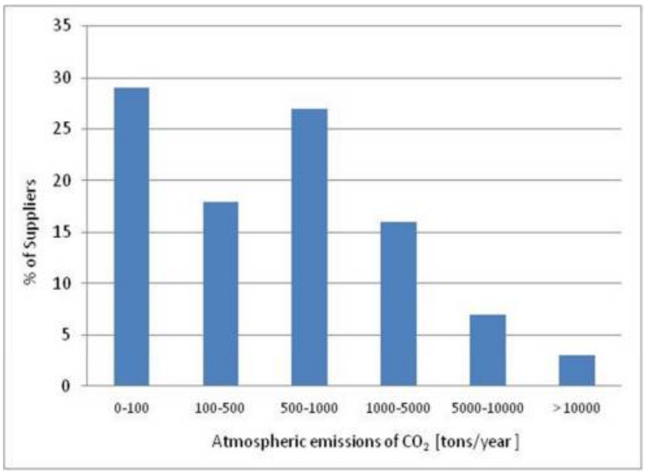


Figure 7 – Data on atmospheric emissions of CO_2 [tons/year]

It can be noted that energy consumption among the suppliers is relatively homogeneously distributed over the different defined ranges. Both the small suppliers (<100 MWh) and the medium sized suppliers (1-10 GWh) each represent around 30% of the total. There is also an appreciable number of suppliers that are large consumers, using between 10 and 100 GWh.

The environmental costs indicator requested that the suppliers would indicate the percentage of spending and investments made on environmental aspects, with respect to the total costs of the company. The data collected show that 35% of the suppliers allocate between 1 and 5% of their total costs to environmental spending, while 30% do not reach the level of 0.5%. Only one supplier admitted having had an environmental accident. The responses to the questionnaire did not indicate any supplier as having been the subject of a complaint, fine or sanction.

Questioning the transport used revealed that the suppliers are mainly located in Spain (56%), Germany (24%) and Portugal (14%). Shipments are made almost entirely by road and truck and the most widely used type of packaging is cardboard (54%), however plastic (19%) and timber (15%) are also present. Due to associated logistics costs, returnable packaging, at 8% of the total, is still not significant. In this case deliveries are usually made weekly. The data collected is displayed in figure 8.

Figure 8 – Type of packaging used by the suppliers

Data on environmental training shows that on average the suppliers spend annually 2.7 hours per worker on environmental training (Figure 9). This is clearly an area in need of improvement if results are to be improved in the future.

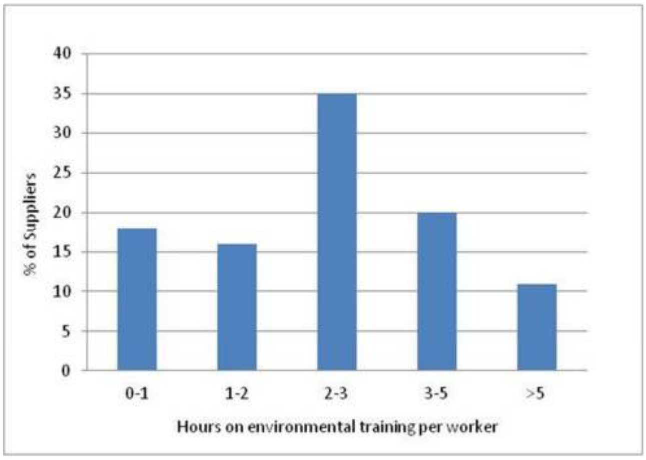


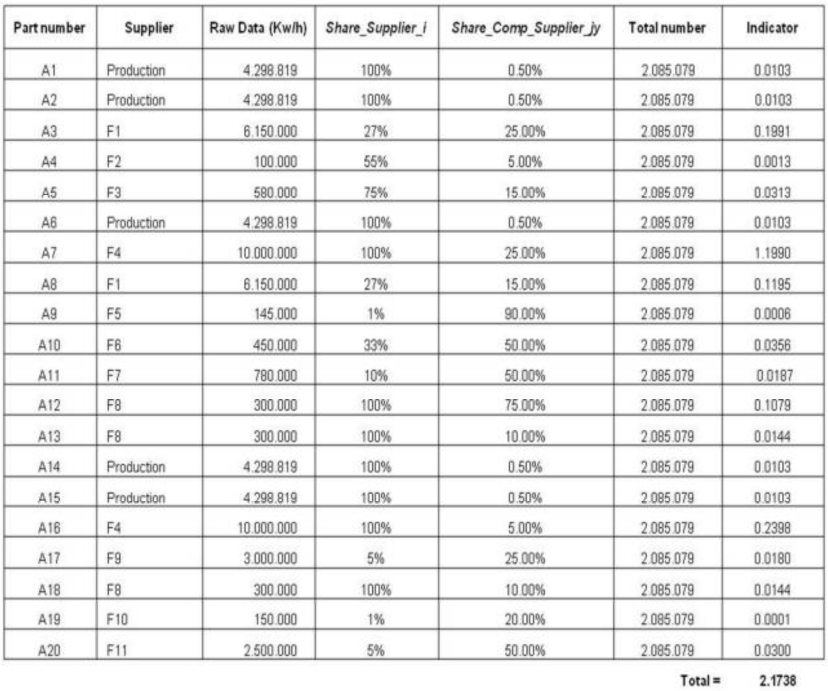
Figure 9 – Data related to hours on environmental training per worker.

Phase 5 – Data processing and implementation of Env_BSC_4_SCPM, including monitoring - PDCA Cycle

Two projects were chosen to test the ability of the Env_BSC_4_SCPM model to assess the environmental performance of the supply chains of equivalent projects currently underway at the company. These projects were the retractable keys produced for two large OEM.

It was decided to test the model with these two projects because they are products which can be easily compared. In addition, the responses to the questionnaires provided all the necessary information for these two projects. The equation for deriving the indicators for each project was applied to calculate the needed indicators for this study.

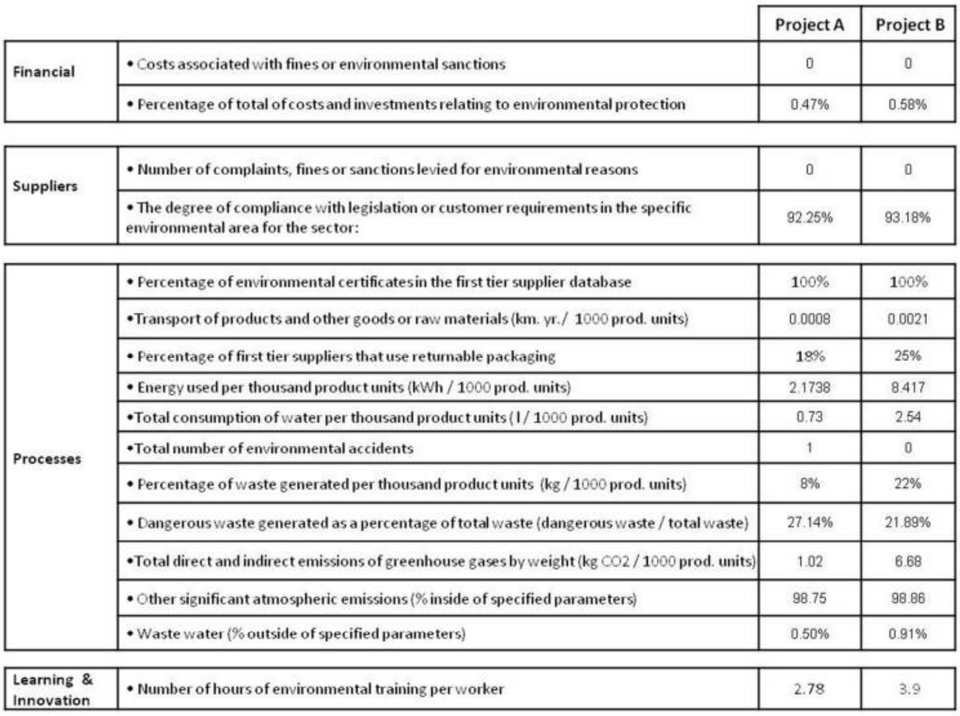
To give an example of how the results are produced in Env_BSC_4_SCPM, Table 1 provides the calculation for the “Energy Consumption” indicator for one of the projects under study.



Part number	Supplier	Raw Data (Kw/h)	*Share_Supplier_i*	*Share_Comp_Supplier_jy*	Total number	Indicator
A1	Production	4.298.819	100%	0.50%	2.085.079	0.0103
A2	Production	4.298.819	100%	0.50%	2.085.079	0.0103
A3	F1	6.150.000	27%	25.00%	2.085.079	0.1991
A4	F2	100.000	55%	5.00%	2.085.079	0.0013
A5	F3	580.000	75%	15.00%	2.085.079	0.0313
A6	Production	4.298.819	100%	0.50%	2.085.079	0.0103
A7	F4	10.000.000	100%	25.00%	2.085.079	1.1990
A8	F1	6.150.000	27%	15.00%	2.085.079	0.1195
A9	F5	145.000	1%	90.00%	2.085.079	0.0006
A10	F6	450.000	33%	50.00%	2.085.079	0.0356
A11	F7	780.000	10%	50.00%	2.085.079	0.0187
A12	F8	300.000	100%	75.00%	2.085.079	0.1079
A13	F8	300.000	100%	10.00%	2.085.079	0.0144
A14	Production	4.298.819	100%	0.50%	2.085.079	0.0103
A15	Production	4.298.819	100%	0.50%	2.085.079	0.0103
A16	F4	10.000.000	100%	5.00%	2.085.079	0.2398
A17	F9	3.000.000	5%	25.00%	2.085.079	0.0180
A18	F8	300.000	100%	10.00%	2.085.079	0.0144
A19	F10	150.000	1%	20.00%	2.085.079	0.0001
A20	F11	2.500.000	5%	50.00%	2.085.079	0.0300
					Total =	**2.1738**

Table 1 – Calculation of the “Energy Consumption” indicator for one of the studied projects

The overall results for the indicators associated to each analyzed project are presented in Table 2.



		Project A	Project B
Financial	• Costs associated with fines or environmental sanctions	0	0
	• Percentage of total of costs and investments relating to environmental protection	0.47%	0.58%
Suppliers	• Number of complaints, fines or sanctions levied for environmental reasons	0	0
	• The degree of compliance with legislation or customer requirements in the specific environmental area for the sector:	92.25%	93.18%
Processes	• Percentage of environmental certificates in the first tier supplier database	100%	100%
	•Transport of products and other goods or raw materials (km. yr./ 1000 prod. units)	0.0008	0.0021
	• Percentage of first tier suppliers that use returnable packaging	18%	25%
	• Energy used per thousand product units (kWh / 1000 prod. units)	2.1738	8.417
	•Total consumption of water per thousand product units (l / 1000 prod. units)	0.73	2.54
	•Total number of environmental accidents	1	0
	• Percentage of waste generated per thousand product units (kg / 1000 prod. units)	8%	22%
	• Dangerous waste generated as a percentage of total waste (dangerous waste / total waste)	27.14%	21.89%
	•Total direct and indirect emissions of greenhouse gases by weight (kg CO2 / 1000 prod. units)	1.02	6.68
	• Other significant atmospheric emissions (% inside of specified parameters)	98.75	98.86
	• Waste water (% outside of specified parameters)	0.50%	0.91%
Learning & Innovation	• Number of hours of environmental training per worker	2.78	3.9

Table 2 – Env_BSC_4_SCPM comparison of the two projects

4.4 Discussion and implications

As previously described, when it is necessary to compare the environmental performance of the different projects, each indicator should be monitored and analyzed separately. While each indicator has different weights, thus contributing differently to the impact that a given supply chain has on the environment, important conclusions can be reached regarding the environmental performance of the supply chains that support the production of each one of these products.

Those areas and suppliers that most negatively impact the environmental performance of the supply chain for the company can be identified clearly and unequivocally. For example, from the analysis of Table 2 it can be concluded that project A has underperformed in more criteria than project B, enabling the areas for improvement to be identified. It is necessary to reinforce the idea that this is a simplistic approach, which should be taken together with a multicriteria model for decision support to decide which is the most advantageous project from the environmental point of view.

At the level of the processes, project A has more positive points than project B. However, project A achieved worse results in the other emissions category (compliance level: 98.75% - A; 98.86% - B) and the level of dangerous waste is higher where an environmental accident occurs. The environmental financial component favors project B. Project B has better results for learning and innovation.

Going further, we can see that project B has levels of energy consumption, water consumption and CO_2 emissions per unit that are respectively around 4, 3 and 6 times the levels given for project A. In other words, the company can develop action plans, in accordance to the principles of the continuous improvement cycle contained in the PDCA cycle. These should be focused on the reduction of energy or water consumption or CO_2 emissions, and developed together with the suppliers involved in the supply of the necessary components for producing project B.

Substantial differences can also be seen in the production of the different types of waste, which could also benefit from the development of action plans. It is as such fundamental that each indicator is analyzed separately and its results are addressed to be able to improve, in an overall way, the environmental performance of the supply chain.

5. Conclusions

The starting point of this study was the assessment of the environmental performance of a supply chain. This objective was achieved with the proposal of the Env_BSC_4_SCPM model and an illustration of its practical application using the example of a first-tier supplier to the automotive industry.

The evaluation process consists of the development of a model for the assessment of the environmental performance of a supply chain, based on four perspectives used in the balanced scorecard, however integrating the environmental concerns into all four perspectives. A group of relevant environmental indicators for each perspective is identified. The significant environmental aspects of the supply chain in question were also taken into account when choosing the indicators.

Using a case study from the automotive industry, the practical application of this model demonstrates its usefulness, revealing both its potential benefits and shortcomings. From the example application, it can be seen which of the two projects has the poorer environmental performance for its supply chain, and in which areas is this performance most lacking. For example, it can be seen that comparably the supply chain for the B key (Project B) is more energy efficient, but worse with respect to dangerous waste production. In this way actions can be take on a sectorial basis for each project, leading to an improvement in the global environmental performance for the supply chain. In this way Env_BSC_4_SCPM can be seen as an effective tool for decision support.

One of the difficulties is related to the correct application of this model, relying on a deep understanding on the environmental impacts of the 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 model, due to the practical difficulties involved in collecting the data. It may be necessary for the organization under study to have significant influence over its suppliers in order to gain the required data. For the case study, a representative response rate was achieved with 105 responses or 77% of the total suppliers for the company.

It should also be noticed that if the assumptions underlying the proxies for *Share_Supplier_i* and *Share_Comp_Supplier_jy* are not valid, the reliability of the resulting metrics is compromised, and could lead to misguided decisions.

As previously noted, there are several paths open to future development of the Env_BSC_4_SCPM model. Widening the frontiers, the next phase may include the application of this model to all the upstream and downstream tiers of the supply chain. It is worth remembering that concepts of sustainability and environmental management are integrating concepts of interactions over the different levels of the chain. As such, it should be made clear that the most precise and correct way to evaluate the environmental performance of the supply chain should measure the impacts from the procurement of the raw materials, through manufacturing, then consumption and final disposal or recycling.

Improvements in the model could include the construction of an aggregate measure, for example an index, to identify which project or supplier has the best environmental performance for their supply chain. This represents a consideration for future work, which would also necessitate the use of multicriteria evaluation models. Another perspective for future work relates to the application of the developed model to other industry sectors, with other impacts, processes, specificities and realities. This would help vindicate the usefulness of the model in a wider, more encompassing way.

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