6th International Conference on Industrial Engineering and Industrial Management.
XVI Congreso de Ingeniería de Organización. Vigo, July 18-20, 2012

A performance measurement framework for monitoring supply chain sustainability

Verdecho MJ[1], Alfaro-Saiz JJ, Rodriguez-Rodriguez R

Abstract In the competitive business environment achieving sustainable supply chains is an issue that is still to be solved despite its relevance. For that reason, there are several tools that have emerged in the last years to aid to understand and support supply chain sustainability. Performance measurement frameworks are useful tools that aid to collect and monitor the evolution of performance of any organization. However, there are few performance measurement frameworks developed in the literature for that purpose, all of them recently published, and lacking of a solid structure that aids to define and implement performance measurement elements in a way that provide an overall evaluation of the sustainability status of the supply chain. This paper introduces a novel performance measurement system to fill this research gap.

Keywords: performance measurement framework; supply chain; sustainability

1.1 Introduction

Collaboration is one strategy used by enterprises to compete and keep focused on their own core competencies. For that reason, many enterprises have engaged in collaborative relationships despite the fact that proper understanding of collaborative implications are often overlooked (Busi and Bititci, 2006; Verdecho et al., 2009) causing collaborative relationships to fail. In order to gain understanding of collaborative contexts, many frameworks and models have been developed to conceptualise the drivers, barriers and effects of collaboration although there are still numerous issues to be solved (Busi and Bititci, 2006).

[1]María José Verdecho (✉)
Research Centre on Production Management and Engineering (CIGIP). Department of Business Organization. Universitat Politècnica de València, Camino de Vera, s/n, 46022 Valencia, Spain
e-mail: mverdecho@cigip.upv.es

One key aspect of collaborative relationships to be solved is their sustainability. Seuring and Müller (2008) define sustainable supply chain as *'the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social into account which are derived from customer and stakeholder requirements'*. Therefore, in sustainable supply chains all three dimensions are to be fulfilled as well as customer and stakeholder requirements. There are various factors that push enterprises to accomplish supply chain sustainability such as legal demands/regulation, response to stake- holders, competitive advantage, customer demands, reputation loss, and environmental and social pressure groups. There is another key factor in the application of sustainable practices that is when a focal enterprise within a supply chain request to the rest of enterprises to meet environmental and social standards e.g. the implementation of these practices in the automotive sector. Despite the existence of success cases implementing sustainable practices, reality does not have to be avoided. Many enterprises have difficulties in the sustainable management of its own business even recognising the fact that its activity depends on its responsibility with its supply chain partners and stakeholders (Dyllick and Hockerts, 2002). For that reason, it is important the design of tools that aid enterprises to develop and manage supply chain sustainability.

In addition, it is essential to note that supply chain sustainability should be derived from the strategy of the own supply chain. This implies that all the enterprises within the supply chain agree on common objectives and those objectives are pursued by all the enterprises in their operations. Otherwise, monitoring sustainability dimensions will be an isolated task lacking value to management. Then, it is necessary to establish mechanisms to deploy the supply chain strategy into operations as well as to monitoring the sustainability of the whole supply chain, which can be measured, and therefore, managed through performance measurement elements (objectives, performance indicators, etc.). Thus, it is needed for those enterprises to define and use a structured performance measurement framework that allows managing performance under various perspectives or dimensions. One of the most important performance frameworks developed in the academic literature and business applications is the Balanced ScoreCard (BSC) by Kaplan and Norton (1992).

Despite its importance, the BSC present some limitations. One limitation is the capability to prioritize, weight and consolidate data from performance elements (Yüksel and Dagdeviren, 2010). In the BSC, once the objectives are defined and performance data gathered from their indicators, it would be useful to aggregate such data in order to obtain a global performance evaluation that will show whether the status of the supply chain is sustainable or not. This paper aims to fill this research gap.

In order to prioritize objectives, it is useful to define weights for the different objectives which can be stated as a multi-criteria problem involving different actors. In the same vein, structuring and consolidating data may also be solved as a

multi-criteria problem. Therefore, multi-criteria methods can contribute to the implementation of the BSC.

The purpose of this paper is to present a multi-criteria performance measurement framework for monitoring supply chain sustainability considering the deployment of the strategy from the strategic level to the operations level and allowing an efficient implementation of its performance measurement elements by introducing an aggregation mechanism that reflects the sustainability status of the supply chain. With this tool, management of the different enterprises of the supply chain will obtain an overall prioritisation of their elements so that decision makers can focus on those elements more relevant for their sustainability and competitiveness.

1.2 Background

Supply chain sustainability is at an initial phase of development (Ageron et al., 2011). This is probably one of reasons why there is few literature in this field, the vast majority published in the recent years. Some of these works have exposed frameworks that aid to conceptualise and classify supply chain sustainability literature such as the works by Seuring and Müller (2008) and Carter and Rogers (2008). Other works present models for evaluating some aspects of supply chain sustainability such as supplier selection (Bai and Sarkis, 2010) or the selection of a supply chain configuration (Sarkis, 2003). In fact, most of these works only consider economic and environmental sustainability and the social dimension has barely been considered (Seuring and Müler, 2008).

Regarding the main focus of this paper, few works deal with the development of performance measurement frameworks for supply chain sustainability. In fact, there are several key characteristics that these frameworks need to fulfil in order to achieve an efficient supply chain sustainability management. First, the performance elements should be derived from the strategy of the supply chain so that the tool supports management of the supply chain enterprises towards the achievement of common objectives. Second, it should provide a methodology that aids to define the necessary steps to be followed to achieve an adequate implementation. Third, it must provide a global performance evaluation that will show whether the status of the supply chain is sustainable or not. These three key characteristics are the basis for analyzing the few performance measurement frameworks for supply chain sustainability (only four works) encountered in the literature as follows.

Erol et al. (2011) presents a fuzzy multi-criteria framework for measuring sustainability performance of a supply chain. Büyüközkan and Berkol (2011) propose a method to design a sustainable supply chain using an integrated analytic network process and goal programming approach in quality function deployment. Hassini et al. (2012) present a performance framework for sustainable supply chain management. However, these frameworks do not consider the strategy of the supply

chain or include an aggregation method to provide a global analysis of supply chain sustainability.

There is only one work, Cetinkaya et al. (2011), that considers the deployment of the strategy of the supply chain into operations. The authors expose a performance measurement system based on the BSC for managing supply chain sustainability. In this case, the framework considers the strategy of the supply chain but lacks of mechanisms to prioritize and weight the objectives defined as well as to evaluate the global status of supply chain sustainability.

The purpose of the next section is to introduce a multi-criteria performance measurement framework that meets all three key characteristics mentioned above.

1.3 The multi-criteria performance measurement framework for monitoring supply chain sustainability

In Verdecho et al. (2010a), the COL-PMS framework for managing performance within collaborative contexts is presented. The COL-PMS framework is an integrated and solid PMS structure based on the BSC for inter-organizational relationships composed by five perspectives (financial, customer, processes, innovation and learning and collaboration perspectives), the first four perspectives are the original ones of the BSC and the fifth perspective is oriented to manage the collaboration aspects (coordination, trust, information sharing, etc.). However, its structure lacks of performance elements to monitor two important dimensions of sustainability: environmental and social dimensions. Thus, the starting point of our work has been to extend the COL-PMS framework to introduce these two dimensions. Then, the framework has been complemented with a methodology that aids to implement the performance measurement framework by using the multi-criteria method the Analytic Hierarchy Process (AHP). AHP, developed by Saaty (1980), aims at integrating different measures into a single assessment for ranking decision alternatives which is the case of our problem. AHP has been used for many applications involving performance measurement criteria such as selecting a supplier (Masella and Ragone, 2000; Verdecho et al. 2010b), selecting performance indicators for supply chain management (Bhagwat and Sharma, 2007), and selecting ERP systems in textile industry (Cebeci, 2009).

The methodology is composed of seven phases. In the phase 1, the performance elements of the performance measurement framework are defined in seven perspectives (financial, customer, process, innovation and learning, collaboration, environmental and social perspectives).

In the phase 2, the AHP method is applied to build a model. The AHP method structures the decision problem in a hierarchy of levels. These levels are linked by unidirectional dependence relationships. In the upper level of the hierarchy, it is defined the ultimate goal of the decision problem. Then, the criteria that contribute to achieve the goal stand in the second level. Then, various intermediate levels

may be modelled to represent different levels of sub-criteria. Finally, in the last level, the decision alternatives are established. The AHP method provides relative weights to each element within a level depending on its contribution to an element linked to it that is located on the immediate upper level. In our case, as we use the AHP model to obtain the weights of the performance objectives, we will have three levels (see Fig. 1.1): vision (supply chain sustainability), perspectives (criteria) and, finally, performance objectives (alternatives).

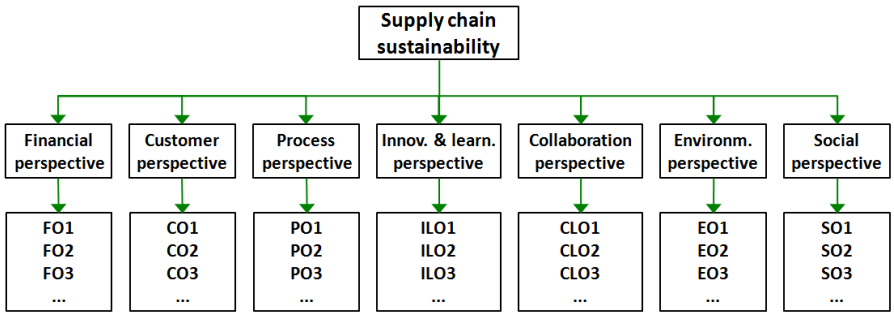

Fig. 1.1 BSC-AHP performance measurement framework for supply chain sustainability

In the phase 3, following the application of AHP, pairwise comparisons are made within each level using the fundamental scale of Saaty (1980), and the local priorities of the compared elements (priority vector) are calculated. Then, the final weights for the alternatives are calculated (phase 4). For that purpose, priorities of objectives are combined together with the sets of priorities of the performance perspectives.

Then, in phase 5, it is performed a sensitive analysis to check how changes in the local weights of one of the perspectives or objectives affect the final priorities previously obtained. The purpose of this phase is to verify that the solution obtained is robust enough. In case that the solution is not robust, it is needed to go back into the phase 3 to analyze the pairwise comparison matrices obtained.

In phase 6, the data regarding the performance indicators is collected, according to the frequency stated in performance measurement framework. Finally, phase 7, it is obtained the overall performance evaluation by multiplying the priority of every performance objective (given by the normalized priority) and the value reached in its corresponding performance indicator. This overall performance evaluation has to be contrasted with a value defined as goal that will represent the degree of sustainability within the supply chain to be reached (defined as a percentage of achievement).

1.4 Case study

The performance measurement framework has been applied to a supply chain belonging to the automotive sector which is composed raw material suppliers, design centres and manufacturing plants working for main OEMs. It has to be noted that this supply chain had already implemented a performance measurement framework so that the development of this approach was easier as the partners had performed a joint definition of a performance measurement framework.

The first phase of the methodology consists of the definition of the performance elements for the seven perspectives. This is a very important task as managing directors of the different enterprises have to reach an agreement on the strategic aspects of the relationship. When enterprises come with different backgrounds, they have to define a common business vision, in this case, regarding the sustainability dimensions. Table 1.1 shows the performance elements (objectives and KPIs) defined for the supply chain for the financial, environmental and social perspectives. It consists of twelve objectives and KPIs.

Table 1.1. Performance elements of the automotive supply chain.

Perspect.	Objectives	KPIs
Financial	FO1 Maintain sales	KPI1 = sales (monthly)
	FO2 Increase high quality product margins by 5%	KPI2 = average of high quality products margin variation (monthly)
	FO3 Increase the capital invested by shareholders 10%	KPI3 = capital invested by shareholders (semester)
	FO4 Increase the number of new investors by 15%	KPI4 =number of investors (quarterly)
Environmental	EO1 Reduce waste by 8%	KPI5 = waste weight (monthly)
	EO2 Reduce energy consumption by 3%	KPI6 = energy consumption (monthly)
	EO3 Increase recycling materials by 5%	KPI7 = recycled materials weight (monthly)
	EO4 Increase number of ISO 14000 certifications by 20%	KPI8 = ISO 14 000 new certifications
Social	SO1 Increase annual training by 20%	KPI9 = number of training hours (semester)
	SO2 Reduce customer complaints by 25%	KPI10 = number of customer complaints (monthly)
	SO3 Increase stakeholder involvement decision-making by 15%	KPI 11 = number of meetings with stakeholders (quarterly)
	SO4 Increase the number of personnel career development programs by 10%	KPI12 = personnel career programs (semester)

These KPIs have been defined by the enterprises based on the objectives that they want to reach. It took three meetings of 1.5 hours, what seems reasonable, to complete the list of objectives and KPIs for the seven perspectives (define the new objectives and KPIs for the new perspectives and check consistency with the objectives and KPIs of the existing performance measurement framework and perform some adjustments).

In the phase 4, the weights of the objectives are obtained. Results showed that the most important objectives representing 65% of the total weight were: FO1 maintain sales (with normalized weight of 0.14), FO3 Increase the capital invested by shareholders (0.11), CO2 Increase market share (0.08), ILO1 Increase innovation capability (0.08), SO2 Reduce customer complaints (0.07), EO2 Reduce energy consumption (0.06), PO1 Decrease product development lead-time (0.06) and CL02 Increase coordination (0.05). It can be observed that the critical objectives belong to all performance perspectives but the importance of the perspectives differ, being the financial perspective the most relevant followed by the customer and the innovation and learning perspectives.

In the last phase it is obtained the final results. The analysis showed that performance was mainly achieved by some of the most relevant objectives (those objectives with highest weight). However, financial objectives, among others, were not accomplished in the desired level (accomplished around 45%) and decision makers have to analyze them further. For those objectives that have not reached the expected results, actions plans are to be developed which allow reassessing the current targets. In general, performance achievement was only reached at the 70% what was under the initial expectations (75%). However, results showed that performance measurement implementation has provided performance knowledge to the supply chain as well as a tool for monitoring sustainability performance.

1.5 Conclusions and research implications

In the recent years, few works have dealt with the development of performance measurement frameworks for supply chain sustainability but they lack of mechanism to weight and consolidate performance data into a global evaluation that allows deciding if the supply chain is achieving its sustainability objectives up to a proper degree. This paper has introduced a performance measurement framework that fills this research gap. Also, it has described a case study in an automotive supply chain providing the main insights in the application of the approach. Further research work will be developed in three main lines: a) validate this performance measurement framework in supply chains of different characteristics and other sectors, b) use other performance structures instead of BSC and other multicriteria methods instead of AHP and c) deploy further the connection between the performance measurement framework for the supply chain and the individual enterprises performance measurement framework.

Acknowledgments This work has been developed within the framework of two research projects titled "Exploration of the hidden information of the performance indicators through its cause-effect relationships in an inter-organizational context" (PAID-06-11-1992) funded by the Polytechnic University of Valencia and "Potenciación de la Competitividad del Tejido Empresarial Español a través de la Logística" funded by the Spanish Ministry of Education and Science (PSE-370500-2007-1).

1.6 References

Ageron B, Gunasekaran A, Spalanzani A (2011) Sustainable supply management: an empirical study. Int. J. Production Economics (in press)

Bai C, Sarkis J (2010) Integrating sustainability into supplier selection with grey system and rough set methodologies. Int. J. Production Economics, 124, 252–264

Bhagwat R, Sharma, MK (2007) Performance measurement of supply chain management using the analytical hierarchy process. Production Planning & Control, 18, 8: 666–680

Busi M, Bititci US (2006) Collaborative performance management: present gaps and future research. Int J of Productivity and Performance Management, 55(1): 7-25

Büyüközkan G, Berkol C (2011) Designing a sustainable supply chain using an integrated analytic network process and goal programming approach in quality function deployment. Expert Systems with Applications 38: 13731–13748

Carter CR, Rogers DS (2008) A framework of sustainable supply chain management: moving toward new theory. Int J of Physical Distribution & Logistics Management, 38(5): 360-387.

Cebeci U (2009) Fuzzy AHP-based decision support system for selecting ERP systems in textile industry by using balanced scorecard Expert Systems with Applications, 36; 8900–8909

Cetinkaya B, Cuthbertson R, Graham E, Klaas-Wissing .et al. (2011) Sustainable Supply Chain Management: Practical Ideas for Moving Towards Best Practice, Springer Verlag.

Dyllick T, Hockerts K (2002) Beyond the business case for corporate sustain- ability Business Strategy and the Environment 11:130–141

Erol I, Sencer S, Sari R (2011) A new fuzzy multi-criteria framework for measuring sustainability performance of a supply chain Ecological Economics, 70(6): 1088-1100.

Hassini E, Surti C, Searcy C (2012). A literature review and a case study of sustainable supply chains with a focus on metrics Int J Production Economics (in press).

Kaplan RS, Norton, DP (1992) The balanced scorecard – measures that drive performance Harvard Business Review, 70(1): 71-79.

Masella C, Rangone A (2000) A contingent approach to the design of vendor selection systems for different types of co-operative customer/ supplier relationships Int J of Oper Prod Mngm, 20(1): 70-84

Saaty TL (1980) The Analytic Hierarchy Process. McGraw-Hill, New York.

Sarkis J (2003) A strategic decision framework for green supply chain management. J of Cleaner Production, 11: 397–409

Seuring S, Müller M (2008) From a literature review to a conceptual framework for sustainable supply chain management. J of Cleaner Production, 16: 1699-1710.

Verdecho MJ, Alfaro JJ, Rodriguez-Rodriguez R (2009) Foundations for collaborative performance measurement. Production Planning and Control. 20 (3), 193–205.

Verdecho, MJ, Alfaro JJ, Rodriguez-Rodriguez R (2010a) COL-PMS: a collaborative performance measurement system. BASYS 2010, IFIP AICT vol. 322, pp. 56-67. Springer, Heidelberg

Verdecho MJ, Alfaro JJ, Rodriguez-Rodriguez R (2010b) A multi-criteria approach to select suppliers based on performance BASYS 2010, IFIP AICT vol. 322, pp.47-55 Springer, Heidelberg.

Yuksel I, Dagdeviren, M. (2010) Using the fuzzy analytic network process (ANP) for Balanced Scorecard (BSC): A case study for a manufacturing firm. Expert Systems with Appl, 37: 1270–1278