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Evaluating the Implementation of GSCM in Industrial Supply Chains: Two Cases in the Automotive Industry

Miguel A. Sellitto*, Sandro A. Bittencourt, Bárbara I. Reckziegel

Universidade do Vale do Rio dos Sinos – UNISINOS – Production and System Engineering Graduate Program
Av. Unisinos 950, 93022-000, Sao Leopoldo, RS, Brazil
sellitto@unisinos.br

The effectiveness of implementation of Green Supply Chain Management (GSCM) can be evaluated by assessing a set of categorical indicators, structured to capture the complexity observed in selected, representative practices usually present in GSCM. The objective of this article is to test and refine a model for the evaluation of the effectiveness of implementation of GSCM in industrial supply chains (SC). Barriers, drivers, green strategy formulation, green procurement, green distribution, reverse logistics, ecodesign, green market, waste disposal, among other greening practices, are present in the model. The research question is how to evaluate the effectiveness of implementation of GSCM in industrial SC? The research method is the qualitative modeling. Previous research proposed a model consisting of three constructs, supported by three sets of green practices, associated with categorical indicators. The constructs are green strategy, green innovation, and green operations. The effectiveness of implementation of each practice is assessed by a five points Likert scale [1 = very high; 0.75 = high; 0.5 = fair; 0.25 = weak; and 0 = null] answered by managers of the SC. Two real-world applications were made in two supply chains of the automotive industries, including suppliers, distributors and logistic operators. The focal companies are a tractors and engines manufacturer, and an electric auto parts manufacturer. The results were integrated by an importance vector obtained by Analytical Hierarchy Process (AHP) method and provided an overall index that can range between 0 % and 100 %. This index informs the global level of implementation of GSCM. The specific results of the cases were 76.25 % and 71.76 %. Improvement actions towards GSCM, conducted by management, should focus on the practices of the constructs with lowest contribution, green strategy and green innovation, respectively.

1. Introduction

Nowadays, environmental objectives have become major technological, societal, and political imperatives (Klemeš et al., 2010). Public and legal pressures have been substantially increased regarding environmental impact caused by industrial activities (Sellitto et al, 2013a). In fact, concerns about climate change and global warming has spurred governments to enact laws regarding the environmental impacts of industrial activity (Gopalakrishnan et al., 2012). In this context, interventions of public agencies as well as pressures from consumers have forced companies to include environmental topics in their new business strategies (Deutsch et al., 2013). This means that regulatory pressures and consumers preferences can influence companies to improve their eco-efficiency (Zhu and Sarkis, 2007) or the environmental performance of their industrial operations (Sellitto et al., 2011). Due to such pressures, paradoxically, some companies now claim for still more restrictive regulations, in order to gain still more advantage and differentiate themselves even more from those competitors that aren´t able to lead environmental initiatives (Kleindorfer et al., 2005). Synthesizing, environmental concerns play now an important role in industrial competition, becoming a central point in operations strategy of certain companies, mainly those belonging to industrial supply chain (SC) networks (Ferretti et al., 2007). A SC network is designed based not only on economic, but also on environmental and social factors (Ng and Lam, 2013).

In many cases, environmental practices and management techniques have generated long-term competitiveness increases in some industries and their internal SC (Paulraj, 2009). For example, in the

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technology-based industry, companies have increased competitiveness incorporating environmental features in their products (Borchardt et al., 2009) and associated services (Borchardt et al., 2011). Research revealed drivers and barriers to the implementation of environmental initiatives in industry, mainly in SC. Some of the main drivers are: compliance to official regulations and customer demands and corporative image (Zhu et al., 2005), the need for elimination or reduction of environmental liabilities in products and services, internal cost reduction, and technological offers from partners (Silva et al., 2013). Some of the main barriers are: little knowledge on the market (Jabbour and Jabbour, 2009), higher costs of new technologies, and incomplete or ambiguous legislation on the theme in some countries (Silva et al., 2013).

One of the most important practices that companies have adopted in environmental management is Green Supply Chain Management (GSCM or GrSCM) (Zhu et al., 2008). The GSCM aims to organize and systematize efforts and environmentally friendly actions within the SC (Seuring and Muller, 2008), redesigning it with the incorporation of environmental practices, such as materials recycling, remanufacturing, reuse of leftovers and ecodesign. In GSCM, companies are urged to integrate their internal practices, like green manufacturing or ecodesign, with external initiatives like cooperation with partners or reverse logistics (Zhu et al., 2012). The on-going practice of GSCM can minimize the total impact of industrial activity along the entire product life cycle (Linton et al., 2008).The motivation for the introduction of green practices can be ethical, reflecting the firm´s values, or economical, reflecting the competition in the industry (Testa and Iraldo, 2010).

Although green practices influence the design and operations of a SC, there are still limited conceptual models on this subject (Koh et al., 2012). Modelling and evaluating green practices in the SC demands specific considerations, since practices occur at dispersed points in the network. If an overall result is to be found, aggregated calculation is needed (Sundarakani et al., 2010). In this context, the purpose of this article is to introduce and test a model for the evaluation of the effectiveness of implementation of GSCM in SC. The research object is the evaluation of the effort done by companies towards GSCM, not the performance achieved in environmental indicators. The research method was the qualitative modeling. After the presentation of the model, two real-world applications were made, in the automotive industry. The results were analysed and used to support directions to improve GSCM practices in the respective SC.

Various models for similar purposes were helpful in this study. Srivastava (2007), Carter and Rogers (2008), and Hervani et al. (2005) provided overviews and proposed frameworks on GSCM and GSCM performance measurement. Sellitto et al. (2010) proposed a model to assess environmental performance in industrial operations. Zhu et al. (2005) organized GSCM in barriers and drivers, operations, and performance. Zhu et al. (2007) used scales and constructs to measure GSCM practices, organized in internal management, green purchasing, collaboration, ecodesign, and investment recovery. Zhu and Sarkis (2004) evaluated relationships between specific GSCM practices and performance. Hervani et al. (2005) organized GSCM practices in: Green Production, and Reverse Logistics; Zhu et al (2005) in: Internal Drivers, Ecodesign, and Investment Recovery; and Lamsali (2006) in: Inbound Greening, Outbound Greening, and External Barriers. Li (2011) proposed twenty indicators organized in seven constructs: ecodesign, green purchasing, green manufacturing, green market and consumption, recycling capability, information technology, and comprehensive management support. Kurien and Qureshi (2012) proposed a performance measurement system for GSCM based on Analytic Hierarchy Process (AHP) and Balanced Scorecard (BSC). Shi et al. (2012) proposed a conceptual structured model of GSCM, with theoretical indication of cause and effect relationships. Govindan et al. (2014) used AHP in order to identify essential barriers in GSCM adoption. Kainuma and Tawara (2006) used multiple attribute utility theory in managing green performance in supply chains. Sundarakani et al. (2010) studied how to measure and control the carbon footprint across SC.

The rest of the article is organized in: (i) the model; (ii) application; and (iii) conclusion and continuity.

2. The Model

In previous research, a structured framework for the evaluation of GSCM in a SC was organized. The structure is composed by three constructs and sixteen practices, each one associated with one variable. An initial, partial application was presented and completely referred in Sellitto et al. (2013b). The evaluation procedure relies on categorical judgement. The effectiveness of implementation of each practice is assessed by a five points Likert scale [1 = very high; 0.75 = high; 0.5 = fair; 0.25 = weak; and 0 = null] fulfilled by managers of the SC. An overall index (GSCME) resumes the level of implementation of GSCM in the SC.

The constructs are green strategy, green innovation, and green operation in the context of the SC. Green strategy is structured in: (i) green strategy formulation; (ii) measurement and control of performance; (iii) cooperation with partners and adaptation; (iv) complexity management and communication; (v) barriers; and (vi) drivers. Green innovation is structured in: (i) green processes, (ii) ecodesign; (iii) green products; and (iv) green market. Green operation is structured in: (i) green purchasing; (ii) green manufacture; (iii) green distribution; (iv) reverse logistic; (v) disposal; and (vi) pollution mitigation. Table 1 synthesizes the model.

Table 1: Model for the evaluation of the implementation of GSCM in a SC

Overall	Construct	Variable	Describes the effectiveness of
GSCME	Strategy	Green strategy formulation	The formulation by SCM (Supply Chain Management) of goals and plans, development of capabilities, allocation of resources, and value added to customers, including EMS
		Measurement and control of performance	Quali-quantitative measurement or assessment models to help SCM controlling the execution of the strategy
		Cooperation with partners and adaptation	The cooperation with and mutual adaptation among partners managed by SCM
		Complexity and communication	The management by SCM of the variety and diversity among partners, including technology and communication
		Barriers	The management by SCM of the factors that difficult the implementation and how the SCM prevent those difficulties
		Drivers	The way SCM take advantage from factors that make more easy the implementation of green initiatives
	Innovation	Green process	The adoption of new process technologies, raw materials and lean/agile related initiatives
		Ecodesign	The management of environmental concerns and life cycle analysis in new products, services, and processes
		Green products	New products launching with environmental features or elimination of liabilities
		Green market	Efforts to identify and describe a potential market interested to buy green products, eventually more expensive
	Operation	Green purchasing	Green specs, vendor selection, inspection procedures, inbound logistics and reward policies to suppliers
		Green manufacturing	The implementation of environmental procedures in manufacturing activities, regarding materials and energy
		Green distribution	Warehousing, packing, outbound logistics and reward policies to distributors and retailers that accomplishes green goals
		Reverse logistics	Reusing, recycling, remanufacturing, integration with direct routes and warehousing, and closed-loop SC activities
		Disposal	The methods that the company uses to dispose materials when reverse logistics is not possible
		Pollution mitigation	The control of final results and pollution measurements in atmosphere, water, soil, and wild life

The model is coherent with the study of Testa and Iraldo (2010), in which the authors verified some hypothesis: (i) image, reputation and the need to be a follower (strategy); (ii) products and/or process development needs (innovation); and (iii) cost saving (operation) influencing companies to adopt GSCM practices. It is also coherent with the study of Srivastava (2007) that separated studies in GSCM in three major blocks: Importance of the GSCM, Ecodesign, and Operations. Seuring e Muller (2008) also classified studies in GSCM in: pressures and barriers, ecodesign, and green purchasing. Kleindorfer et al. (2005) separated the research on sustainable operations in: leaning and greening operations management (strategy), new products and new processes (innovation), and remanufacture and closed-loop supply-chain (operation). Finally, Li (2011) identified twenty practices that can explain the level of implementation of GSCM in an industry. Some of them are equivalent to those used in our model and can be aggregated.

3. Application

The research question was: how to evaluate the effectiveness of implementation of GSCM in an industrial SC? The research method was the qualitative modeling. Two real-world applications in SC from the automotive industry, both in Southern Brazil, illustrate the method. In focus group sessions, mediated by researchers, three managers of each focal company prioritized constructs of Table 2 with AHP (as AHP is widely described in literature, no further comment is necessary). The members of the groups work in the respective SCM, with managerial actions involving suppliers, manufactures and distributors of the SC.

The preference matrices, the prioritization vectors, and the consistency ratios (CR%) for both cases are shown in Tables 2 and 3, respectively. As both CR% are less than 10 %, the choices and respective matrices can be considered consistent and the resulting vector can be used as a preference structure (Saaty, 1980).

Table 2: Preference matrix and prioritization for the first case, a tractor and engine manufacturer

	Operation	Strategy	Innovation	vector	CR%
Operation	1	2	3	54.0 %	1 %
Strategy	½	1	2	29.7 %	
Innovation	1/3	1/2	1	16.3 %	

Table3: Preference matrix and prioritization for the second case, an electrical auto part manufacturer

	Innovation	Strategy	Operation	vector	CR%
Innovation	1	2	3	54.0 %	1 %
Strategy	½	1	2	29.7 %	
Operation	1/3	1/2	1	16.3 %	

For each SCM, the group also fulfilled scales representing the situation of each indicator, regarding the effectiveness of each included management technique. Based on the given prioritization and answers, overall indexes were calculated and gaps analysed. The value for the judgement is an absolute number. The values for importance and evaluation are given in percentage points (pp) and their sum in percentage (%).Table 4 shows the results. For the variables, only a keyword was referred in the table.

Table 4: Results for the first and second case

	First case			Second case		
Variable (keyword)	Judgement	Importance (pp)	Evaluation (pp)	Judgement	Importance (pp)	Evaluation (pp)
Formulation	1	9.00	9.00	0.75	4.95	3.71
Performance	0.75	9.00	6.75	1	4.95	4.95
Cooperation	0.75	9.00	6.75	0.75	4.95	3.71
Complexity	0.75	9.00	6.75	0.5	4.95	2.48
Barriers	0.75	9.00	6.75	0.5	4.95	2.48
Drivers	0.75	9.00	6.75	0.75	4.95	3.71
Process	0.5	4.08	2.04	1	13.50	13.50
Ecodesign	0.5	4.08	2.04	0.75	13.50	10.13
Green products	0.75	4.08	3.06	0.5	13.50	6.75
Green market	1	4.08	4.08	0.5	13.50	6.75
Purchasing	0.75	4.95	3.71	0.75	2.72	2.04
Manufacturing	0.75	4.95	3.71	1	2.72	2.72
Distribution	0.75	4.95	3.71	0.75	2.72	2.04
Rev. logistics	0.5	4.95	2.48	1	2.72	2.72
Disposal	1	4.95	4.95	0.75	2.72	2.04
Pollution	0.75	4.95	3.71	0.75	2.72	2.04
Total		100.00 %	76.25 %		100.00 %	71.76 %

Both companies have an overall index greater than 70 %. This result can be interpreted in two ways: (i) companies execute satisfactorily more than 70 % than would be considered an ideal implementation of GSCM; or (ii) companies do only 70 % of what they should do. In both cases, grows the relevancy of the missing part, the gap. This means, the GSCM techniques that don´t allow the evaluation to reach 100 %. In this context, measures are necessary to make more effective the efforts of GSCM developed by the companies.

Indicators of the same construct are expected to be correlated to each other (Sellitto et al., 2012). So, improvement actions focused on a particular indicator are also expected to influence, although indirectly, other indicators in the construct. In the first case, the construct with the greatest difference between importance and evaluation is green strategy (importance = 54 pp, evaluation = 43 pp, gap = 9 pp). In order to fulfill the gap, the

company must focus on the five techniques that haven´t received the highest evaluation (all but formulation). So, in order to improve and qualify GSCM efforts, the company should first improve the strategic process, by refining performance measurement, exploring more the cooperation with partners, managing better communication, exploring drivers and preventing barriers to the development of the GSCM. Regarding mentioned correlations, single actions can at same time influence more than one indicator.
In the second case, the construct with the greatest difference between importance and evaluation is green innovation (importance = 54 pp, evaluation = 37.3 pp, gap = 16.8 pp). In order to fulfill the gap, the company must focus mainly on green products and green markets. The company must focus on key actions that can modify the situation and improve the implementation of green products and green markets. Regarding previous mentioned correlations, those actions probably will affect also ecodesign and processes.

4. Conclusions

This article is an early attempt to evaluate and eventually control the effort done by a company towards GSCM. This means that the study is focused on evaluating or estimating the effectiveness of a set of selected green practices spread over the entire supply chain. We limit our research to two four-echelon locally-based supply chain, involving supply, manufacture, distribution/sales, and returns. Its purpose was to introduce and test a model for the evaluation of the effectiveness of the implementation of GSCM in industrial supply chains. As the model is categorical, its evaluation relies on the opinion of managers and experts and in the research procedures that must assure reliability and validity to the results.
The main conclusions of the article are: (i) in the first SC, GSCM must focus on the green strategic process; and (ii) in the second case, GSCM must focus on the green innovation process.
The model helps to understand what practices support the execution of the green strategy in the SCM. Consequently, the method helps giving information to control the execution. This article can be extended by considering also the opinions of practitioners of partner companies. In addition, other multicriterial methods should be tested in further applications. Finally, in-depth case studies are to be conducted in the studied companies, in order to investigate and understand the motivations for the adoption or not, and in the case of adoption, for the intensity observed in which each managerial practice. The proposed model is by its very nature incomplete. Whenever new practices are consolidated in the literature, they should be incorporated. In particular, green innovation must be improved, since only four practices have been by now considered.

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