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LARG index: A benchmarking tool for improving the leanness, agility, resilience and greenness of the automotive supply chain

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LARG index

A benchmarking tool for improving the leanness, agility, resilience and greenness of the automotive supply chain

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Abstract

Purpose – The purpose of this paper is to suggest a lean, agile, resilient, and green (LARG) index as a benchmarking tool to assess the leanness, agility, resilience and the greenness of the automotive companies and corresponding supply chain (SC).

Design/methodology/approach – The proposed index incorporates LARG supply chain management paradigms and corresponding practices being both weighted according to their importance for the automotive SC sustainability. The Delphi technique is used to obtain the weights for each SC paradigm and a linear aggregated method is proposed. A case study approach related to the automotive SC is chosen to illustrate the LARG index application.

Findings – The case study results confirmed the usefulness and ease of application of LARG index in a real world SC. The application of the suggested index to a set of companies, and consequently to their SC, makes possible to identify: the better and worst performer company in each paradigm, the LARG practices with higher levels of application among the companies, the LARG index for each company and also for the corresponding SC. This becomes an important benchmarking tool since comparative analysis regarding the LARG behaviours are possible to perform with the suggested index.

Research limitations/implications – More LARG practices could be considered to improve the robustness of the index. Future studies should be conducted across more companies for improving the effectiveness of the approach, and more members should be included in the panel of Delphi technique for enhancing the validity of the suggested approach.

Practical implications – SC companies will be able to assess their performance in terms of leanness, agility, resilience and greenness. A study like this could encourage all automotive companies to benchmark their organizations as regards their competitors, the best in class, and also the industry average.

Originality/value – This paper contributes to the literature by introducing a new index for measuring the leanness, agility, resilience and greenness of companies and SCs. This index can be used by managers as a benchmarking tool to identify their LARG behaviour and compare it with their SC partners and seek for improvement.

Keywords Decision support systems, Supply chain management, Agility, Lean production, Industrial performance, Lean, Green, Agile, Index, Automotive industry, Resilient

Paper type Research paper

1. Introduction

The increased pressure from community and environmentally conscious consumers has lead to rigorous environmental regulations, forcing companies to integrate environmental and social concerns into their management practices (Rao and Holt, 2005; Paulraj, 2009). As Pagell and Wu (2009) assert, beyond the immediate economic concerns, business needs to deal with environmental and social issues in order to be more sustainable. Vachon and Klassen (2008) stressed that environmental management

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has evolved from the internal organization focus to a supply chain (SC) perspective. Supply chain management (SCM), besides increasing organizational effectiveness, enhancing competitiveness, customer service and profitability, is also a crucial influence on the sustainable development of a business (Azevedo *et al.*, 2012a, b, c).

The sustainable development of business means adopting business strategies that meet the needs of the organization today while protecting, sustaining and enhancing the human and natural resources that will be needed in the future (van Someren, 1995). It is crucial to implement management practices that not only promote the organization and overall SC efficiency, but also that focuses on sustainability, this is, considering social, economic and environmental concerns. Among the diversity of SCM issues, the supplier management for environmental and social risks and the triple bottom line performance (economic, social and environmental performance) improvement are considered critical to ensure SC sustainability (Seuring and Muller, 2008). Therefore management systems play an important role and can be related to the minimum performance required. Among the various SCM paradigms the following ones are considered critical to ensure SC sustainability: the lean, the agile, the resilient and the green paradigms (designated by the acronym LARG) (Carvalho *et al.*, 2010, 2011, 2012; Azevedo *et al.*, 2012a).

The best combination of LARG practices to implement in companies is not a trivial question; there are some trade-offs among the paradigms. A representative example is the presence of strategic inventory, it reduces the organization's vulnerability to unexpected events that may interrupt materials supply, but it could hide the causes of a bad SC performance and generate material obsolescence; for that reason, the lean and green paradigms prescribe the minimization of inventory levels. The utilization of benchmarking tools can assist the managers in the selection of the best combination of LARG practices, since it allows discover new ideas, methods and processes as well as to identify the highest standards of excellence (Björklund, 2010). Also it could provide insights on the best management practices with higher positive impact on performance.

In the literature there is a set of sustainability benchmarking tools (e.g. Hong *et al.*, 2012; Colicchia *et al.*, 2011; Presley and Meade, 2010; Björklund, 2010; Hemming *et al.*, 2004). However, none is focused on the four researched paradigms. Despite the relevancy of the topic, there is a lack of feasible indexes that makes possible to develop a benchmarking analysis to compare the level of leanness, agility, resilience and greenness in the companies that belong to the same SC. To address this research gap this paper aims to propose an index named by LARG index to evaluate the degree of leanness, agile, resilience and greenness that companies and respective SC possess. Also it intends to give continuity to the already comprehensive investigation developed in the domain of LARG paradigms in the SCM context. This research extends the works of Azevedo *et al.* (2012b, c) that propose two indexes: an "Ecosilient index" to assess the greenness as well as the resilience and an "Agilean index" to assess the agility and leanness of individual companies and the corresponding SC. These previous efforts motivated the necessity to expand the research to the development of benchmarking tools settled on LARG practices as an inductor of the SC sustainability. A benchmarking tool will be proposed, in the form of an index, to support the assessment of each paradigm implementation level considering the organization and respective SC perspective. Namely it intends to:

- propose an index named by LARG to reflect the leanness, agility, resilience and the greenness of companies and corresponding SC; and
- illustrate the application of the integrated index in a case study related to the automotive SC.

Using the proposed benchmarking tool organizations will be able to improve not only their sustainability but also of the SC where they are inserted.

The paper is organized as follows. Following the introduction, a literature review on the four paradigms LARG are described from a SCM perspective being pointed out various management practices. Subsequently, an integrated assessment model is proposed to evaluate the company's and the SC's level of leanness, agility, resilience and greenness. Next, are presented some insights on the LARG index construction including the description of the Delphi method. After that, a case study approach is developed to illustrate the suggested LARG index application. Finally, some conclusions are drawn.

2. Theoretical background

2.1 LARG SCM paradigms and sustainability

According to Redclift (1993) sustainability involves a compromise between the natural environment and the pursuit of economic growth. Among the diverse interpretations of sustainability three interdependent and interrelated components can be found: society, environment and economy. These are consistent with the notion of a triple bottom line (people, planet and profit) (Seuring and Muller, 2008). The term sustainability has been applied in most cases to an individual company context (Hahn and Scheermesser, 2006; Eweje, 2011), but it should also be a concern and a priority to SCs (Ashby *et al.*, 2012; Xia and Tang, 2011; Winter and Knemeyer, 2013). Rodrigue *et al.* (2001) highlight that the integration of environmental concerns into logistic systems are leading to the creating of trade-offs or paradoxes. For example in the global and integrated SC's the just-in-time (JIT) practices are leading to more flexible and efficient distribution systems, but at the same time the frequent delivery of small quantities demands more energy consumption and produces a high level of air emissions. Those authors classify the green logistics paradoxes in six dimensions: costs, time/flexibility, network, warehousing and e-commerce. More recently Carvalho *et al.* (2011) propose the deployment of LARG practices in the SC context as a way of overcoming these paradoxes: to reduce cost, improve flexibility and responsiveness, reliability and reduce the SC negative environmental externalities. The adoption of LARG SCM practices is also an important contribution to improve the sustainability of individual companies and corresponding SC.

The lean approach essentially focuses on waste reduction as a means to increase actual value-added, to fulfil customer needs and maintain profitability (Womack *et al.*, 1991). Disney *et al.* (1997) extend the lean to the SC context; they state that lean processes create value through the elimination of "waste" in the SC. Several companies have successfully implemented lean principles to achieve sustainable benefits. Lean principles are viable to ensure sustainable benefits (Fliedner, 2008). The application of lean principles promotes the minimization of negative environmental impacts, i.e. the company is both lean and green (Carvalho *et al.*, 2010). The elimination of environmental wastes using lean initiatives enables the acquisition of business values (Kaebernick *et al.*, 2003). The effective interaction between lean and sustainable efforts enables companies to avoid risks of noncompliance with regulatory requirements and explore new ways of improving operational and environmental performances (Herron and Braiden, 2006). Anand and Kodali (2008) stress also that a lean SC involves integrating all the upstream and downstream activities into a coherent whole looking for ways to reduce demand variation by simplifying, optimizing, streamlining and creating capability by using assets more effectively than in traditional systems. Some lean practices that can be found in the literature are: respect for people (Treville and Antonakis, 2006); customer

relationship (Anand and Kodali, 2008); quality management (Brown and Mitchell, 1991); JIT (Gurumurthy and Kodali, 2009); pull production/flow (Brown and Mitchell, 1991; Anand and Kodali, 2008); supplier relationships (Gurumurthy and Kodali, 2009); and mistake-proofing (Stewart and Grout, 2001). At the operational level, the Lean paradigm is implemented by using a number of techniques such as kanban, 5S, visual control, takt-time, poke-yoke and SMED (Melton, 2005).

Since customer requirements are continually changing it is more difficult to SCs attain their objectives, this is delivering the right product, in the right quantity, in the right condition, to the right place, at the right time, for the right cost. To overcome these conditions Hoek *et al.* (2001) suggest that flexible and responsive capabilities in terms of SCs processes, networks and how they are integrated across other organizations should be developed, that is, they should be Agile. The deployment of agile practices contributes also to the sustainability improvement. The flexibility of companies to produce different products and services, as well as to reorganize their business structures, is a fundamental requirement of agile systems. Agile practices have been deployed by companies as a strategy for responding to the rapid growth and continuously changing market, as a method of organizational sustainability (Flumerfelt *et al.*, 2012). Some of the main agile practices in the SC context are: to increase the frequencies of new product introductions (Agarwal *et al.*, 2007); to speed customer service (Swafford *et al.*, 2008); to develop centralized and collaborative planning (Agarwal *et al.*, 2007); to use IT to coordinate/integrate activities in manufacturing and in design and development (Lin *et al.*, 2006; Swafford *et al.*, 2008); to have the ability to change delivery times of supplier's order (Swafford *et al.*, 2008); to reduce development cycle times (Swafford *et al.*, 2008); and to increase the frequencies of new product introductions (Agarwal *et al.*, 2007).

Today's marketplace is also characterized by higher levels of turbulence and volatility. As a result, SCs are more vulnerable to disruption and, in consequence, the risk to business continuity has increased (Azevedo *et al.*, 2008). Whereas in the past the principal objective in SC design was cost minimization or service optimization, the emphasis today has to be upon resilience (Tang, 2006). Resilience is referred as the SC ability to cope with unexpected disturbances (Carvalho *et al.*, 2012). The aim of resilience strategies has two manifolds (Haimes, 2006): to recover to a desired state of the system that has been disturbed, within an acceptable time period and at an acceptable cost; and to reduce the disturbance impact by changing the effectiveness level of a potential threat. The relationships between resilience and sustainability can be found in the literature in a farm SC context (Darnhofer *et al.*, 2010; Eakin and Wehbe, 2009). According to these authors a farm is a complex system that is unlikely to be resilient per se, but can be resilient given its ecological, economic and political context. For this kind of system to achieve sustainability, it must be able to take advantage of current opportunities, while managing the conditions that expand future possibilities. It must ensure adaptability and transformability and may allow the identification of factors enhancing system' resilience so as to achieve sustainability. A representative sample of the main resilient practices in the SC context founded in the literature is: strategic stock (Tang, 2006); lead time reduction (Christopher and Peck, 2004); maintaining a dedicated transit fleet (Rice and Caniato, 2003); flexible supply base/flexible sourcing (Tang, 2006); sourcing strategies to allow switching of suppliers (Rice and Caniato, 2003); creating total SC visibility (Iakovou *et al.*, 2007); flexible transportation (Tang, 2006); developing visibility to a clear view of downstream inventories and demand conditions (Christopher and Peck, 2004).

The green management approach is recognized as contributing to cost reduction by using resources, such as water, energy and raw materials, more efficiently (Walker *et al.*, 2010). Companies that do not use resources efficiently will miss out on potential commercial opportunities and will lose out as prices for scarce commodities rise. In addition, to achieve higher levels of sustainability, environmental issues must be integrated into SCM. Srivastava (2007) defined green SCM as an "integrating environmental thinking into SCM, including product design, material sourcing and selection, manufacturing processes, final product delivery to customers as well as end-of-life disposal".

There exists a relationship between the adoption of green management practices and the sustainability. Some authors (Hart, 1997; Azevedo *et al.*, 2012a) highlight the specific contribution of the development of green products by companies for the sustainability. This is expected to occur since a product is considered green "when its environmental and societal performance, in production, use and disposal, is significantly improved and improving in comparison to conventional or competitive products offerings" (Peattie, 1995, p. 181). Some of green practices suggested in the SC context are: environmental collaboration with suppliers (Holt and Ghobadian, 2009); ISO 14001 certification (Gonzalez *et al.*, 2008); minimization of waste (Rao and Holt, 2005); reverse logistics (Gonzalez *et al.*, 2008); environmental monitoring upon suppliers (Paulraj, 2009); to reduce energy consumption (Zhu *et al.*, 2008); to reuse/recycling materials and packaging (Paulraj, 2009); environmental collaboration with the customer (Hu and Hsu, 2006); reverse logistics (Srivastava, 2007).

2.2 Utilization of indexes as a benchmarking tool

Up until recent years benchmarking was almost solely used to compare business or product performance. The move from performances to practices can be seen as the evolution of the concept itself (Voss *et al.*, 1997). Synthetic benchmarking refers to the use of analysis and comparison tools which contain knowledge that is codified and can be easily understood and used even when certain managerial skills are lacking (Ashton, 1998; Flynn *et al.*, 1995).

Benchmarking with a focus on performance is underway by gathering quantitative information making possible comparison to the target, highlighting any gaps between the benchmark and the performance under consideration. According to Drew (1997) benchmarking on performances is only useful when it is used as a diagnostic tool in the initial stages of a benchmarking process, i.e. when this process is considered to be a tool for organizational improvement. The processes behind the performances must be analysed to understand what improvements should be made and how to go about making them. It is also difficult to carry out a benchmarking on performances because it is very much conditioned by situational factors.

Benchmarking on practices is different because it forces the company to "understand" its own practices as well as those presented by the tool, starting from the first stage of application and the process of "comparing" the practices used with those codified in the tool can only be carried out once this "understanding" has taken place. Furthermore, the definition of gaps between current practices and the targets contributes not only to highlight the need to activate improvements but also to suggest how the improvements can be carried out promoting a learning process and working as an engine for change (Elmuti and Kathawala, 1997).

In the literature some indexes have been proposed as benchmarking tools. From a macro perspective, Huggins (2003) suggests a single index to assess the relative

economic competitiveness of regions and localities in the UK, so performing local and regional benchmarking analysis. Also the World Bank develop a logistic performance index (http://lpi.worldbank.org/) to serve as a benchmarking tool to help countries identifying the opportunities in their performance on trade logistics. This is an index that evaluate the countries international logistic trade performance (customs performance, infrastructure quality and timeliness of shipments) and internal determinants for overall logistic performance (infrastructure, services, border procedures and time, and supply chain reliability). Considering the sustainability perspective Lau (2011) suggests a composite index to perform a benchmarking analysis on the green logistics performance among industries and countries. However, there are indexes develop considering the company perspective, e.g. Tavana *et al.* (2003) propose a total quality index as a benchmarking tool for helping managers assess a total quality management programme in organizational processes. Considering the SC context Azevedo *et al.* (2012b) propose an index to assess the greenness as well as the resilience of a SC and in a parallel study they also develop an index to assess the agility and leanness of individual companies and the corresponding SC (Azevedo *et al.*, 2012c). Since there are trade-offs and synergies among the paradigm deployment in SC sustainability new integrative indexes are need to deal with the sustainability challenges and give managers information to support their making decision on the kind of practices they must invest on attending to their positive impact on companies and corresponding SC performance. In this study an aggregated index will be also suggested as a benchmarking tool for individual companies and SC comparison as regards the leanness, agility, resilience and greenness behaviour.

3. Development of a LARG index

The main objective of this section is to propose an LARG index to assess the companies and the SCs level of leanness, agility, resilience and greenness. The rationale behind this model is that since the SC is composed by a set of n companies, each one with different implementation degrees of LARG practices, the SC overall behaviour will be computed by the aggregation of individual companies' behaviours. In this research the methodology suggested by Azevedo *et al.* (2012b, c) has been followed in the construction of the LARG index. The deployment of LARG practices within the companies and respective SC intents to achieve compatibility between the application of lean production principles (based on the zero stock, without waste and activities that do not add value), with agility (which assume the adjustment of the markets in constant change), at the same time considering the necessary production system resiliency to possible disturbances and risks (some can be predictable, but others occur in a completely unexpected way) and also green principles to reduce the environmental impacts.

3.1 Integrated assessment model for the LARG index

In a first step it is necessary to compute the individual company behaviour according to each four research paradigms. The hierarchical relationships evolved in this assessment are described in Figure 1.

Each indicator in Figure 1 intends to reflect the individual company behaviour in terms of its leanness, agility, resilience and greenness. These indicators are obtained by combining the information from a set of sub-indicators: lean SC practices (P_{L1}, …, P_{Lv}); agile SC practices (P_{A1}, …, P_{As}); resilient SC practices (P_{R1}, …, P_{Rt}); and green SC

practices (P_{G1}, …, P_{Gv}). Each sub-indicator is assessed on a five-point Likert scale where 1 means "practice not implemented" and 5 "practice totally implemented".

For each company a set of four indicators is proposed:

(1) lean behaviour (B_L): it represents a set of SCM practices implemented by the company to maximize customer value while minimizing waste;

(2) agile behaviour (B_A): it reflects the company's ability to respond rapidly and cost effectively to unpredictable changes;

(3) resilient behaviour (B_R): it represents a set of SCM practices reflecting the company's ability to cope with unexpected disturbances; and

(4) green behaviour (B_G): it represents the set of SCM practices to achieve corporate profit and market-share objectives by reducing environmental risks and impacts while improving the company ecological efficiency.

It is supposed that for each company the indicators can be computed aggregating the correspondent individual sub-indicators according to their importance. For each company j a generic formula in Equation (1) can be used to compute each indicator B_x according to the paradigm x, being $x = L$ (for lean), A (for agile), R (for resilient) or G (for green). Equation (1) shows that the company behaviour according to a particular paradigm is function of each practice implementation level (P_{xy}) and corresponding weight (w_{xy}):

$$(B_x)_j = f\left[w_{x1} \times (P_{x1})_j, \ldots, w_{xy-1} \times \left(P_{xy-1}\right)_j, w_{xy} \times \left(P_{xy}\right)\right]$$

$$\text{being } w_{xi} \geqslant 0 \text{ and } \sum_i w_{xi} = 1 \tag{1}$$

where $(B_x)_j$ represents the behaviour of company j according to the paradigm x ($x = L, A, R$ or G). $(P_{xi})_j$ represents for company j the implementation level of practice i of paradigm x. A total of y practices are considered for each paradigm. Each practice implementation level is assessed on a five-point Likert scale where 1 means "practice not implemented" and 5 "practice totally implemented. w_{xi} is the weight of practice i of paradigm x. This weigh is common for all companies belonging to the

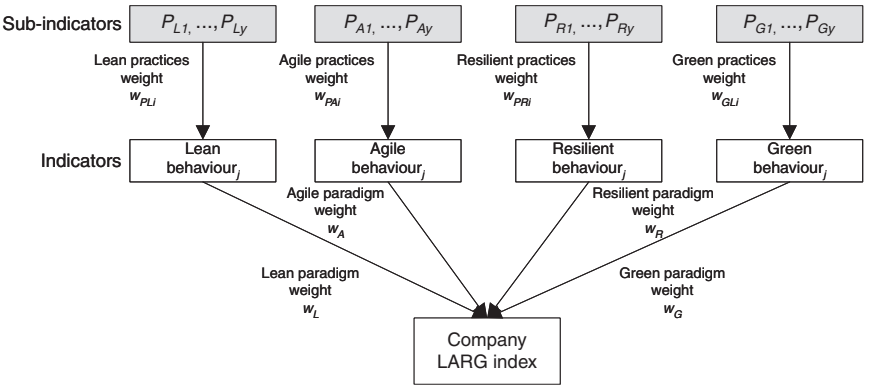

Figure 1.
Hierarchical relationships evolved in the LARG company behaviour assessment

same SC. The weight values reflect the importance of each practice in the SC. It assumes values between 0 (not important) and 1 (extremely important).

Equation (1) shows that the company behaviour according to a particular paradigm is function of each practice implementation level and the corresponding weight. For each company the behaviour B_x according to each paradigm goes from 1 (none paradigm practice implemented) to 5 (all the research paradigms practices are implemented).

The LARG index for a particular company ($LARG_j$) is a composite indicator which is function of the company indicators of each paradigm and corresponding weights:

$$LARG_j = f\left[w_L \times (B_L)_j, w_A \times (B_A)_j, w_R \times (B_R)_j, w_G \times (B_G)_j\right]$$

$$\text{being } w_L, w_A, w_R, w_G \geqslant 0 \text{ and } w_L, w_A, w_R, w_G = 1 \tag{2}$$

where $(B_x)_j$ represents the company j behaviour according to the paradigm x ($x = L$, A, R or G); and w_L, w_A, w_R, w_G, represent, respectively, the weight of LARG paradigms. The weight values reflect the importance of each paradigm for the SC sustainability. It assumes values between 0 (not important) to 1 (extremely important).

The company LARG index goes from 1 (none paradigms are deployed in the company) to 5 (all the paradigms are completely deployed in the company).

To assess the SC LARG index ($LARG_{sc}$) the individual companies' LARG behaviours can then be used as sub-indicators according to the hierarchical relations of Figure 2.

The individual company j behaviour $(B_x)_j$ can be aggregated using the following equation to obtain each SC indicator according to each paradigm (SCI_x):

$$SCI_x = \frac{\sum_{j=1}^{n} (B_x)_j}{n} \tag{3}$$

where n is the number of companies considered in a particular SC; and $(B_x)_j$, is the company j behaviour according to the paradigm x ($x = L$, A, R or G).

The LARG index for a particular SC ($LARG_{SC}$) is a composite indicator which is a function of the SC indicators of each paradigm and corresponding weights:

$$LARG_{SC} = f(w_L \times SCI_L, w_A \times SCI_A, w_R \times SCI_R, w_G \times SCI_G)$$

$$\text{being } w_L, w_A, w_R, w_G \geqslant 0 \text{ and } w_L, w_A, w_R, w_G = 1 \tag{4}$$

where SCI_L, SCI_A, SCI_R, SCI_G, represents, respectively, the SC behaviour according to LARG paradigms; and w_L, w_A, w_R, w_G, represents, respectively, the weight of LARG paradigms. The weight values reflect the importance of each paradigm for the SC sustainability. It assumes values between 0 (not important) to 1 (extremely important).

The $LARG_{SC}$ index goes from 1 (none paradigms put into practice in the SC companies) to 5 (all the paradigms are completely deployed in the SC companies).

3.2 LARG index construction

The proposed model to assess the SC behaviour in terms of LARG paradigms can be used to derive an index considering the following: the set of LARG practices should be appropriate to the type of SC; the weight of the practices and paradigms should be accessed by a set of experts; and the variables independence should be asses to a correctly interpretation of the composite additive weighting index.

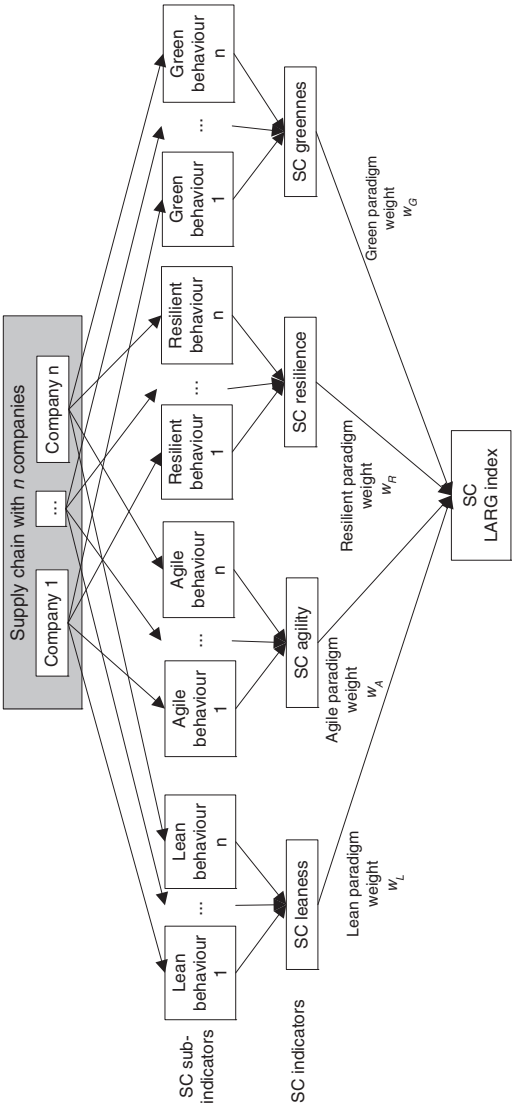

Figure 2.
Hierarchical relationships involved in the supply chain LARG index

Considering the theoretical model proposed in the previous section, a model for the automotive SC is derived considering the set of LARG constructs and respective weights proposed by Azevedo *et al.* (2012b, c) as presented in Table I. In this table the LARG constructs are defined using a set of sub-indicators (which are management practices) as in Azevedo *et al.* (2012b, c).

In previous research there are no evidences of the relative weights of paradigms. In the indexes proposed by Azevedo *et al.* (2012b, c) it was considered that the paradigms have equal importance. However, this assumption is not followed in this study. In this paper a Delphi approach is used to compute the weight for each SCM paradigm. Each SCM paradigm importance was measured using a score between 1 and 5, with 1 representing "nothing important" and 5 representing "extremely important" to the automotive SC sustainability. Then the weight for each paradigm was computed by using the following equation (Yeung *et al.*, 2007):

$$w_x = \frac{M_x}{\sum_{g=1}^{n} M_g} \tag{5}$$

where w_x represents the weighting of the paradigm x; M_x represents the mean rating of the particular paradigm x; and $\sum_{g=1}^{n} M_g$ represents the summation of mean rating for each paradigm.

3.2.1 Delphi study. The Delphi technique is a highly formalized method of communication that is designed to extract the maximum amount of unbiased information from a panel of experts (Chan *et al.*, 2001). It offers important advantages in situations where it is crucial to define areas of uncertainty or disagreement, as it is the case. The Delphi technique has been used to determine indexes in SC context, such as: to propose a risk assessment index (Rao and Schoenherr, 2011; Gaudenzi and Borghesi, 2006); to develop SC performance indexes (Nunlee *et al.*, 2000); to propose a "fragility index" for helping SC managers assess sources and potential costs of fragility and sustainability (Stonebraker *et al.*, 2009); and to propose a collaboration index to measure the extent of collaboration between retailers and manufacturers in the apparel SC (Anbanandam *et al.*, 2011). According to Linstone and Turoff (1975) the key steps in preparing a Delphi study are: the definition of experts and their selection; the number of rounds; and the questionnaire structure in each study round. Generally, the number of suggested rounds ranges from two to seven and the number of participants varies between 3 and 15 (Rowe and Wright, 1999).

The success of the Delphi method depends on the careful selection of the panel members (Chan *et al.*, 2001). As the information solicited requires in-depth knowledge and sound experience about, for one hand the automotive industry, and for the other the LARG paradigms, a purposive approach was adopted to select this group of experts (Chan *et al.*, 2001). The panel is made up of academics and professionals. To identify eligible academics for this part of the study the following two criteria were formulated: having current/recent involvement in automotive industry research topics; having a sound knowledge and understanding on LARG paradigms. In order to obtain the most valuable opinions, only academics who met the two selection criteria were considered. The criterion used to select professionals was that they should work in automotive companies in some capacity. According to Grisham (2009) it is important to select members who have a balance between impartiality, and an interest in the topic. So academics and professionals were invited to make part of the panel. This same

Constructs	Sub-indicators (practices)	Authors	Weights (w_{xi})
B_L = lean behaviour[a]	P_{L1} = just-in-time (first tier supplier→focal company)	Demeter and Matyusz (2011)	0.15
	P_{L2} = supplier relationships/long-term business relationship	Parveen and Rao (2009)	0.14
	P_{L3} = just-in-time (focal company)	Demeter and Matyusz (2011) and Furlan *et al.* (2011)	0.17
	P_{L4} = pull flow	Demeter and Matyusz (2011)	0.14
	P_{L5} = total quality management	Demeter and Matyusz (2011)	0.14
	P_{L6} = customer relationships	Lee *et al.* (2007)	0.12
	P_{L7} = just-in-time (focal company→first tier customer)	Furlan *et al.* (2011)	0.14
B_A = agile behaviour[a]	P_{A1} = to use IT to coordinate/integrate activities in design and development	Agarwal *et al.* (2007) and Swafford *et al.* (2008)	0.15
	P_{A2} = ability to change delivery times of supplier's order	Swafford *et al.* (2008)	0.18
	P_{A3} = to use IT to coordinate/integrate activities in manufacturing	Swafford *et al.* (2008)	0.14
	P_{A4} = to reduce development cycle times	Swafford *et al.* (2008)	0.16
	P_{A5} = centralized and collaborative planning	Agarwal *et al.* (2007)	0.14
	P_{A6} = to increase frequencies of new product introductions	Lin *et al.* (2006)	0.11
	P_{A7} = to speed in improving customer service	Swafford *et al.* (2008)	0.12
B_R = resilient behaviour[b]	P_{R1} = sourcing strategies to allow switching of suppliers	Rice and Caniato (2003)	0.15
	P_{R2} = flexible supply base/flexible sourcing	Tang (2006)	0.16
	P_{R3} = strategic stock	Christopher and Peck (2004) and Tang (2006)	0.14
	P_{R4} = lead time reduction	Christopher and Peck (2004) and Tang (2006)	0.14
	P_{R5} = creating total supply chain visibility	Iakovou *et al.* (2007)	0.15
	P_{R6} = flexible transportation	Tang (2006)	0.14
	P_{R7} = developing visibility to a clear view of downstream inventories and demand conditions	Christopher and Peck (2004)	0.12
B_G = green behaviour[b]	P_{G1} = environmental collaboration with suppliers	Hu and Hsu (2006), Zhu *et al.* (2007) and Holt and Ghobadian (2009)	0.15
	P_{G2} = environmental monitoring upon suppliers	Hu and Hsu (2006) and Paulraj (2009)	0.10
	P_{G3} = ISO 14001 certification	Rao and Holt (2005) and Zhu *et al.* (2008)	0.14
	P_{G4} = to reduce energy consumption		0.17
	P_{G5} = to reuse/recycling materials and packaging	Holt and Ghobadian (2009)	0.17
	P_{G6} = environmental collaboration with the customer	Zhu *et al.* (2007) and Vachon (2007)	0.13
	P_{G7} = reverse logistics	Routroy (2009) and Vachon (2007)	0.14

Note: [a]Azevedo *et al.* (2012c); [b]Azevedo *et al.* (2012b)

Table I.
Constructs, sub-indicators and weights for the construction of the LARG index

author considers that it is important to consider in the Delphi panel academics and professional because both have perspectives that are not only valid, but also essential for consideration in research.

A total of ten academics and ten professionals were invited to participate in this study, but only nine academics and five professionals agreed on collaborate.

Virtual (by e-mail) interviews were launched with academics and professionals to rank the four management paradigms according to their perceptions on their importance to the sustainability of the automotive SC. The Delphi method used in this research comprised three rounds. The first round of Delphi questionnaire (see Appendix 1) was sent to the group of 20 panel members by e-mail. The panel members constituted by academics and professionals were informed that would be several rounds of questionnaires. In the first round the academics and professionals were invited to give their perception about the importance of LARG paradigms for the competitiveness of the automotive industry. From these nine academics and five professionals responses were collected. In the second round respondents were provided with the consolidated results from the first round and were invited to reconsider their options to see if they would like to adjust their original choice. After that one more round was developed.

Using Equations (5) and (6), respectively, the weighting for each LARG paradigm was computed. In order to obtain a measure of consistency among the 14 panel members responses, the Kendall's Coefficient of concordance (W) is used since it gives the degree of association among the rankings of several objects by several judges (Israel, 2009). This coefficient varies between "0" indicating no agreement between judges and "+1" indicating complete agreement among the judges on the ranking of various attributes.

Table II shows the importance of each SCM paradigm according to the perceptions of the nine academics and five professionals. The order of importance of the LARG paradigms obtained from academics and professionals, after the three rounds, is the following one: the most important is lean, followed by resilient, agile and green. As can be seen from the Kendall's coefficient of concordance the consistency of the academics and professionals rankings was improved after the third round. Also according to Scheibe *et al.* (2002) the agreement and confidence associated to the Kendall's coefficient

	Statistics								
	First round			Second round			Third round		
Variables	Mean rating	Rank	Weighting	Mean rating	Rank	Weighting	Mean rating	Rank	Weighting
LARG paradigm									
Lean	4.7	1	0.28	4.6	1	0.28	4.9	1	0.30
Agile	4.4	2	0.26	4.2	3	0.26	4.1	2	0.25
Resilient	4.4	2	0.26	4.3	2	0.26	4.0	3	0.25
Green	3.4	3	0.20	3.1	4	0.19	3.1	4	0.19
Number (n)	14			14			14		
Kendall's coefficient of concordance (W)	0.496			0.642			0.701		
Level of significance	0.000			0.000			0.000		

Note: For "Mean rating" = 1 nothing important and 5 = extremely important

Table II.
Delphi results of first and second rounds for the paradigms importance

is strong when its value is between 0.7 and 0.9, that is the case. So, using this rule of thumb three rounds of questionnaires were performed in this research.

3.2.2 LARG index. The proposed composite LARG index is composed by the weights determined through the three rounds of the Delphi questionnaire using the additive weighting method of aggregation. In order to test the assumption of a linear model a Pearson correlation matrix was determined. The correlation coefficient values range from "−1" to "+1". The value "−1" indicates a perfect negative linear relationship between variables, a value "+1" indicates a perfect positive linear relationship between variables and "0" indicates no linear relationship between variables (Israel, 2009). Table III contains the correlation matrix for the four paradigms.

Table III reveals that the paradigms are not highly correlated to each other at 5 per cent significance level since only between the resilient and the agile variables there is a moderate positive relationship. Therefore, it is valid to consider a linear additive weighting model in deriving the LARG index ($LARG_{SC}$).

After the weights computed and the linear model assumption verified it is now possible to compute a LARG index to assess the level of leanness, agility, resilience and greenness for the automotive SC through the following composite indicator:

$$LARG_{SC} =$$

$$0.30 \times \frac{\sum_{j=1}^{n} \left(0.15 \times P_{L1j} + 0.14 \times P_{L2j} + 0.17 \times P_{L3j} + 0.14 \times P_{L4j} + 0.14 \times P_{L5j} + 0.12 \times P_{L6j} + 0.14 \times P_{L7j}\right)}{n} +$$

$$0.25 \times \frac{\sum_{j=1}^{n} \left(0.15 \times P_{A1j} + 0.18 \times P_{A2j} + 0.14 \times P_{A3j} + 0.16 \times P_{A4j} + 0.14 \times P_{A5j} + 0.11 \times P_{A6j} + 0.12 \times P_{A7j}\right)}{n} +$$

$$0.25 \times \frac{\sum_{j=1}^{n} \left(0.15 \times P_{R1j} + 0.16 \times P_{R2j} + 0.14 \times P_{R3j} + 0.14 \times P_{R4j} + 0.15 \times P_{R5j} + 0.14 \times P_{R6j} + 0.12 \times P_{R7j}\right)}{n} +$$

$$0.19 \times \frac{\sum_{j=1}^{n} \left(0.15 \times P_{G1j} + 0.10 \times P_{G2j} + 0.14 \times P_{G3j} + 0.17 \times P_{G4j} + 0.17 \times P_{G5j} + 0.13 \times P_{G6j} + 0.14 \times P_{G7j}\right)}{n} \quad (6)$$

where n is the number of companies considered in a particular SC; and $(P_{xi})_j$ represents for company j the level of implementation of practice i of paradigm x. A total of seven practices ($i = 1, \ldots, 7$) is considered to each paradigm. The implementation level for each practice is assessed on a five-point Likert scale where 1 means "practice not implemented" and 5 "practice totally implemented.

The LARG index is a composite indicator constituted by a set of sub-indicators reflecting the SC behaviour in terms of LARG paradigms. This composite indicator is computed to a specific SC, considering the implementation level of the focused practice in the companies belonging to the SC. The LARG index goes from 1 (none paradigm is

	Lean	Agile	Resilient	Green
Lean	1			
Agile	0.139	1		
Resilient	−0.265	0.416*	1	
Green	0.410	0.297	−0.248	1

Note: *Correlation is significant at the 0.05 level (two-tailed)

Table III.
Pearson correlations

put into practice in the SC companies) to 5 (all the paradigms are completely deployed in the SC companies).

Considering that a SC is a "network of companies that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer" (Christopher, 1998) the LARG index for the SC will assist decision makers by reducing the quantity of information, (Alfsen and Saebo, 1993; Callens and Tyteca, 1999; Gustavson *et al.*, 1999) and providing informative and reliable analytical results expressed in a range of values which can provide a holistic picture of the leanness, agility, resilience and greenness of the companies that belong to the same SC. The LARG index for the SC reflects the level of sustainability of the SC attending to the implementation of the four SCM paradigms. It means that, the higher de LARG index for the SC, the better is the sustainability of the SC.

4. LARG index application: a case study in automotive supply chain

4.1 Methodology

Since the main objective of this research is to propose a LARG index for the SC, a case study approach was chosen to illustrate the LARG index application and to validate it. Validity represents the integrity of the conclusions that are generated from a piece of research (Bryman, 2008). To illustrate the applicability of the LARG index and to attain the integrity of the conclusions a qualitative research was performed. According to Lamnek (2006) qualitative researches achieve higher validity because the data are closer to the research field than in quantitative research. As Bulmer (1979) states qualitative researches try to achieve validity not through manipulation of variables but rather through the study of the empirical world, as it is the case. This approach is adequate when the boundaries of a phenomenon are not only still unclear, but there is also no control over behavioural events (Rowley, 2002). According to McCutcheon and Meredith (1993) case studies can be comprehended as a useful approach for assessing real world examples allowing also direct observation of the field, which would be particularly suitable for approaching several stages of a SC (Seuring, 2008). In recent years the importance of case-based research has been highlighted by a number of authors for SCM (Hilmola *et al.*, 2005; Seuring, 2005). The single case study (the automotive SC) used in this research allowing researchers to have an opportunity to observe and analyse a phenomenon (Yin, 2003), in this case the application of the proposed LARG Index in a real world context. A sample consisted of six companies within the Portuguese automotive SC was selected. The case study comprises one automaker, four first tier suppliers and one second tier supplier.

To limit expert bias in the study results, data concerned to the personal judgment of the participants were obtained through structured interviews. Two visits were made to the company's facilities. In the first one the research was presented and general information on products and processes was collected. At the second visit, one interview was made to each company manager according to the interview protocol (Appendix 3).

The case study objective is to illustrate the application of the proposed LARG index as a benchmarking tool.

4.2 Case study profile

This paper focuses the companies belonging to the automotive SC which are situated in Portugal. Table IV summarizes the six case studies profiles according to the product

Table IV.
Case studies profile

Company descriptor	Product lines	Position in the supply chain	Company size (employees)	Interviewed
Company 1	Vehicles	Automaker	More than 1,000	SC supervisor
Company 2	Plastic parts	First tier supplier	200-500	Product engineer
Company 3	Front rear	First tier supplier	50-100	Logistics manager
Company 4	Exhaust systems	First tier supplier	50-100	Lean manager
Company 5	Electronic key systems and lock sets	First tier supplier	350	Quality manager
Company 6	Plastic injection moulding	Second tier supplier	800-1000	Lean manager

lines, position in the SC and company size. The company under study belong to different SC levels: four companies are first tier suppliers, one is a second tier supplier, and also one automaker.

4.3 LARG index calculation

In a first stage the data related to the implementation of the suggested LARG practices were collected for each company (Table V). Considering the weights in Table I it is now possible to compute the LARG behaviour to each company $(B_x)_j$ and for the respective SC (SCI_x) (Table V).

Table V shows the LARG behaviour for individual companies and for the SC computed according to Equation (1) for the individual company behaviour and Equation (3) for the SC behaviour.

Attending to the information in Table V it is possible to state that the company with higher leanness behaviour is the company 5 with a value of 5.00. This means that this company has a higher level of implementation of all lean researched practices. Considering the agile paradigm the company with better performance in terms of agile behaviour is also the company 5 with a moderate value of 3.74. Considering the resilient paradigm, the company 2 presents a high level of implementation of the resilient practices which makes it a better performer in terms of resilient behaviour. Finally, as regards the green paradigm the company 5 deserves a special highlight since it presents a green behaviour of 4.32 being the better performer in what this paradigm respects.

The possibility of doing this comparative analysis of LARG behaviour deployed by individual companies represents also an important contribution for a benchmarking analysis considering different kinds of SC. Looking to the last column of the Table V it is also possible to identify in which LARG paradigm the research SC is a better performer. Performing this analysis it is possible to say that the research SC presents a leanness behaviour (4.11), however, with less favourable behaviour in terms of agility.

Using now the information collected in the Table V and considering the weights attributed by experts to each paradigm according to their contribution to the sustainability of the automotive industry (Table II), the LARG index for the individual company and for the SC can finally be computed (Table VI).

Attending to the Table VI among the researched companies the paradigm with a higher level of implementation is the lean (4.11), followed by the green (3.84), the resilient (3.78) and finally the agile (3.40). So it is possible to state that the researched automotive SC has a leanness behaviour and a week agile behaviour. This may be explained because the lean philosophy always made part of the automotive industry and is viewed as an important enabler for cost reduction (Pepper and Spedding, 2010).

LARG practices	w_{xi}	Practices implementation level Companies ($n=6$) 1	2	3	4	5	6	Behaviour for SC $SCI_x = \sum(B_x)_j/n$
P_{L1} = just-in-time (first tier supplier→focal company)	0.15	5	1	4	4	5	1	Lean behaviour for SC = 4.11
P_{L2} = supplier relationships/long-term business relationship	0.14	4	4	5	5	5	5	
P_{L3} = just-in-time (focal company)	0.17	5	5	5	5	5	1	
P_{L4} = pull flow	0.14	5	5	5	5	5	3	
P_{L5} = total quality management	0.14	5	5	5	5	5	2	
P_{L6} = customer relationships	0.12	4	4	5	5	5	3	
P_{L7} = just-in-time (focal company→first tier customer)	0.14	2	5	5	5	5	1	
Lean behaviour $(B_L)_j = \sum(w_{Li} \times (P_L)_j)$		4.32	4.14	4.85	4.14	5.00	2.22	
P_{A1} = to use IT to coordinate/integrate activities in design and development	0.15	4	3	3	3	1	4	Agile behaviour for SC = 3.40
P_{A2} = ability to change delivery times of supplier's order	0.18	3	3	3	2	5	3	
P_{A3} = to use IT to coordinate/integrate activities in manufacturing	0.14	4	4	4	4	4	3	
P_{A4} = to reduce development cycle times	0.16	5	4	5	5	4	3	
P_{A5} = centralized and collaborative planning	0.14	3	2	2	2	4	3	
P_{A6} = to increase frequencies of new product introductions	0.11	4	2	2	2	3	3	
P_{A7} = to speed in improving customer service	0.12	3	4	4	5	5	3	
Agile behaviour $(B_A)_j = \sum(w_{Ai} \times (P_A)_j)$		3.72	3.17	3.33	3.27	3.74	3.15	
P_{R1}	0.15	4	5	3	4	3	1	Resilient behaviour for SC = 3.78
P_{R1} = sourcing strategies to allow switching of suppliers	0.16	4	5	4	4	3	1	
P_{R2} = flexible supply base/flexible sourcing	0.14	5	5	5	5	4	4	
P_{R3} = strategic stock	0.14	4	4	4	4	3	4	
P_{R4} = lead time reduction	0.15	5	4	5	4	4	1	
P_{R5} = creating total supply chain visibility	0.14	4	4	3	4	3	3	
P_{R6} = flexible transportation	0.12	5	4	5	4	4	1	
Resilient behaviour $(B_R)_j = \sum(w_{Ri} \times (P_R)_j)$		4.41	4.45	4.12	4.14	3.41	2.12	
P_{G1} = environmental collaboration with suppliers	0.15	4	2	2	2	4	4	Green behaviour for SC = 3.83
P_{G2} = environmental monitoring upon suppliers	0.10	5	3	3	3	4	4	
P_{G3} = ISO 14001 certification	0.14	5	5	5	5	5	5	
P_{G4} = to reduce energy consumption	0.17	4	4	4	4	4	4	
P_{G5} = to reuse/recycling materials and packaging	0.17	4	4	4	4	5	4	
P_{G6} = environmental collaboration with the customer	0.13	3	3	3	3	3	4	
P_{G7} = reverse logistics	0.14	4	4	4	4	5	1	
Green behaviour $(B_G)_j = \sum(w_{Gi} \times (P_G)_j)$		4.14	3.61	3.61	3.61	4.32	3.72	

Table V.
LARG behaviour for individual company and supply chain

Compiling the LARG behaviour of the six companies into the LARG index it is produced an overall value of 3.75. Since the LARG index is between 1 and 5, this means that the SC in this case exhibits a moderate value index. Also, analysing the columns of the Table VI it is possible to state that the companies with a higher scores on the SC LARG index are the company 1 (automaker) and also the company 5 (first tier supplier) These results seem reasonable, since the automakers have a strong influence on the practices implemented by its suppliers (Dyer and Chu, 2011) and therefore it also has a strong impact on the LARG index results. The LARG index highlights the difference of performance among companies belong to the same SC, supporting the identification of the companies that should be a priority in SC redesign programs in order to improve its sustainability. In the case study company 6 is the worst performer; this is a second tier supplier and its process are not under the influence of the automaker. This suggests that companies belonging to this SC echelon should be monitored closely and cooperation programs should be develop to help them to achieve the necessary level of LARG to not compromise the SC overall behaviour.

The LARG index for SC represents the level of sustainability of the SC attending to the implementation of the four SCM paradigms focused in this paper. This means that, the higher de LARG index for the SC, the better his sustainability is.

The assessment of the this Index for the SC is crucial since from the theoretical perspective the proposed index represents an initial contribution for the development of integrative indexes considering the trade-offs that exist in the SC when different management paradigms are implemented on different SC echelons. It supports the identification of practices that promote the level of sustainability at the company level, but also the impact of these practices on the overall sustainability of SCs.

From the industry perspective, it allows implementing a functional benchmarking approach since the assessment of the LARG index in companies belonging to the same automotive SC makes possible a comparison between their practices, having as reference the best in class (Camp, 1995; Fong *et al.*, 1998; Zairi, 1992). This contributes to the individual company and SC improvement meeting or surpassing industry best practices obliging them to be more rigorous in establishing priorities, targets and goals in terms of leanness, agility, resilience and greenness.

This case study makes possible to highlight the main advantages of using the proposed LARG index by the automotive industry. The use of the LARG index can simplify the LARG behaviour benchmark analysis and provides a simple and objective method to compare between companies and SCs. The proposed index may also assist on formulating sustainable policies and promoting the implementation of LARG practices in various industry sectors.

Table VI. LARG index for individual company and supply chain

	$(B_x)_j$ Companies									
Paradigm x	1	2	3	4	5	6	$\sum (B_x)_j/6$	w_x	SC behaviour	$LARG_{SC}$
Lean	4.32	4.14	4.85	4.14	5.00	2.22	4.11	0.30	1.23	$= 3.75$
Agile	3.72	3.17	3.33	3.27	3.74	3.15	3.40	0.25	0.85	
Resilient	4.41	4.45	4.12	4.14	3.41	2.12	3.78	0.25	0.94	
Green	4.14	3.61	3.61	3.61	4.32	3.72	3.84	0.19	0.73	
$LARG_j$ for individual company	4.11	3.83	4.00	3.78	4.11	2.69				

The proposed model to assess the SC behaviour is an important contribution to managers. The proposed index allows to identify the practices that should be extended to improve SC performance and to be more competitive and sustainable. The proposed index could help companies managers and SC professionals to have an idea on their performance in terms of LARG behaviours compared to their partners and competitors in the SC. Carvalho *et al.* (2013) study about LARG trade-offs among SC echelons suggest that some companies built their capabilities at the expenses of others SC echelons. For example, the automakers develop resilience in their operations relying on the resilience of their suppliers. The quantification of this type of behaviour could be used as an argument in procurement negotiation, mainly by suppliers.

It represents an important tool for companies identify some practices with low levels of implementation which are affecting their performance in terms of leanness, agility, resilience and also greenness. So, if companies need to improve in some specific behaviour the associated practices must be also improved. Therefore, the index can be further used in self-assessment and to facilitate systematic continuous quality improvement over the full range of practices and processes.

Therefore it serves as a tool to managers do a checklist of the implementation level of a set of practice considered as most important to individual companies and also SC to be betters performers in the four paradigms implementation. By this way, they can adjust the company' behaviour according to the reached LARG index score in order to: maximize customer value and minimize waste; to respond rapidly and cost effectively to unpredictable changes; to improve its ability to cope with unexpected disturbances; and to reduce environmental risks and impacts while improving company ecological efficiency.

5. Conclusions

This paper follows an innovative approach suggesting an integrated composite index, entitled LARG index, to assess the automotive SC behaviour in terms of leanness, agility, resilience and greenness. The proposed integrated assessment model supports the development of two LARG indexes: one to assess the individual company behaviour in terms of the four SCM paradigms, and the other one to determine the same behaviour, but for the entire SC.

This research approach was developed in touch with the automotive SC reality. The LARG index was constructed with the collaboration of academics and professionals from the automotive industry with knowledge on the LARG paradigms and also on the automotive reality. Besides this, the implementation of the proposed LARG index is illustrated by a case study approach using the information gathered from six automotive companies. The main objective of doing a case study is to illustrate the LARG index application in the focused SC in order to guide managers in its implementation.

The proposed composite index is a way to fulfil the research gap on an integrated approach about the leanness, agility, resilience and greenness of the SC, and in particular on the automotive SC. This research represents an important contribution for research since it contributes to highlight the importance of the focused four SCM paradigms (LARG) for the sustainability of the automotive industry. Also it makes possible for the professionals of this industry to monitor and control the behaviour of their companies as regards the leanness, agility, resilience and greenness allowing by this way identifying the practices where companies are better and worse performers.

The content of this paper is particularly important to managers do a checklist of a set of practices implementation level considered as most important to individual companies and SC sustainability. By this way, they can adjust the organizational

behaviour according to the suggested LARG index score in order to maximize customer value and minimize waste, to respond rapidly and cost effectively to unpredictable changes, to improve its ability to cope with unexpected disturbances, and to reduce environmental risks and impacts while improving company ecological efficiency. Also, it makes possible to implement functional benchmarking approaches in the automotive SC and to do a ranking among the companies, according to the proposed LARG index. This serves as a motivation to companies try to reach a better position among their partners and to be more rigorous in establishing priorities, targets and goals, in terms of leanness, agility, resilience and greenness. This index represents an important framework for supporting decision makers of individual company and also for the SC. As regards the individual company the value reached in the LARG index gives insight on the position of the company in terms of leanness, agility, resilience and greenness. This perception makes possible to adjust the kind of practices implemented by the companies attending to the importance gave by managers to each of the four considered management paradigm. The same can be observed in a SC context. Also, the dynamic process associated to the construction of the LARG index should be enhanced. Managers can adapt the parameters of the LARG index to their reality using, for example other panel members in the Delphi technique for weighting not only the importance of the SCM paradigms for the sustainability of their industry but also the importance of the associated practices.

Despite the important contributions of this paper, limitations of the study should be noted. First, the proposed index is focused on the automotive industry. So, the practices suggested in the integrated assessment model translate particularly the reality of this sector making it not adjusted to a different sector. Second, the Delphi method used to support the weighting determination was developed through only two rounds. Besides it respects the number of rounds referred by Rowe and Wright (1999), which is between two and seven, if more rounds were developed the validity of the answers collected from the questionnaires will be improved. The research contributes to define LARG behaviour in companies and SC and assess its level of implementation in the automotive sector. However, the data set is not robust enough to make generalizations for the entire industry as to the potential benefit of LARG for its various sectors. Therefore, the resulting LARG index coefficients and scores presented in this paper could be biased by differences in specific variables associated to the research companies. While the study is adequate as a pilot to prove the feasibility of the concept, the developed LARG index may need to include other LARG practices in order to be more comprehensive and adjusted to the reality. Also larger survey covering more companies and industries would be needed for further investigation.

Building on from this study, future research should therefore be directed at exploring the application of the suggested LARG index in an extended automotive SC. Also, based on the theoretical approach performed in this study, a deeper analysis of the kind of relationships between the SCM paradigms and corresponding practices should be explored to different kind of mathematical models.

References

Agarwal, A., Shankar, R. and Tiwari, M. (2007), "Modeling agility of supply chain", *Industrial Marketing Management*, Vol. 36 No. 4, pp. 443-457.

Alfsen, K.H. and Saebo, H.V. (1993), "Environmental quality indicators: background, principles and examples from Norway", *Environmental and Resource Economics*, Vol. 3 No. 5, pp. 415-435.

Anand, G. and Kodali, R. (2008), "A conceptual framework for lean supply chain and its implementation", *International Journal of Value Chain Management*, Vol. 2 No. 3, pp. 313-357.

Anbanandam, R., Banwet, D.K. and Shankar, R. (2011), "Evaluation of supply chain collaboration: a case of apparel retail industry in India", *International Journal of Productivity and Performance Management*, Vol. 60 No. 2, pp. 82-98.

Ashby, A., Leat, M. and Hudson-Smith, M. (2012), "Making connections: a review of supply chain management and sustainability literature", *Supply Chain Management: An International Journal*, Vol. 17 No. 5, pp. 497-516.

Ashton, C. (1998), *Managing Best Practices*, Business Intelligence, London.

Azevedo, S.G., Carvalho, H., Duarte, S. and Cruz-Machado, V. (2012a), "Influence of green and lean upstream supply chain management practices on business sustainability", *IEEE Transactions on Engineering Management*, Vol. 59 No. 4, pp. 753-765.

Azevedo, S.G., Govindan, K., Carvalho, H. and Cruz-Machado, V. (2012b), "Ecosilient index to assess the greenness and resilience of the upstream automotive supply chain", *Journal of Cleaner Production*, Vol. 56 No. 1, pp. 131-146.

Azevedo, S.G., Govindan, K., Carvalho, H. and Cruz-Machado, V. (2012c), "An integrated model to assess the leanness and agility of the automotive industry", *Resources, Conservation and Recycling*, Vol. 66, September, pp. 85-94.

Azevedo, S.G., Machado, V., Barroso, A. and Cruz-Machado, V. (2008), "Supply chain vulnerability: environment changes and dependencies", *International Journal of Logistics and Transport*, Vol. 1 No. 1, pp. 41-55.

Björklund, M. (2010), "Benchmarking tool for improved corporate social responsibility in purchasing", *Benchmarking: An International Journal*, Vol. 17 No. 3, pp. 340-362.

Brown, K. and Mitchell, T. (1991), "A comparison of just-in-time and batch manufacturing: the role of performance obstacles", *Academy of Management, Journal*, Vol. 34 No. 4, pp. 906-917.

Bryman, A. (2008), *Social Research Methods*, 3rd ed., Oxford University Press, Oxford.

Bulmer, M.G. (1979), *Principles of Statistics*, Dover, New York, NY.

Callens, I. and Tyteca, D. (1999), "Towards indicators of sustainable development for firms", *Ecological Economics*, Vol. 28 No. 1, pp. 41-53.

Camp, R. (1995), *Business Process Benchmarking: Finding and Implementing Best Practices*, ASQC Quality Press, Milwaukee, WI.

Carvalho, H., Azevedo, S.G. and Cruz-Machado, V. (2010), "Supply chain performance management: lean and green paradigms", *International Journal of Business Performance and Supply Chain Modelling*, Vol. 2 Nos 3/4, pp. 304-333.

Carvalho, H., Azevedo, S.G. and Cruz-Machado, V. (2012), "Agile and resilient approaches to supply chain management: influence on performance and competitiveness", *Logistics Research*, Vol. 4 Nos 1/2, pp. 49-62.

Carvalho, H., Azevedo, S.G. and Cruz-Machado, V. (2013), "An innovative agile and resilient index for the automotive supply chain", *International Journal of Agile Systems and Management*, Vol. 6 No. 3, pp. 259-283.

Carvalho, H., Duarte, S. and Cruz-Machado, V. (2011), "Lean, agile, resilient and green: divergencies and synergies", *International Journal of Lean Six Sigma*, Vol. 2 No. 2, pp. 51 -179.

Chan, A.P.C., Yung, E.H.K., Lam, P.T.I., Tam, C.M. and Cheung, S.O. (2001), "Application of Delphi method in selection of procurement systems for construction", *Construction Management & Economics*, Vol. 19 No. 7, pp. 699-718.

Christopher, M. (1998), *Logistics & Supply Chain Management: Strategies for Reducing Cost and Improving Service*, Financial Times Professional Limited, London.

Christopher, M. and Peck, H. (2004), "Building the resilient supply chain", *The International Journal of Logistics Management*, Vol. 15 No. 2, pp. 1-14.

Colicchia, C., Melacini, M. and Perotti, S. (2011), "Benchmarking supply chain sustainability: insights from a field study", *Benchmarking: An International Journal*, Vol. 18 No. 5, pp. 705-732.

Darnhofer, I., Fairweather, J. and Moller, H. (2010), "Assessing a farm's sustainability: insights from resilience thinking", *International Journal of Agricultural Sustainability*, Vol. 8 No. 3, pp. 186-198.

Demeter, K. and Matyusz, Z. (2011), "The impact of lean practices on inventory turnover", *International Journal of Production Economics*, Vol. 133 No. 1, pp. 154-163.

Disney, S.M., Naim, M.M. and Towill, D.R. (1997), "Dynamic simulation modeling for lean logistics", *International Journal of Physical Distribution & Logistics Management*, Vol. 27 Nos 3/4, pp. 174-196.

Drew, S.A.W. (1997), "From knowledge to action: the impact of benchmarking on organizational performance", *Long Range Planning*, Vol. 30 No. 3, pp. 427-441.

Dyer, J. and Chu, W. (2011), "The determinants of trust in supplier-automaker relations in the US, Japan, and Korea: a retrospective", *Journal of International Business Studies*, Vol. 42 No. 4, pp. 28 -34.

Eakin, H.C. and Wehbe, M.B. (2009), "Linking local vulnerability to system sustainability in a resilience framework: two cases from Latin America", *Climatic Change*, Vol. 93 Nos 3\4, pp. 355-377.

Elmuti, D. and Kathawala, Y. (1997), "An overview of benchmarking process: a tool for continuous improvement and competitive advantage", *Benchmarking for Quality Management & Technology*, Vol. 4 No. 4, pp. 229-243.

Eweje, G. (2011), "A shift in corporate practice? Facilitating sustainability strategy in companies", *Corporate Social Responsibility and Environmental Management*, Vol. 18 No. 3, pp. 125-136.

Fliedner, G. (2008), "Sustainability: a new lean principle", Proceedings of the 39th Annual Meeting of the Decision Sciences Institute, Baltimore, MD.

Flumerfelt, S., Siriban-Manalang, A.B. and Kahlen, F.J. (2012), "Are agile and lean manufacturing systems employing sustainability, complexity and organizational learning?", *The Learning Organization*, Vol. 19 No. 3, pp. 238-247.

Flynn, B.B., Schroeder, R.G. and Sakakibara, S. (1995), "The impact of quality management practices on performance and competitive advantage", *Decision Science*, Vol. 26 No. 5, pp. 659-691.

Fong, S.W., Cheng, E.W.L. and Ho, D.C.K. (1998), "Benchmarking a general reading for management practitioners", *Management Decision*, Vol. 36 No. 6, pp. 407-418.

Furlan, A., Vinelli, A. and Pont, G.D. (2011), "Complementarity and lean manufacturing bundles: an empirical analysis", *International Journal of Operations & Production Management*, Vol. 31 No. 8, pp. 835-850.

Gaudenzi, B. and Borghesi, A. (2006), "Managing risks in the supply chain using the AHP method", *International Journal of Logistics Management*, Vol. 17 No. 1, pp. 114-136.

Gonzalez, P., Sarkis, J. and Adenso-Diaz, B. (2008), "Environmental management system certification and its influence on corporate practices: evidence from the automotive industry", *International Journal of Operations & Production Management*, Vol. 28 No. 11, pp. 1021-1041.

Grisham, T. (2009), "The Delphi technique: a method for testing complex and multifaceted topics", *International Journal of Managing Projects in Business*, Vol. 2 No. 1, pp. 112-130.

Gurumurthy, A. and Kodali, R. (2009), "Application of benchmarking for assessing the lean manufacturing implementation", *Benchmarking: An International Journal*, Vol. 16 No. 2, pp. 274-308.

Gustavson, K., Longeran, S. and Ruitenbeek, H.J. (1999), "Selection and modelling of sustainable development indicators: a case study of the Fraser River Basin, British Columbia", *Ecological Economics*, Vol. 28 No. 1, pp. 117-132.

Hahn, T. and Scheermesser, M. (2006), "Approaches to corporate sustainability among German companies", *Corporate Social Responsibility and Environmental Management*, Vol. 13 No. 3, pp. 150-165.

Haimes, Y.Y. (2006), "On the definition of vulnerabilities in measuring risks to infrastructures", *Risk Analysis*, Vol. 26 No. 2, pp. 293-296.

Hart, S.L. (1997), "Beyond greening: strategies for a sustainable world", *Harvard Business Review*, Vol. 75 No. 1, pp. 66-77.

Hemming, C., Pugh, S., Williams, G. and Blackburn, D. (2004), "Strategies for sustainable development: use of a benchmarking tool to understand relative strengths and weaknesses and identify best practice", *Corporate Social Responsibility and Environmental Management*, Vol. 11 No. 2, pp. 103-113.

Herron, C. and Braiden, P.M. (2006), "A methodology for developing sustainable quantifiable productivity improvement in manufacturing companies", *International Journal of Production Economics*, Vol. 104 No. 1, pp. 143-153.

Hilmola, O.-P., Hejazi, A. and Ojala, L. (2005), "Supply chain management research using case studies: a literature analysis", *International Journal of Integrated Supply Management*, Vol. 1 No. 3, pp. 294-311.

Hoek, V.R.I., Harrison, A. and Christopher, M. (2001), "Measuring agile capabilities in the supply chain", *International Journal of Operations & Production Management*, Vol. 21 Nos 1/2, pp. 126-148.

Holt, D. and Ghobadian, A. (2009), "An empirical study of green supply chain management practices amongst UK manufacturers", *Journal of Manufacturing Technology Management*, Vol. 20 No. 7, pp. 933-956.

Hong, P., Roh, J.J. and Rawski, G. (2012), "Benchmarking sustainability practices: evidence from manufacturing firms", *Benchmarking: An International Journal*, Vol. 19 Nos 4/5, pp. 634-648.

Hu, A.H. and Hsu, C.W. (2006), "Empirical study in the critical factors of green supply chain management (GSCM), practice in the Taiwanese electrical and electronics industries", *Proceeding of 2006 IEEE International Conference on Management of Innovation and Technology*, *Singapore, 21-23 June*, pp. 853-857.

Huggins, R. (2003), "Creating a UK competitiveness index: regional and local benchmarking", *Regional Studies*, Vol. 37 No. 1, pp. 89-96.

Iakovou, E., Vlachos, D. and Xanthopoulos, A. (2007), "An analytical methodological framework for the optimal design of resilient supply chains", *International Journal of Logistics Economics and Globalisation*, Vol. 1 No. 1, pp. 1-20.

Israel, D. (2009), *Data Analysis in Business Research: A Step-by-Step Nonparametric Approach*, Sage Publications Pvt Ltd, Thousand Oaks, CA.

Kaebernick, H., Kara, S. and Sun, M. (2003), "Sustainable product development and manufacturing by considering environmental requirements", *Robot Robotics and Computer-Integrated Manufacturing*, Vol. 19 No. 6, pp. 461-468.

Lamnek, S. (2006), "Qualitative Sozialforschung: Lehrbuch 4., vollst. überarb. Au., [Nachdr.].", Beltz PVU, Weinheim.

Lau, K.H. (2011), "Benchmarking green logistics performance with a composite index", *Benchmarking: An International Journal*, Vol. 18 No. 6, pp. 873-896.

Lee, C.W., Kwon, I.-W.G. and Severance, D. (2007), "Relationship between supply chain performance and degree of linkage among supplier, internal integration, and customer", *Supply Chain Management: An International Journal*, Vol. 12 No. 6, pp. 444-452.

Lin, C., Chiu, H. and Chu, P. (2006), "Agility index in the supply chain", *International Journal of Production Economics*, Vol. 100 No. 2, pp. 285-299.

Linstone, H.A. and Turoff, M. (Eds) (1975), *The Delphi Method: Techniques and Applications*, Addison-Wesley, London.

McCutcheon, D.M. and Meredith, J.R. (1993), "Conducting case study research in operations management", *Journal of Operations Management*, Vol. 11 No. 3, pp. 239-256.

Melton, T. (2005), "The benefits of lean manufacturing what lean thinking has to offer the process industries", *Chemical Engineering Research and Design*, Vol. 83 No. 6, pp. 662-673.

Nunlee, M., Qualls, W. and Rosa, J.A. (2000), "Antecedents of supply chain management: a performance measurement model", *Conference Proceedings 2000 AMA, American Marketing Association, Brisbane*, pp. 354-360.

Pagell, M. and Wu, Z. (2009), "Building a more complete theory of sustainable supply chain management using case studies of 10 exemplars", *Journal of Supply Chain Management*, Vol. 45 No. 2, pp. 37-56.

Parveen, M. and Rao, T.V.V.L.N. (2009), "An integrated approach to design and analysis of lean manufacturing system: a perspective of lean supply chain", *International Journal of Services and Operations Management*, Vol. 5 No. 2, pp. 175-208.

Paulraj, A. (2009), "Environmental motivations: a classification scheme and its impact on environmental strategies and practices", *Business Strategy and the Environment*, Vol. 18 No. 7, pp. 453-468.

Peattie, K. (1995), *Environmental Marketing Management*, Pitman Publishing, London.

Pepper, M.P.J. and Spedding, T.A. (2010), "The evolution of lean six sigma", *International Journal of Quality & Reliability Management*, Vol. 27 No. 2, pp. 138-155.

Presley, A. and Meade, L. (2010), "Benchmarking for sustainability: an application to the sustainable construction industry", *Benchmarking: An International Journal*, Vol. 17 No. 3, pp. 435-451.

Rao, P. and Holt, D. (2005), "Do green supply chains lead to competitiveness and economic performance?", *International Journal of Operations and Production Management*, Vol. 25 No. 9, pp. 898-916.

Rao, T. and Schoenherr, T. (2011), "Assessing and managing risks using the supply chain risk management process (SCRMP)", *Supply Chain Management*, Vol. 16 No. 6, pp. 474-483.

Redclift, M. (1993), "Sustainable development: needs, values, rights", *Environmental Values*, Vol. 2 No. 1, pp. 3-20.

Rice, J. and Caniato, F. (2003), "Building a secure and resilient supply network", *Supply Chain Management Review*, Vol. 7 No. 5, pp. 22-31.

Rodrigue, J.P., Slack, B. and Comtois, C. (2001), "Green logistics (the paradoxes of)", in Brewer, A., Button, K., Hensher, D. and Pergamon (Eds), *Handbook of Logistics and Supply Chain Management*, Pergamon/Elsevier, London, pp. 339-351.

Routroy, S. (2009), "Antecedents and drivers for green supply chain management implementation in manufacturing environment", *ICFAI Journal of Supply Chain Management*, Vol. 6 No. 1, pp. 20-35.

Rowe, G. and Wright, G. (1999), "The Delphi technique as a forecasting tool: issues and analysis", *International Journal of Forecasting*, Vol. 15 No. 4, pp. 353-375.

Rowley, J. (2002), "Using case studies in research", *Management Research News*, Vol. 25 No. 1, pp. 16-27.

Scheibe, M., Skutsch, M. and Schofer, J. (2002), "Experiments in Delphi methodology", in Linstone, H.A. and Turoff, M. (Eds), *The Delphi Method: Techniques and Applications*, Addison-Wesley, London, pp. 257-271.

Seuring, S. (2005), "Case study research in supply chains – an outline and three examples", in Kotzab, H., Seuring, S., Muller, M. and Reiner, G. (Eds), *Research Methodologies in Supply Chain Management*, Physica-Verlag, Heidelberg, pp. 235-250.

Seuring, S. and Müller, M. (2008), "From a literature review to a conceptual framework for sustainable supply chain management", *Journal of cleaner production*, Vol. 16 No. 15, pp. 1699-1710.

Seuring, S.A. (2008), "Assessing the rigor of case study research in supply chain management", *Supply Chain Management: An International Journal*, Vol. 13 No. 2, pp. 128-137, doi: 10.1108/13598540810860967.

Srivastava, S.K. (2007), "Green supply-chain management: a state-of-the-art literature review", *International Journal of Management Reviews*, Vol. 9 No. 1, pp. 53-80.

Stewart, D. and Grout, J. (2001), "The human side of mistake-proofing", *Production and Operations Management*, Vol. 10 No. 4, pp. 440-459.

Stonebraker, P.W., Goldhar, J. and Nassos, G. (2009), "Weak links in the supply chain: measuring fragility and sustainability", *Journal of Manufacturing Technology Management*, Vol. 20 No. 2, pp. 161-177.

Swafford, P.M., Ghosh, S. and Murthy, N. (2008), "Achieving supply chain agility through IT integration and flexibility", *International Journal of Production Economics*, Vol. 116 No. 2, pp. 288-297.

Tang, C.S. (2006), "Robust strategies for mitigating supply chain disruptions", *International Journal of Logistics: Research and Applications*, Vol. 9 No. 1, pp. 33-45.

Tavana, M., Mohebbi, B. and Kennedy, D.T. (2003), "Total quality index: a benchmarking tool for total quality management", *Benchmarking: An International Journal*, Vol. 10 No. 6, pp. 507-527.

Treville, S. and Antonakis, J. (2006), "Could lean production job design, be intrinsically motivating? Contextual, configurational, and levels-of-analysis issues", *Journal of Operations Management*, Vol. 24 No. 2, pp. 99-123.

Vachon, S. (2007), "Green supply chain practices and the selection of environmental technologies", *International Journal of Production Research*, Vol. 45 No. 18, pp. 4357-4379.

Vachon, S. and Klassen, R.D. (2008), "Environmental management and manufacturing performance: the role of collaboration in the supply chain", *International Journal of Production Economics*, Vol. 111 No. 2, pp. 299-315.

van Someren, T.C. (1995), "Sustainable development and the firm: organizational innovations and environmental strategy", *Business Strategy and the Environment*, Vol. 4 No. 1, pp. 23-33.

Voss, C.A., Åhlström, P. and Blackmon, K. (1997), "Benchmarking and operational performance: some empirical results", *Benchmarking for Quality Management & Technology*, Vol. 4 No. 4, pp. 273-285.

Walker, E.A., Redmond, J. and Giles, M. (2010), "A proposed methodology to promote adoption of green production by small firms", *International Journal of Business Studies*, Vol. 18 No. 1, pp. 39-48.

Winter, M. and Knemeyer, A.M. (2013), "Exploring the integration of sustainability and supply chain management: current state and opportunities for future inquiry", *International Journal of Physical Distribution & Logistics Management*, Vol. 43 No. 1, pp. 18-38.

Womack, J., Jones, D. and Roos, D. (1991), *The Machine that Change the World*, HarperCollins Publishers, New York, NY.

Xia, Y. and Tang, T.L.P. (2011), "Sustainability in supply chain management: suggestions for the auto industry", *Management Decision*, Vol. 49 No. 4, pp. 495-512.

Yeung, J., Chan, A., Chan, D. and Li, L.K. (2007), "Development of a partnering performance index (PPI) for construction projects in Hong Kong: a Delphi study", *Construction Management and Economics*, Vol. 25 No. 12, pp. 1219-1237.

Yin, R.K. (2003), *Case Study Research: Design and Methods*, 3rd ed., Sage Publications, Thousand Oaks, CA.

Zairi, M. (1992), "The art of benchmarking: using customer feedback to establish a performance gap", *Total Quality Management*, Vol. 3 No. 2, pp. 177-187.

Zhu, Q., Sarkis, J. and Lai, K.H. (2007), "Initiatives and outcomes of green supply chain management implementation by Chinese manufacturers", *Journal of Environmental Management*, Vol. 85 No. 1, pp. 179-189.

Zhu, Q., Sarkis, J. and Lai, K.H. (2008), "Confirmation of a measurement model for green supply chain management practices implementation", *International Journal of Production Economics*, Vol. 111 No. 2, pp. 261-273.

Further reading

Azevedo, S., Carvalho, H., Cruz-Machado, V. and Grilo, F. (2010), "The influence of agile and resilient practices on supply chain performance: an innovative conceptual model proposal", in Blecker, T., Kersten, W. and Luthje, C. (Eds), *Innovative Process Optimization Methods in Logistics: Emerging Trends, Concepts and Technologies*, Erich Schmidt Verlag GmbH & Co. KG, Berlin, pp. 265-281.

Chapra, S.C. and Canale, R.P. (2010), *Numerical Methods for Engineers*, 6th ed.., McGraw-Hill.

Creswell, J.W. (2006), *Qualitative Inquiry and Research Design: Choosing among Five Traditions*, 2nd ed., Sage, Thousand Oaks, CA.

Hsu, C.-C. and Sandford, B.A. (2007), "The Delphi technique: making sense of consensus", *Practical Assessment, Research & Evaluation*, Vol. 12 No. 10, pp. 1-9.

Kumar, A., Motwani, J., Douglas, C. and Das, N. (1999), "A quality competitiveness index for benchmarking", *Benchmarking: An International Journal*, Vol. 6 No. 1, pp. 12-21.

Appendix 1

Structured Interview Protocol – First Round

This framework is intended to support a research regarding the development of an LARG index proposal to the Automotive Industry. To do this, it is important to get information about expert's perception on the importance of Lean, Agile, Resilient, and Green paradigms to the automotive industry sustainability. Try to answer the questions, please.

Academic/expert identification
Faculty Department:
Area(s) of expertise:
Do you have any research on the automotive industry?
If "Yes" in what kind of field(s)?
____ Strategy ____ Operations Management ____ Logistics
____ Supply chain Management _____ Equipment/maintenance _____ Ergonomics
Others: _____

1 - For the following supply chain management paradigms, please describe your perception about their importance to the sustainability of the automotive industry.

	1 nothing important	**2**	**3**	**4**	**5 extremely important**
Lean					
Agile					
Resilient					
Green					

Thanks for the collaboration.

Appendix 2

Structured Interview Protocol – Second Round

This framework is intended to support a research regarding the development of an LARG index proposal to the Automotive Industry. To do this, it is important to get information about expert's perception on the importance of Lean, Agile, Resilient, and Green paradigms to the automotive industry sustainability.

This is a second round questionnaire which incorporates the average answers obtained from the first round. Knowing this information, try to answer to the questions, please.

Academic/expert identification

Faculty Department:
Area(s) of expertise:
Do you have any research on the automotive industry?
If "Yes" in what kind of field(s)?
____ Strategy ____ Operations Management ____ Logistics
____ Supply chain Management _____ Equipment/maintenance _____ Ergonomics
Others: _____

1 - For the following supply chain management paradigms, please describe your perception about their importance to the sustainability of the automotive industry.

	1 nothing important	2	3	4	5 extremely important	1st round Average
Lean						4.7
Agile						4.4
Resilient						4.4
Green						3.4

Thanks for the collaboration.

Appendix 3

Structured Interview Protocol

This framework is intended to support a research regarding the determination of a lean, agile, resilient and green index to the automotive supply chain.

A – Firm characterization

Please indicate the following data that characterize your company:

- Sector
- Number of employees
- Primary product(s)
- Primary customer activity(ies)
- Your job title
- Your job responsibilities
- Your firm's position in the supply chain

B – Lean practices

For the following practices, please give information on their implementation level in your company (considering the following scale: 1 not implemented, 2, 3, 4, 5 totally implemented)

- Just in time (First tier supplier→Focal company)
- Supplier relationships/long-term business relationship
- Just in time (Focal company)
- Pull flow
- Total quality management
- Customer relationships
- Just in time (Focal company→ first tier customer)

C – Agile practices

For the following practices, please give information on their implementation level in your company (considering the following scale: 1 not implemented, 2, 3, 4, 5 totally implemented)

- Ability to change delivery times of supplier's order
- To use IT to coordinate/integrate activities in manufacturing
- To reduce development cycle times
- Centralized and collaborative planning
- To increase frequencies of new product introductions
- To Speed in improving customer service

D – Resilient practices

For the following practices, please inform on their implementation level in your company (considering the following scale: 1 not implemented, 2, 3, 4, 5 totally implemented)

- Sourcing strategies to allow switching of suppliers
- Flexible supply base/flexible sourcing
- Strategic stock
- Lead time reduction
- Creating a total supply chain visibility
- Flexible transportation
- Developing visibility to a clear view of downstream inventories and demand conditions

E – Green practices

For the following practices, please inform on their implementation level in your company (considering the following scale: 1 not implemented, 2, 3, 4, 5 totally implemented)

- Environmental collaboration with suppliers
- Environmental monitoring upon suppliers
- ISO 14001 certification
- To reduce energy consumption
- To reuse/recycling materials and packaging
- Environmental collaboration with the customer
- Reverse logistics

Thanks for the collaboration.

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