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Lean management - a step towards sustainable green supply chain

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Abstract

Purpose – The purpose of this paper is to identify important factors which contribute to the evolution of Green Supply Chain (GSC) initiatives framework as a result of sustained lean strategies predominantly but not confined to aviation sector.

Design/methodology/approach – This research is exploratory in nature and studies lean management implementation environment with focus on developing a framework for a GSC established through a path of identifying waste minimization techniques which automatically contribute to green initiatives in supply chain design invariably qualifying an ordinary supply chain as GSC. The approach is of identifying the framework parameters for both carbon footprint analysis and lean management. The focus of study is cross-sectional, within and outside aviation industry based on the information collected through survey methodology.

Findings – The paper identifies the key factors that are responsible to make a "green" supply chain and presents a framework to establish the same through rigorous evaluation while not losing sight of lean management requirements so that operational management perspective is not lost.

Research limitations/implications – The target of the study is the aviation industry and its supportive upstream and downstream beneficiaries. The study has implications for managers in all types of industrial environment, especially in aviation, in the era of globalized lean supply chain establishment which helps them to convert their present lean management initiatives to GSC.

Practical implications – Inputs obtained are from both literary and industrial research in a live environment and hence impacts lean management outlook and its benefits to industries.

Social implications – This paper has vast impact on the social well being with the focus on techno – environmental green initiatives factor identification through simple implemented and available procedures with no additional cost implication.

Originality/value – This paper presents unique inputs regarding conversion of lean implementation scenario in aviation and other industries to a GSC model, with suitable incorporation of recognized factors which are outcome of complicated internal processes. It also tries to establish factors relevant for any organization in assessing lean initiatives.

Keywords Lean management, Green supply chain management, Performance measurement system, Carbon footprint analysis

Paper type Research paper

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1. Introduction

The term "Supply Chain Management" (SCM) was first introduced by consultants in the early 1980s (Oliver and Webber, 1982; Raghu Kumar *et al.*, 2015). The concept was mainly used to discuss the benefits of integrating a firm's internal business functions, such as purchasing, manufacturing, sales and distribution (Harland, 1996; Raghu Kumar *et al.*, 2015). SCM is the coordination and management of a complex network of activities involved in delivering a finished product to the end-user or customer (Hervani *et al.*, 2005):

> The idea of lean thinking comprises complex cocktail of ideas including continuous improvements, flattened organization structures, team work, elimination of waste, efficient use of resources and cooperative SCM (Green, 2000, p. 524).

In 1990, the "Problems of Production" were in fact had become foremost issue in any industry (Raghu Kumar *et al.*, 2015). The culmination was perhaps the publication of a book in 1990 *The Machine That Changed the World*, preaching the gospel of lean production and offering the promise of two-for-one improvement for all who followed those Japanese-initiated doctrines (Haslam *et al.*, 1996). Until recently, most logistics and SCM research have examined issues such as the environment, safety and human rights in a standalone fashion, without consideration of the potential interrelationships among these and other aspects of social responsibility (Carter and Jennings, 2002; Craig and Dale, 2008). Despite numerous calls for more theory development in SCM research (Kent and Flint, 1997; Mentzer and Kahn, 1995; Meredith, 1993; Melynk and Handfield, 1998; Wacker, 1998), there has been, respectively, little theory-building research appearing within the broad field of SCM to date (Carter and Ellram, 2003; Craig and Dale (2008). Three supply chain trends in particular are converging to create an increasingly complex business environment: a move toward green initiatives, the utilization of lean processes and globalization (Mollenkopf *et al.*, 2010). The globalization of supply chains involves dimensions such as offshoring of production, inventories, suppliers and customers and differences in economies, infrastructures, cultures and politics in the competitive environment (Manuj and Mentzer, 2008; Schmidt and Wilhelm, 2000; Christopher, 2005; Mollenkopf *et al.*, 2010).

1.1 Supply chain as network

As the competition among the supply chains increase, they need to become more resilient to the attrition of the modern day global scenario of access to the techno-logistical needs of the industry. This means the industry is required to function more as a cohesive network rather than an isolated entity as in the distant past. There is an increase in awareness that businesses cannot compete as isolated entities, yet can do so as networks (Min and Zhou, 2002; Carvalho *et al.*, 2011). In this process, supply chains can be divided into external (inter-organizational) and internal (intra-organizational) components (Harms, 2011). Consequently, business operations are subject to increasing pressures and scrutiny from various stakeholders inside and outside organization such as government agencies, workers, neighbors and not-for-profit groups (Zhu and Sarkis, 2006).

1.2 Lean supply chain

As noted by Melnyk *et al.* (2003), firms that have successfully reduced their internal waste through lean production methods also implement practices for better

environment management. Many companies pursue operations innovation for good reasons, and that bring radical changes to business mostly struggling with change management, whether that means beginning a new lean program, redesigning a process or enabling employees to take ownership in key functions (Suo, 2012). The current economic crisis which has engulfed the world has forced the businesses around the globe to reassess their strategies. The lean supply chain is a multi-dimensional approach that is focused on cost reduction by eliminating non-value-added activities through the adoption of lean tools (Al-Aomar and Weriakat, 2012). Lean supply chain strategies focus on waste reduction, helping firms eliminate non-value-adding activities related to excess time, labor, equipment, space and inventories across the supply chain (Corbett and Klassen, 2006; Mollenkopf *et al.*, 2010). Lean practices are becoming increasingly difficult to implement and sustain as supply chains increase in complexity and length (Mollenkopf *et al.*, 2010). According to (Womak and Jones, 1996; Emiliani, 1998; Spear, 2004; Murman *et al.*, 2002a; Hopp and Spearman, 2004; Raghu Kumar *et al.*, 2015), lean thinking can be summarized in five principles: precisely specify value by specific product, identify the value stream for each product, make value flow without interruptions, let the customer pull value from the producer and pursue perfection. In a very short time, the lean management terminology and tenets of lean production had become indisputably important in the plans of a large fraction of the world's manufacturing base. Kenny and Florida (1993) pointed out that not every company may realize the same dramatic benefits from lean production as Toyota (Charles *et al.*, 2006). Specifically, for hardwood products manufacturers, raw material (lumber) cost accounts for more than 50 per cent of total production cost (Charles *et al.*, 2006).

1.3 Green supply chain

The trend of developing green supply chain (GSC) is fast gaining popularity owing to the perceived benefits. Lean and green initiatives are emerging technologies in the area of SCM that aim at increasing the effectiveness of the supply chain by reducing numerous types of waste using lean techniques while making the supply chain less harmful to the environment through the utilization of green technology (Al-Aomar and Weriakat, 2012). Therefore, there exists an overlap between green and lean practices in waste reduction and flow streamlining. For example, while lean and green are often seen as compatible initiatives due to each one's focus on waste reduction, lean strategies that require just-in-time delivery of small lot sizes require increased transportation, packaging and handling that may contradict a green approach[1]. A GSC focus requires working with suppliers and customers, analysis of internal operations and processes, environmental considerations in the product development process and extended stewardship across products' life-cycles (Corbett and Klassen, 2006; Mollenkopf, 2006; Mollenkopf *et al.*, 2010). It has become increasingly significant for organizations facing competitive, regulatory and community pressures to balance economic and environmental performance (Shultz *et al.*, 1999). The past literatures have showed these two paradigms were related to each other (Srivastava, 2007). A simple search across the net gives us a list of 60 different types of wastes generated by the industry[2]. This fact makes it more complicated to introduce a framework which is generic to most of the industries and which can make the green analysis simple. The main objective of green SCM is to extend the traditional SC to deal with the effects of products and processes (Al-Aomar and Weriakat, 2012).

2. Literature review

As concern mounts over rising fuel prices, the long-term availability of energy, and climate change, companies are turning their attention to one area where opportunities to conserve energy and reduce carbon emissions abound: the industrial supply chain (Grenon *et al.*, 2008). International Motor Vehicle Program (IMVP), founded at the Massachusetts Institute of Technology in 1979, has mapped lean methodologies, established benchmarking standards and probed the entire automotive value chain[4]. This is what the researchers involved in the IMVP who included the environment as one of the major activities needing monitoring had to say:

> We worked closely with other IMVP researchers to adapt the key components of the environment survey for use in the assembly plant study, with a particular emphasis on extracting the key elements that help define environmental performance (Chu *et al.*, 2002).

Auto suppliers at all levels may consider aviation work if there is a mid- to long-term opportunity to make a reasonable return on their investment (Grieco, 1749). Similarly, The Lean Advancement Initiative was a consortium of industry, government and labor union members funding MIT to help research and enable implementation of lean thinking in the aerospace sector (Murman *et al.*, 2002b). "[…] a corporation's ultimate success or health can and should be measured not just by the traditional financial bottom line, but also by its social/ethical and environmental performance" (Wayne and MacDonald, 2004; Raghu Kumar *et al.*, 2015). Environmental management may also represent an untapped avenue for further reduction of supply chain costs through more efficient use of natural resources (Hart, 1995; Florida, 1996). The issue, however, of how to address the environmental management practices of suppliers may prove to be a costly endeavor for the supply chain if not managed taking into consideration a number of important economic factors (Dayna and Damien, (2005). A well-developed and routinized supply relationship arguably encourages a joint approach to problem solving and leads to reductions in costs, improvements in quality and the import of new and critical knowledge (Lamming, 1993; Krause *et al.*, 2000; Dyer and Nobeoka, 2000). Recent research has found high levels of advanced pollution prevention occurring among firms that use lean manufacturing strategies (Rothenberg *et al.*, 2001; King and Lenox, 2001). The relation between the leanness and the GSC becomes critical if we note that the supply chain polluting more obviously has to be wasting more. The lean production philosophy focuses on avoiding seven forms of waste and on respecting customers, employees and suppliers (Womack *et al.*, 1990; Womack and Jones, 1996; Monden, 1997; Dayna and Damien, 2005). The benefits to the firm arising from advanced environmental management practice can include cost reduction (efficient use of raw materials, reduction in fines, risks or insurance costs); quality improvement; early adoption of new regulations; and better human resource management practice (Welford and Starkey, 1996; Porter and Van Der Linde, 1995; Theyel, 2000; Dayna and Damien, 2005). The objective of green supply chain management (GSCM) is to eliminate or minimize negative environmental impacts (air, water and land pollution) and waste of resources (energy, materials and products) from the extraction or acquisition of raw materials up to final use and disposal of products (Hervani *et al.*, 2005). This is a more complex GSCM strategy normally adopted by organizations that focus on eco-efficiency or lean and green approach to GSCM (Mutingi *et al.*, 2014a, 2014b). Several studies have considered the concept of ecological sustainability as a framework for studying

management practices in both operational and strategic contexts (Sarkis and Rasheed, 1995; Klassen and McLaughlin, 1996; King and Lenox, 2001; Hervani *et al.*, 2005). As part of this effort, other studies have examined the greening of supply chains within various contexts including in product design (Allenby, 1993; Gupta, 1995), process design (Porter and Van der Linde, 1995a; Klassen and McLaughlin, 1996), manufacturing practices (Winsemius and Guntram, 1992), purchasing (Handfield *et al.*, 2002) and a broad mixture of these elements (Bowen *et al.*, 2001a). Of the studies conducted along these lines, pioneerism must be attributed to Lamming and Hampson (1996), who proposed a series of environmental indicators for supplier selection. The researchers concluded there was no standard for criteria, or for use, on the part of analyzed companies (Ana and Charbel, 2009). Additional considerations were developed later (Azzone and Noci, 1998; Walton *et al.*, 1998, Ana and Charbel, 2009). Although these studies identify the need and tendency to include environmental criteria in the supplier selection process, they fail to systematize, categorize and detail a framework for this theme (Ana and Charbel, 2009). Significant progress in the search for a framework to consider environmental aspects in the supplier selection process was achieved by communicating the results of the study by Humphreys *et al.* (2003). These authors discussed a model comprising environmental criteria that must be considered when selecting suppliers. These criteria can be grouped according to two perspectives – quantitative criteria and qualitative criteria. If on one hand, environmental criteria and assumptions for supplier selection based on environmental performance are encouraging, they tend to be more of a theoretical argument than an organizational practice inserted in the dynamics of the supply chain (Ofori, 2000). Eltayeb and Zailani (2009) reviewed more than 20 literatures on GSC initiatives and concluded that the GSC can be generally classified into three major elements, namely, design for environment, green purchasing and reverse logistics (Al-Aomar and Weriakat, 2012).

2.1 Gaps in literature

Most of the adapted green solutions, especially in developing countries, remain to be the traditional command-and-control or "end-of-the- pipe" solutions where a firm tries to eliminate or reduce negative environmental impacts, after they are created, rather than adopting a proactive approach to reduce the sources of waste or pollution (Anbumozhi and Kanada, 2005; Walton *et al.* 1998). Thus, there are no in-process evaluation techniques available in the literature which are assessing the processes and providing a real-time feedback to the organization to arrest any non-environment friendly processes. Sundarakani *et al.* (2010) examined the carbon footprint (CF) across supply chains and contributed to the knowledge and practice of GSCM. The results show that carbon emissions across stages in a supply chain can constitute a significant threat that warrants careful attention in the design phase of supply chains (Al-Aomar and Weriakat, 2012). Azevedo *et al.* (2011) recommended the following Green practices: environmental collaboration with suppliers, environmentally friendly purchasing practices, working with designers and suppliers to reduce and eliminate product environmental impact, minimizing waste, decrease the consumption of hazardous and toxic materials, ISO 14,001 certification, reverse logistics, environmental collaboration with customers, environmentally friendly packaging and working with customers to change product specifications (Al-Aomar and Weriakat, 2012). There is of course significant literature on sustainability and operations in general (Kleindorfer *et al.*, 2005;

Linton *et al.*, 2005; Srivastava, 2007; Corbett and Klassen, 2006; Benjaafar *et al.*, 2013). However, the concern in that body of literature tends to be more focused on product recycling or reuse (Flapper *et al.*, 2005; Guide and Van Wassenhove, 2006; Benjaafar *et al.*, 2013) or product life cycle assessment (Guide and Van Wassenhove, 2009; Matos and Hall, 2007; Benjaafar *et al.*, 2013).

3. Research methodology

3.1 Motivation and research objective

Many progressive companies such as Canon, General Motor and Sony are realizing the importance of corporate social responsibility and are now focusing on the environmental burden of their logistics processes (Sundarakani *et al.*, 2008). The motivation for the research was also the interaction with the respondents of an interview conducted earlier for the purpose of evaluating the relevancy of the lean management (Raghu Kumar *et al.*, 2015). While extending the lessons learnt from earlier foray into the lean initiatives, it was appreciated that the environmental concerns can be addressed if a similar analysis is undertaken to understand the concerns of the enlightened customers and at the same time ensure that the organizations are able to meet futuristic environmental standards, while continuing to work in present era.

3.2 Statement of the problem

The first phase of the research was dedicated to an extensive literature survey to ascertain the adequacy of techniques available. This yielded insight to the present practices and global scenario of expected environmental commitment of various organizations. In as much as several researchers have investigated the concepts of greening the environment at strategic and operational levels, many related researchers have studied greening practices, such as green product design (Gupta, 1995; Allenby, 1993), green process design (Porter and Van der Linde, 1995a; Klassen and McLaughlin, 1996), green purchasing (Handfield *et al.*, 2002) and green manufacturing practices at large (Winsemius and Guntram, 1992; Mutingi, 2012; Hu *et al.*, 2006). To achieve the GSC, manufacturing organizations must follow the basic principles established by ISO 14,000; In particular, organizations must develop procedures that focus on operations analysis, continuous improvement, measurement and objectives (Benita, 1999). The ISO 14,000 series consists of the following (Source: International Organization for Standardization - 1996; Benita, 1999):

- ISO 14001 – specific minimum requirements for achieving ISO 14,000 certification;
- ISO 14004 – sets guidelines for developing an environmental management (EM) system;
- ISO 14010 – establishes the general principles of environmental auditing;
- ISO 14011 – establishes auditing procedures for the auditing of EM systems; and
- ISO 14012 – establishes qualification criteria for environmental auditors.

The ISO 14,000 is indicative of the recent shift in environmental philosophy; ISO 14,000 focuses on procedures and systems and says nothing of discharge standards, limits or test methods (Pratt, 1997; Benita, 1999). Yang *et al.* (2011) explored the relationships between lean manufacturing practices, environmental management and business

performance outcomes. The findings suggest that environmental management practices alone are negatively related to market and financial performance (Al-Aomar and Weriakat, 2012).

3.3 Purpose of the research

Lean-based strategies go beyond regulatory compliance through the requirement for the suppliers to meet operation-based targets (Mutingi *et al.*, 2014a, 2014b). This strategy maximizes on economic performance while simultaneously providing secondary environmental performance benefits through waste and resource use reductions (Mutingi *et al.*, 2014a, 2014b). Lean-based economic performance indicators suggested by Mutingi *et al.* (2014a, 2014b) are summarized in Table I which form the lean techniques and inputs into the framework being proposed in this paper.

According to Rawabdeh (2005) and Carter (2011), there are at least seven areas that can be looked at for ways to reduce waste or excess of a product – motion excess, over production, over-processing, waiting time, defects, inventory excess and transportation. These are appended suitably in the Table II. However, though they cater to the requirements of the lean tenets, they do nothing to mitigate or change the green conditions of the organization, unless suitable drivers are identified and a transition condition specified through which the organization can fruitfully realize GSC. This

No.	Indicator	Description
1.	Material costs	Decrease of materials purchasing costs
2.	Energy	Decrease of energy consumption costs
3.	Inventory costs	Decrease of inventory (storage) costs
4.	Waste treatment	Decrease of fees paid for waste treatment
5.	Waste discharge	Decrease of fees paid for waste discharge
6.	Transportation	Decrease of transportation related costs

Source: Mutingi *et al.* (2014a, 2014b)

Table I. Lean-based economic indicators

Serial no.	Supply chain elements
1	Distribution network configuration
2	Inventory control
3	Production sourcing
4	Supply contracts
5	Distribution strategies
6	SC integration and strategic partnering
7	Outsourcing and offshoring strategies
8	Product design
9	IT and decision support system
10	Customer value
11	Smart pricing
12	Local issues

Source: Simchi *et al.* (2008)

Table II. Supply chain matrix elements for LeGreen evaluation framework – sustainability assessment (Strategic, tactical and operational)

would entail identification of the green efforts of the organization and a framework or a "gauge" which would precisely quantify these efforts.

Ana and Charbel (2009) analyzed the inclusion of environmental criteria in the supplier selection process at five companies located in Brazil. They verified that these companies have difficulties in including environmental aspects in the supplier selection. The more advanced companies were those that presented greater environmental management maturity, with changes in their product development process. This shows that the selection of environmentally fit suppliers must be part of a broader environmental performance process by organizations. Much attention has been paid to the importance of GSCM development, which is expected to effectively create a win–win relationship between environmental performance and economic efficiency throughout the supply chain (Huang *et al.*, 2015). The environmental awareness of an organization will influence the perspective from which green strategies are developed (Korchi, 2014).

3.4 LeGreen evaluation framework

To develop an effective green performance measurement system (PMS) for the GSC, the decision maker needs a guide or framework for developing the PMS and for identifying appropriate green performance indicators (Mutingi *et al.*, 2014a, 2014b). There are four basic requirements that should be considered when developing an effective PMS that can support GSC performance (Azzone *et al.*, 1998).

- *Strategic focus*: The ability of the PMS system to account for the long-term impacts.
- *Measurability*: The ease of measurement, to enable assessment of green efficiency.
- *Completeness*: Ability of the PMS to account for all relevant performance indicators.
- *Timeliness*: The amount of time taken by the PMS to collect and analyze the performance related data.

In the most ideal case, effective PMSs should basically include both physical and economic indicators in an integrated framework (Azzone *et al.*, 1998). Walton *et al.* (1998) conducted a study in five American industries to identify GSCM practices adopted by the companies. The authors classified the GSCM practices into five categories:

- products designed with eco-friendly materials;
- design process of the product;
- improvements in supplier processes;
- evaluation of suppliers; and
- internal logistics process.

Meanwhile, Hervani *et al.* (2005) found that GSCM can be defined as the combination of the following activities:

- green purchasing;
- green manufacturing and materials management;
- green distribution/marketing; and
- reverse logistics.

There are few theoretical or theoretical-empirical studies that consider environmental criteria in the supplier selection process and in SCM (Lin *et al.*, 2001; Ana Beatriz and Charbel, 2009). This was endorsed in the study by Humphreys *et al.* (2003), which involves criteria evaluated qualitatively, and organized in the following categories:

- environmental management competencies;
- environmental image of suppliers;
- development of products with high environmental performance;
- environmental management system; and
- environmental competencies.

Koplin *et al.* (2007) proposed a conceptual model that integrates GSCM with regulatory requirements, the anticipated detection of risks, the supply process and monitoring and development of suppliers linked to the automotive industry. The authors concluded that for the effective implementation of sustainability in the automotive industry, it is necessary to go far beyond stating the mission to find practical approaches to sustainable development with the companies themselves, as well as in relation to their supply chains.

3.5 Framework Characteristics

Few companies consider the full spectrum of their environmental impact, says Anant Sundaram, a professor at the Tuck School of Business at Dartmouth University who teaches a course on business and climate change[3]. In an effort to identify a framework which can be all encompassing, most of the parameters given in the literature were assessed but were found to be lacking some or the other important criteria. As the internal processes were different from industry to industry, for e.g. from Construction to Automobile industry, there has to be a method to assess which can be a single window criterion.

3.6 Development of framework

In fact, one could argue that many of the popular business practices, such as just-in-time manufacturing and lean production, which favor frequent deliveries with less than truckload shipments, small production runs and multiple regional warehouses, could have as much of an impact on the CF of a firm as the energy efficiency of individual units deployed in production or distribution (Benjaafar *et al.*, 2013). The term "carbon footprint" refers to the total amount of carbon dioxide (CO2) and other greenhouse gases emitted over the entire lifecycle of a product or service (Grenon *et al.*, 2008). Typically expressed in tons or grams of CO2, the carbon-footprint concept helps businesses and governments understand the relative amount of damage a particular product or service causes to the environment (Grenon *et al.*, 2008). Although a lot has been written about the CF of supply chains in the popular press and in trade magazines (Lee, 2010; Parry *et al.*, 2007; Plambeck, 2007; Lash and Wellington, 2007; Benjaafar *et al.*, 2013), and although numerous websites, non-profit organizations, trade groups and government bodies have been dedicated to the issue, the research community in operations and SCM has only recently begun to pay attention to this area. Given the potential impact of operational decisions on carbon emissions, there is clearly a need for operations management research that incorporates carbon emission concerns that would

complement (and benefit) from the body of knowledge in other disciplines (Benjaafar *et al.*, 2013) . In particular, there is a need for model-based research that extends quantitative models, which typically focus on either minimizing cost or maximizing profit, to include CF. A recent survey showed that a product's environmental footprint is a critical factor for the 83 per cent of the European Union citizens when deciding to purchase (European Commission, 2009). In practice, firms are using CF analysis so as to guarantee sustainability, which denotes both environmental friendliness of their products and cost effectiveness of their supply chain activities (Aivazidou *et al.*, 2013). There are three types of emissions a CF analysis examine, Sundaram says[3]:

- *direct fuel consumption*, such as gas burned by employees commuting and driving cars on company business;
- *the pollution emitted from the electricity* that powers your store or office; and
- *the indirect emissions* associated with the business, such as the impact of mining necessary raw materials for manufacturing or the fuel used to ship goods to stores and out to customers.

The point here is not to assume that a popular measure such as recycling or evaluation of fuel consumed is the only way to reduce carbon emissions for every product (Grenon *et al.*, 2008). Because each product's CF is unique, the solutions for shrinking that footprint will also be unique (Grenon *et al.*, 2008). There are also several other factors which needs to be examined while analyzing the CF of various organizations. This task was accomplished by revisiting the basic principles of the SCM as given in the succeeding paragraphs.

3.7 Working principles

While applying the basic principles, we see that the companies have the established way for classification in which the green efforts are categorized as per the tasks carried out. Whereas this paper is proposing to eradicate the same and instead channelize the entire efforts in the form of something more tangible, namely, a "GRADE" or "NUMBER" which is the exact reflection of the CF assessment made. In other words, the tasks are converted to CF left behind by the present effort *vis-à-vis* efforts earlier. For instance, consider the following examples.

One company (ABC) website has the following information about the green initiatives:

- recycling of scrap metal, bulk paper and cardboard products;
- reduction of paper usage through the use of electronic documents;
- major heating processes are electric powered, and tankless water heating systems are widely used;
- water soluble or biodegradable quenchants and bulk process lubricants;
- evaporative based cooling systems are used where applicable;
- energy efficient roofing systems;
- low power lighting systems with natural lighting assistance in most buildings; and
- low volatile organic compounds (VOC) emissions.

Another company (XYZ) has the following green initiatives:

- a closed loop water filtration system which recycles the water used through out the manufacturing process;
- creation of a paperless document system which drastically reduced printing and paper consumption;
- retrofit of lighting fixtures to reduce electricity consumption by approximately 30 per cent;
- an internal recycling program for plastic bottles and aluminum cans;
- all Styrofoam products removed from cafeteria and replaced with paper;
- all electronic components sent to offsite recycling programs;
- waste reduction system which cut our hazardous waste output by over 85 per cent;
- Project Green Sweep which reduces the amount of printed mailings and flyers sent to our facility;
- Green Technology initiatives to reduce energy footprint; and
- In YEAR – Certified to the ISO 14,001 (environmental) standards.

The framework formulation was initiated with the identification of the supply chain basic elements from a reliable source, just to ensure that the framework itself is founded upon well established principles during design.

The development of the framework was taken up with the guiding principle as derived in the preceding paragraphs of CF analysis. Direct implication on the environment needed to be drawn before finalizing the framework. This strategy helped in homing on to the CF evaluation while reducing the wastes using the lean fundamentals, which already had been established in most of the industries. The interaction with the respondents who had participated in an earlier interview helped in formulating the lean principles as found generically applicable to all organizations. The universally applicable framework can be derived using the following three simple principles (Grenon *et al.*, 2008):

- understand the CF of each product or service;
- separate necessary emissions from those that could be reduced or eliminated; and
- zero in on measures that provide the greatest benefits for the cost involved.

3.8 Discussions on the proposed framework

The core premise is that producing the same output with less resources (materials, energy and capital) is inherently good for the environment while also reducing the cost of operation for the company (Florida, 1996). Similarly, by improving quality (a core lean objective), there are less production defects and resultant scrap/rework, further reducing cost and environmental impact (Simpson and Power, 2005). Florida (1996) suggested that environmental and industrial/economic performance improvement is interlinked as both stem from a common drive: "Firms that are innovative in terms of their manufacturing process are likely to be more imaginative in addressing environmental costs and risks" (Florida, 1996; Piercy and Rich, 2015). This draws focus onto the strategic and tactical issues apart from the operational ones. If we may bifurcate the

environmental concerns into different perspectives, we see that core issues which affect the industry and the environment together form the strategic plateau. Therefore, the strategic focus should comprise the environmental management competencies, environmental image of suppliers, development of products with high environmental performance and environmental management system. Now the strategic focus needs to get an assessment of the greening effect which is basically the introduction of "*Measurability*" to the framework, so that the efforts at tactical and operational levels are suitably documented. This measurability should depend on the CF generated as the result of the green efforts. Though there are many ways of doing it, this paper considers some well-known methods to document the green efforts such as – green purchasing, green manufacturing and materials management, green distribution/marketing and reverse logistics. The belief further accentuated through this paper is the fixation of timeline for the entire exercise, without which the efforts may not be fruitful as delayed action loses its intended effect on the environment. Therefore, "*Timeliness*" which understands the process and aids synchronized action is the need of the hour. The "*Completeness*", for products designed with eco-friendly materials, design process of the product, improvements in supplier processes, evaluation of suppliers and internal logistics process gain the last block in the framework. *The proposed model while addressing the strategic, tactical and operational issues of lean management at the grass root levels, by integrating the environmental concerns (like environmental management systems and environmental performance) with the production issues (like design process of the product), which has not been addressed hitherto fore in a global approach.*

4. Conclusion

4.1 Research summary

The focus has been maintained on the development of the framework as proposed in the initial part of the paper. As promised the framework tries to create a win–win situation by creating a seamless combine of the operational issues and environmental issues with the help of a single window criterion, namely, the CF analysis. This is exploratory research and tries to build on the body of knowledge that is helping the industry to grapple with the deteriorating scenario of environmental management and operational sustainability of the organization. The reduction of the concerning factors to the CFA is not a simple task and needs all the inputs possible to be generated by the industry in formulating a model. This is as said earlier an explorative research and within a small timeframe could not include the vast representation of the industrial spectrum and its environmental effects. The aviation environment inherently carries a rider in the form of a term called – Flight Safety‖ (FS) which makes each and every aspect of maintenance become weak kneed, irrespective of how good the management technique is; this is due to the fact that the cost cuttings derived are always scrutinized against a scanner called FS which may entail scrapping of the entire technique, if found that the technique is even remotely affecting the FS (Raghu Kumar *et al.*, 2015). Therefore, while analyzing the aerospace sector, these are the concerns which need to be addressed before effecting the environmental framework as the industrial survivability is as important as the environmental impact the industry has with its interactive neighbors. This just highlights the fact that the model only gives the basic guidelines for CF analysis in a generic form which can be further optimized for industry specific applications.

Serial no.	Supply chain elements	Leanness applicability	Greening effect/Barriers	Remarks
1	Distribution network configuration	Warehouse location/Capacity	Reduction of fuel consumption	Strategic
2	Inventory control	Supplier alliances and management Inventory excess Over production Over-processing	Reasons for the excesses and elimination	Strategic
3	Production sourcing	Demand management Waiting time	Results in excess usage of all green components like Power, Transportation, etc.	Strategic
4	Supply contracts	Motion excess Network design Retailing	Cost of implementation Lack of preparedness	Operational
5	Distribution strategies	Coordination/Integration activities Global integration problems Performance measurement Consumption	Results in excess usage of all green components like Power, Transportation, etc.	Operational
6	SC integration and strategic partnering	Information sharing Strategic partnering	Recycling/Remanufacture	Operational
7	Outsourcing and offshoring Strategies	Transportation	Reduction of fuel consumption	Strategic
8	Product design	Defects	Recyclable raw materials	Strategic
9	IT and decision support system	Infrastructure requirement Data safety	Mathematical model creation for green evaluation	Operational
10	Customer value	Waiting time Defects	Reverse logistics	Tactical
11	Smart pricing	Customer approach	Cost of Green implementation	Tactical
12	Local issues	Government related Other organizations like NGO related	Involvement of local population	Tactical

Table III.
Correlatives with the supply chain elements

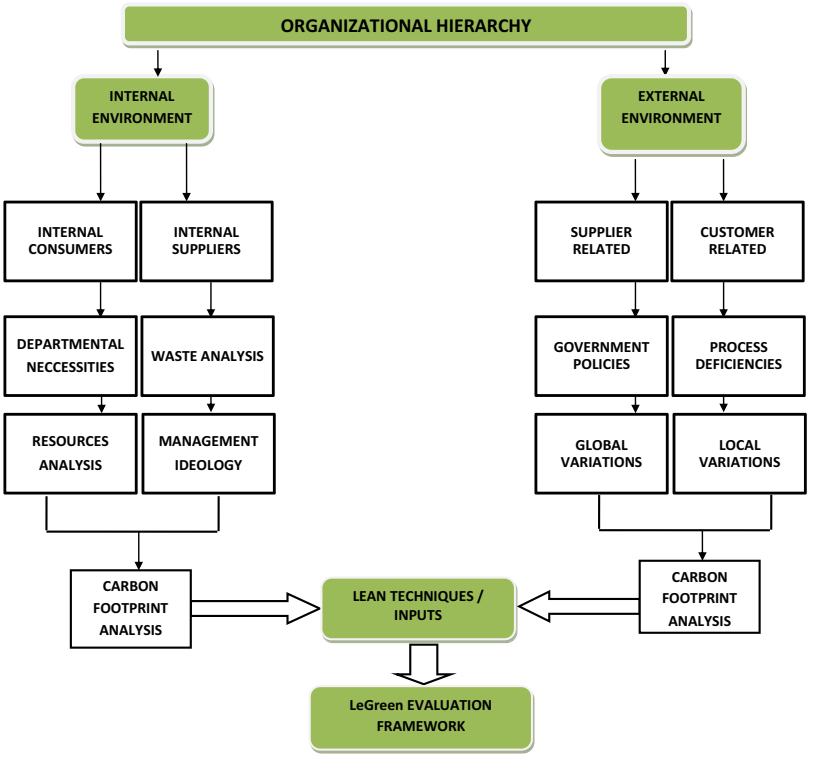

Figure 1.
LeGreen framework – organizational strategy

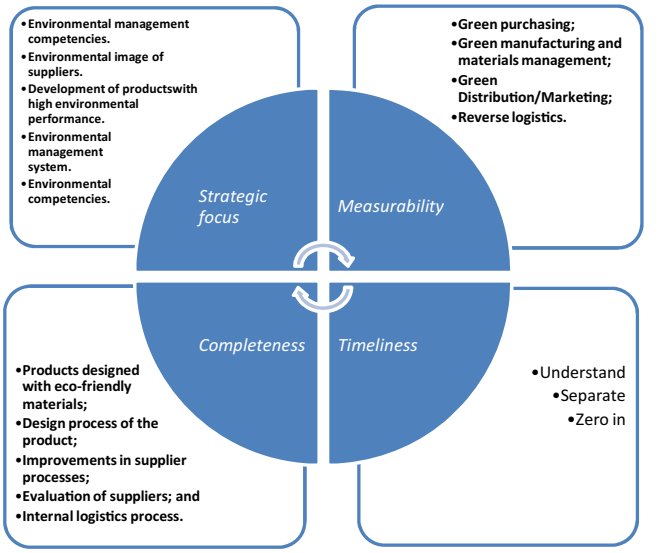

Figure 2.
The LeGreen evaluation model

5. Limitations

5.1 Future research dimension

The limitation of aviation field research exists in this paper, which needs to be assessed in different type of industries. Future research dimension includes the validation and verification of the drivers and indicators as identified in the Table III and Figure 1 in a real world scenario. This will help to establish the various categories of green strategies as applicable to individual industry. Furthermore, new comprehensive or hybrid indicators may be designed for integrated assessment of both environmental and economic performance (Mutingi *et al.*, 2014a, 2014b). The need for integrated measurement application (Mollenkopf *et al.*, 2010) is realized as one of the foremost driver in establishing the green innovation across organizations. The applicability of the model needs to be tried out in different types of industries to modify or add factors which represent a complete reflection of the industry spectrum.

Notes

1. Available at: www.industryweek.com/articles/can_you_have_a_leangreenglobal_supply_chain_19335.aspx
2. Available at: http://en.wikipedia.org/wiki/List_of_waste_types
3. Available at: www.entrepreneur.com/article/226467
4. Available at: https://en.wikipedia.org/wiki/International_Motor_Vehicle_Program

References

Aivazidou, E., Iakovou, E., Vlachos, D. and Keramydas, C. (2013), "A methodological framework for supply chain carbon footprint management", *Chemical Engineering Transactions*, Vol. 35 No. 1, pp. 313-318. doi: 10.3303/CET1335052.

Al-Aomar, R. and Weriakat, D. (2012), "A framework for a green and lean supply chain: a construction project application", *Proceedings of the 2012 International Conference on Industrial Engineering and Operations Management Istanbul*, *Istanbul*, 3-6 July.

Allenby, B. (1993), "Supporting environmental quality: developing an infrastructure for design", *Total Quality Environmental Management*, Vol. 2 No. 3, pp. 303-308.

Ana Beatriz, L.S.J. and Charbel, J.C.J. (2009), "Are supplier selection criteria going green? Case studies of companies in Brazil", *Industrial Management & Data Systems*, Vol. 109 No. 4, pp. 477-495.

Anbumozhi, V. and Kanada, Y. (2005), "Greening the production and supply chains in Asia: is there a role for voluntarily initiatives?", IGES Kansai Research Center Discussion Paper, KRC-2005, No. 6E, available at: www.iges.or.jp

Azevedo, S.G., Carvalho, H. and Machado, V.C. (2011), "The influence of green practices on supply chain performance: a case study approach", *Transportation Research Part E: Logistics and Transportation Review*, Vol. 47 No. 6, pp. 850-871.

Azzone, G. and Noci, G. (1998), "Identifying effective PMSs for the deployment of green manufacturing strategies", *International Journal of Operations & Production Management*, Vol. 18 No. 4, pp. 308-335.

Benita M.B. (1999), "Designing the green supply chain", *Logistics Information Management*, Vol. 12 No. 4, pp. 332-342.

Benjaafar, S., Li, Y. and Daskin, M. (2013), "Carbon footprint and the management of supply chains: insights from simple models", *IEEE Transactions on Automation Science and Engineering*, Vol. 10 No. 1.

Bowen, F.E., Cousins, P.D., Lamming, R.C. and Faruk, A.C. (2001a), "Horses for courses: explaining the gap between the theory and practice of green supply", *Greener Management International*, Vol. 35 No. 1, pp. 41-60.

Carter, C.R. and Ellram, L.M. (2003), "Thirty-five years of the journal of supply chain management: where have we been, where are we going?", *Journal of Supply Chain Management*, Vol. 39 No. 2, pp. 27-39.

Carter, C.R. and Jennings, M.M. (2002), "Logistics social responsibility: an integrative framework", *Journal of Business Logistics*, Vol. 23 No. 1, pp. 145-180.

Carvalho, H., Duarte, S. and Machado, V.C. (2011), "Lean, agile, resilient and green: divergencies and synergies", *International Journal of Lean Six Sigma*, Vol. 2 No. 2, pp. 151-179.

Charles, D.R., Xiaoqiu, Z., Judd, H.M. and Janice, K.W. (2006), "The lean index: operational lean metrics for the wood products industry", *Wood and Fiber Science*, Vol. 38 No. 2, pp. 238-255.

Christopher, M. (2005), *Logistics & Supply Chain Management: Creating Value-Adding Networks*, 3rd ed., Pearson Education, Harlow.

Corbett, C.J and Klassen, R.D. (2006), "Extending the horizons: environmental excellence as key to improving operations", *Manufacturing & Service Operations Management*, Vol. 8 No. 1, pp. 5-22.

Craig, R.C. and Dale, S.R. (2008), "A framework of sustainable supply chain management: moving toward new theory", *International Journal of Physical Distribution & Logistics Management*, Vol. 38 No. 5, pp. 360-387.

Dayna, F.S. and Damien, J.P. (2005), "Use the supply relationship to develop lean and green suppliers", *Supply Chain Management: An International Journal*, Vol. 10 No. 1, pp. 60-68.

Dyer, J. and Nobeoka, K. (2000), "Creating and managing a high-performance knowledge-sharing network: the Toyota case", *Strategic Management Journal*, Vol. 21 No. 3, pp. 345-367.

Eltayeb, T.K. and Zailani, S. (2009), "Going green through green supply chain initiatives towards environmental sustainability", *Operations and Supply Chain Management*, Vol. 2 No. 2, pp. 93-110.

Emiliani, M.L. (1998), "Lean behaviors", *Management Decision*, Vol. 36 No. 9, pp. 615-631.

Flapper, S.D.P, Van Nunen, J.A. and Van Wassenhove, L.N. (2005), *Managing Closed-Loop Supply Chains*, Springer-Verlag, New York, NY.

Florida, R. (1996), "Lean and green: the move to environmentally conscious manufacturing", *CA Management Review*, Vol. 39 No. 1, pp. 80-105.

Green, S.D. (2000), "The future of lean construction: a brave new world", *Proceedings of the 8th Annual Conference of the International Group for Lean Construction*, *Brighton*, pp. 1-11.

Guide, V.D.R. Jr and Van Wassenhove, L.N. (2006), "Closed-loop supply chains: an introduction to the feature issue (part 1)", *Production and Operations Management*, Vol. 15 No. 3, pp. 345-350.

Guide, V.D.R. Jr. and Van Wassenhove, L.N. (2009), "The evolution of closed-loop supply chain research", *Operations Research*, Vol. 57 No. 1, pp. 10-18.

Gupta, M. (1995), "Environmental management and its impact on the operations function", *International Journal of Operations & Production Management*, Vol. 15 No. 8, pp. 34-51.

Handfield, R., Walton, S.V., Sroufe, R. and Melnyk, S.A. (2002), "Applying environmental criteria to supplier assessment: a study in the application of the analytical hierarchy process", *European Journal of Operational Research*, Vol. 141 No. 1, pp. 70-87.

Harland, C. (1996), "Supply chain management: relationships, chains and networks", *British Journal of Management*, Vol. 7 No. 1, pp. 63-80.

Harms, D. (2011), "Environmental sustainability and supply chain management – a framework of cross-functional integration and knowledge transfer", *Journal of Environmental Sustainability*, Vol. 1 No. 1, pp. 121-141.

Hart, S. (1995), "A natural-resource based view of the firm", *Academy of Management Review*, Vol. 20 No. 4, pp. 986-1000.

Haslam, C., Williams, K., Johal, S. and Williams, J. (1996), "A fallen idol? Japanese management in the 1990s", *Asia Pacific Management Review*, Vol. 2 No. 4, pp. 21-43.

Hervani, A.A., Helms, M.M. and Sarkis, J. (2005), "Performance measurement for green supply chain management", *Benchmarking: An International Journal*, Vol. 12 No. 4, pp. 330-335.

Hopp, W.J. and Spearman, M.L. (2004), "To pull or not to pull: what is the question?", *Manufacturing & Service Operations Management*, Vol. 6 No. 2, pp. 133-148.

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", *IEEE International Conference on Management of Innovation and Technology*, Singapore, pp. 853-857.

Huang, X., Tan, B.L. and Ding, X. (2015), *Journal of Manufacturing Technology Management*, Vol. 26 No. 1, pp. 80-103.

Humphreys, P.K., Wong, Y.K. and Chan, F.T.S. (2003), "Integrating environmental criteria into the supplier selection process", *Journal of Materials Processing Technology*, Vol. 138 Nos 1/3, pp. 349-356.

Kenny, M. and Florida, R. (1993), *Beyond Mass Production*, Oxford University Press, Oxford and New York, NY, p. 410.

Kent, J.L., Jr and Flint, D.J. (1997), "Perspectives on the evolution of logistics thought", *Journal of Business Logistics*, Vol. 18 No. 2, pp. 15-29.

King, A.A. and Lenox, M.J. (2001), "Lean and green? An empirical examination of the relationship between lean production and environmental performance", *Production and Operations Management*, Vol. 10 No. 3, pp. 244-256.

Klassen, R.D. and McLaughlin, C.P. (1996), "The impact of environmental management of firm", *Performance Management Science*, Vol. 42 No. 8, pp. 1199-1215.

Kleindorfer, P.R. Singhal, K. and Van Wassenhove, L.N. (2005), "Sustainable operations management", *Production and Operations Management*, Vol. 14 No. 4, pp. 482-492.

Koplin, J., Seuring, S. and Mesterharm, M. (2007), "Incorporating sustainability into supply management in the automotive industry and the case of the Volkswagen AG", *Journal of Cleaner Production*, Vol. 15 No. 11, pp. 1053-1062.

Korchi, A.E. (2014), "Conditions of emergence of OEM's reverse supply chains", *Journal of Remanufacturing*, Vol. 4 No. 3. doi: 10.1186/2210-4690-4-3.

Krause, D., Scannell, T. and Calantone, R. (2000), "A structural analysis of the effectiveness of buying firms' strategies to improve supplier performance", *Decision Sciences*, Vol. 31 No. 1, pp. 33-55.

Lamming, R. (1993), *Beyond Partnership: Strategies for Innovation and Lean Supply*, Prentice-Hall, New York, NY.

Lamming, R. and Hampson, J. (1996), "The environment as a supply chain management issue", *British Journal of Management*, Vol. 7 No. 1, pp. 45-62.

Lash, J. and Wellington, F. (2007), "Competitive advantage on a warming planet", *Harvard Business Review*, Vol. 85 No. 3, pp. 95-102.

Lee, H. (2010), "Don't tweak your supply chain – Rethink it end to end", *Harvard Business Review*, Vol. 88 No. 10, pp. 62-69.

Lin, B., Jones, C.A. and Hsieh, C. (2001), "Environmental practices and assessment: a process perspective", *Industrial Management & Data Systems*, Vol. 101 No. 2, pp. 71-79.

Linton, J.D., Klassen, R. and Jayaraman, J. (2007), "Sustainable supply chains: an introduction", *Journal of Operations Management*, Vol. 25 No. 6, pp. 1078-1082.

Manuj, I. and Mentzer, J.T. (2008), "Global supply chain risk management", *Journal of Business Logistics*, Vol. 29 No. 1, pp. 133-155.

Matos, S. and Hall, J. (2007), "Integrating sustainable development in the supply chain: the case of life cycle assessment in oil and gas and agricultural biotechnology", *Journal of Operations Management*, Vol. 25 No. 1, pp. 1083-1102.

Melynk, S.A. and Handfield, R.B. (1998), "May you live in interesting times: the emergence of theory-driven empirical research", *Journal of Operations Management*, Vol. 16 No. 4, pp. 321-329.

Melnyk, S.A., Sroufe, R.P. and Calantone, R.J. (2003), "Assessing the impact of environmental management systems on corporate and environmental performance", *Journal of Operations Management*, Vol. 21 No. 3, pp. 329-351.

Mentzer, J.T. and Kahn, K.B. (1995), "A framework for logistics research", *Journal of Business Logistics*, Vol. 16 No. 1, pp. 231-250.

Meredith, J. (1993), "Theory building through conceptual methods", *International Journal of Operations & Production Management*, Vol. 13 No. 5, pp. 3-11.

Min, H. and Zhou, G. (2002), "Supply chain modelling: past present and future", *Computers and Industrial Engineering*, Vol. 43 No. 1, pp. 231-249.

Mutingi, M., Mapfaira, H. and Monageng, R. (2014a), "An analysis of remanufacturing practices in Japan", *Journal of Remanufacturing*, Vol. 4 No. 6, available at: www.journalofremanufacturing.com/4/1/6; doi: 10.1186/s13243-014-0006-z.

Mutingi, M., Mapfaira, H. and Monageng, R. (2014b), "Developing performance management systems for the green supply chain", *Journal of Remanufacturing*, Vol. 4 No. 6, available at: www.journalofremanufacturing.com/4/1/6

Mollenkopf, D., Wendy, H.S., Tate, L. and Ueltschy, M. (2010), "Green, lean, and global supply chains", *International Journal of Physical Distribution & Logistics Management*, Vol. 40 Nos 1/2, pp. 14-41.

Mollenkopf, D.A. (2006), *Environmental Sustainability: Examining the Case for Environmentally-sustainable Supply Chains*, Council of Supply Chain Management Professionals, Lombard, IL.

Monden, Y. (1997), *Toyota Production System: An Integrated Approach to Just-in-Time*, Engineering and Management Press, Norcross, GA. ISBN 0-89806 – 180-6.

Murman, E., Allen, T., Bozdogan, K., Cutcher-Gershenfeld, J., McManus, H., Nightingale, D., Rebentisch, E., Shields, T., Stahl, F., Walton, M., Warmkessel, J., Weiss, S. and Widnall, S. (2002a), *Lean Enterprise Value*, Palgrave, London.

Murman, E., Allen, T., Bozdogan, K., Cutcher-Gershenfeld, J., McManus, H., Nightingale, D., Rebentisch, E., Shields, T., Stahl, F., Walton, M., Warmkessel, J., Weiss, S. and Widnall, S. (2002b), *Lean Enterprise Value: Insights from MIT's Lean Aerospace Initiative*, Palgrave, Hampshire, New York, NY.

Ofori, G. (2000), "Greening the construction supply chain in Singapore", *European Journal of Purchasing and Supply Management*, Vol. 6 Nos 3/4, pp. 195-206.

Oliver, R. and Webber, M. (1982), "Supply-chain management: logistics catches up with strategy", in Christopher, M. (Ed.), *Logistics: The Strategic Issues*, Champmon, London, pp. 63-75.

Parry, P., Martha, J. and Grenon, G. (2007), "The energy-efficient supply chain", *Strategy Bus*, Vol. 47 No. 1, pp. 22-26.

Piercy, N. and Rich, N. (2015), "The relationship between lean operations and sustainable operations", *International Journal of Operations & Production Management*, Vol. 35 No. 2, pp. 282-315.

Plambeck, E. (2007), "The greening of Walmart's supply chain", *Supply Chain Management Review*, Vol. 11 No. 5, pp. 18-25.

Porter, M. and Van der Linde, C. (1995a), "Green and competitive: ending the stalemate", *Harvard Business Review*, Vol. 1 No. 1, pp. 120-134.

Pratt, K.M. (1997), "Environmental standards could govern trade", *Transportation and Distribution*, Vol. 38 No. 1, pp. 68-76.

Raghu Kumar, B.R., Sharma, M.K. and Agarwal, A. (2015), "An experimental investigation of lean management in aviation", *Journal of Manufacturing Technology Management*, Vol. 26 No. 2, pp. 231-260.

Rawabdeh, I.A. (2005), "A model for the assessment of waste in job shop environments", *International Journal of Operations & Production Management*, Vol. 25 No. 8, pp. 800-822.

Rothenberg, S., Pil, F. and Maxwell, J. (2001), "Lean, green and the quest for superior environmental performance", *Production and Operations Management*, Vol. 10 No. 3, pp. 228-243.

Sarkis, J. and Rasheed, A. (1995), "Greening the manufacturing function", *Business Horizons*, Vol. 38 No. 5, pp. 17-27.

Schmidt, G. and Wilhelm, W.E. (2000), "Strategic, tactical and operational decisions in multi-national logistics networks: a review and discussion of modelling issues", *International Journal of Production Research*, Vol. 38 No. 7, pp. 1501-1523.

Shultz, C.J., II Holbrook, M.B. (1999), "Marketing and tragedy of the commons: a synthesis commentary and analysis for action", *Journal of Public Policy and Marketing*, Vol. 18 No. 2, pp. 218-229.

Simpson, D. and Power, D. (2005), "Use the supply relationship to develop lean and green suppliers", *Supply Chain Management: An International Journal*, Vol. 10 No. 1, pp. 60-68.

Spear, S.J. (2004), "Learning to lead at Toyota", *Harvard Business Review*, Vol. 82 No. 5, pp. 78-86.

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.

Sundarakani, B., Goh, M., de Souza, R. and Shun, C. (2008), "Measuring carbon footprints across the supply chain", *Proceeding of the 13th International Symposium on Logistics (ISL2008): Integrating the Global Supply Chain*, Nottingham University Business School, Nottingham, pp. 555-562.

Theyel, G. (2000), "Management practices for environmental innovation and performance", *International Journal of Operations & Production Management*, Vol. 20 No. 2, pp. 249-266.

Wacker, J.G. (1998), "A definition of theory: research guidelines for different theory-building research methods in operations management", *Journal of Operations Management*, Vol. 16 No. 4, pp. 361-385.

Walton, S.V., Handfield, R.B. and Melnyk, S.A. (1998), "The green supply chain: integrating suppliers into environmental management process", *International Journal of Purchasing and Materials Management*, Vol. 34 No. 2, pp. 2-11.

Winsemius, P. and Guntram, U. (1992), "Responding to the environmental challenge", *Business Horizons*, Vol. 35 No. 2, pp. 12-20.

Womack, J., Jones, D. and Roos, D. (1990), *The Machine that Changed the World*, Rawson Associates, New York, NY.

Womak, J.P. and Jones, D.T. (1996), *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*, Simon and Schuster, New York, NY.

Yang, M.G., Hong, P. and Modi, S.B. (2011), "Impact of lean manufacturing and environmental management on business performance: an empirical study of manufacturing firms", *International Journal of Production Economics*, Vol. 129 No. 2, pp. 251-261.

Zhu, Q.H. and Sarkis, J. (2006), "An inter-sectoral comparison of green supply chain management in China: drivers and practice", *Journal of Cleaner Production*, Vol. 14 No. 5, pp. 471-486.

Books/Websites/OtherResources

Carter, P. (2011), "7 wastes", available at: http://cisystem-ltd.blogspot.com/2011/03/7-wastestransportation.html (accessed 2 March 2012).

Chu, W., MacDuffie, J.P., Nobeoka, K. and Pil, F.K. (2002), "Management of the extended enterprise", Project Report to International Motor Vehicle Program (IMVP), M.I.T., International Assembly Plant Study, available at: https://dspace.mit.edu/bitstream/handle/1721.1/747/Asystudy.pdf?sequence=1

European Commission (2009), "Europeans' attitudes towards the issue of sustainable consumption and production", available at: ec.europa.eu/public_opinion/flash/fl_256_en.pdf (accessed 14 2 2013).

Grenon, G., Martha, J. and Turner, M. (2008), *How Big Is Your Carbon Footprint? Before You Can Build an Energy-Efficient Supply Chain, You Need to Understand Your Company's Carbon Emissions*, Booz Allen Hamilton, Virginia.

Grieco, D.M. (1749), *Automotive Approaches For General Aviation Aircraft*, Munro and Associates, Northwood Drive, Troy, available at: dgrieco@munroassoc

Simchi, D., Levi, P.K., Simchi, E.L. and Shankar, R. (2008), *Designing and Managing the Supply Chain – Concepts, Strategies and Case Studies*, Third Edition, Tata McGraw Hill Education Private, New Delhi. ISBN-13: 978-0-07-066698-6.

Suo, S. (2012), "A conceptual framework for adopting sustainability in the supply chain", available at: www.researchgate.net/profile/Stuart_So/publication/235405694_A_conceptual_framework_for_adopting_sustainability_in_the_supply_chain/links/09e415114b88ed4063000000.pdf

Wayne, N. and MacDonald, C. (2004), "Getting to the bottom of 'Triple Bottom Line'", *Business Ethics Quarterly*, April, pp. 1-19, available at: http://isites.harvard.edu/fs/docs/icb.topic549945.files/Canadian%20Paper.pdf

Welford, R. and Starkey, R. (1996), *Business and the Environment*, Earthscan Publications, London.

Further reading

Emiliani, M.L. and Stec, D.J. (2004), "Leaders lost in transformation", *Leadership and Organization Development Journal*, Vol. 26 No. 5, pp. 370-387.

EPA Report (2000), "The lean and green supply chain", United States Environmental Protection Agency, EPA 742-R-00-001, WA.

Gunasekaran, A., Patel, C. and Tirtirogulu, E. (2001), "Performance measures and metrics in supply chain environment", *International Journal of Operations & Production Management*, Vol. 21 No. 2, pp. 71-87.

Zhu, Q. and Sarkis, J. (2007), "The moderating effects of institutional pressures on emergent green supply chain practices and performance", *International Journal of Production Research*, Vol. 45 Nos 18/19, pp. 4333-4355.

Zhu, Q., Sarkis, J. and Lai, K.-H. (2008), "Green supply chain management implications for closing the loop", *Transportation Research Part E: Logistics and Transportation Research*, Vol. 44 No. 1, p. 18.

Available at: www.journalofremanufacturing.com/4/1/6

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