Current research trend in lean and green Supply Chain Management

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Abstract: Lean Management (LM) is a production philosophy attracting a wider number of industries worldwide. Its purpose is to increase productivity and efficiency and to reduce wastes and *muda's*. In parallel, great attention rises toward Green Management (GM) and environmental sustainability, minimising emissions and the carbon footprint of the industrial activities. In the recent years, the scientific community investigates the possibility of joining lean and green best practices. Starting from a review of contributions on the integration of LM and GM, this work outlines the current research trend existing in the field, taking into account the ISO 9000 and ISO 14000 guidelines, as well as the recent EU regulations, directives, recommendations and opinions. A two-step methodology is followed. The former step identifies the topics and targets; the latter step builds a spider diagram highlighting the existing connections and research streams. Evidences show win-win synergies from the implementation of lean-green practices. LM has positive effects on green practices, while GM can improve waste cut off and the process quality.

Keywords: Lean Management, Green Management, Sustainability, Supply Chain Management

1. Introduction

In the last years, there is a growing need for integrating environmental issues and practices into supply chain management (SCM) within multiple industrial sectors to minimise landfilled waste, drained wastewater and pollutant emissions (Melo et al., 2009; Bortolini et al., 2016a). Green Management (GM) can be defined as the integration of environmental thinking into SCM, including sustainable product design, low carbon material sourcing and selection, green manufacturing processes, short-route delivery of the final products as well as end-of-life management and reverse logistics of the products at the end of their lifespan (Srivastava, 2007). To achieve these goals, GM adopts a number of environmental practices and tools, such as Life Cycle Assessment (LCA), Design for Environment (DfE), Cleaner Production (CP), Eco-efficiency, Eco-labels and Eco-design (Dües et al., 2013; Brasco Pampanelli et al., 2013). Final scope of GM is to reduce waste in the form of excessive use of water, energy and resources, pollution, rubbish, greenhouse gases effects and eutrophication (Dües et al., 2013; Verrier et al., 2013). In parallel, at first developed in the Japanese manufacturing industries, LM is actually the main paradigm for a large number of industrial companies. It aims at reducing waste and improve value by using resources efficiently and effectively. To achieve these goals, LM uses some practices and tools, such as Just-in-Time (JIT) and Pull Management System, 5S technique, Total Quality Management (TQM), Poka Yoke approach, Cellular Manufacturing and clustering techniques, Value Stream Mapping and Single Minute Exchange of Die (SMED) (Bortolini et al., 2011; Dües et al., 2013; Brasco Pampanelli et al., 2013). Final scope of LM is to reduce waste in the form of overproduction, inventory, defects, transporting, inappropriate processing, excessive motion and, finally, waiting queues (Dües et al., 2013; Verrier et al., 2013). LM and GM share the common goal of waste elimination even if they target to a different type of waste. The current literature on industrial management focuses on these two topics separately. In fact, few attempts have been made to investigate the possibility of simultaneously implementing these practices. Starting from this background, this paper outlines the current research trends existing in this field. A two-step methodology is followed. The former identifies the topics and targets; the latter builds a spider diagram highlighting the existing connections and research streams.

The reminder of this paper is organised as follows: the next Section 2 revises the literature on the topic. Section 3 presents the two-step methodology for the investigation of the current research trends existing in this field. Finally, section 4 concludes this paper with final remarks and future research opportunities.

2. Literature review

Galeazzo et al. (2013), using a case study methodology, try to discern how the lean and green practices interact and how they yield maximum synergy in improving both operational and environmental performances. They find that lean and green practices can be implemented either sequentially or simultaneously, producing sequential or reciprocal interdependences, respectively. According to the Authors, the involvement of external suppliers as well

as the collaboration between operational and environmental managers are key elements for the development of reciprocal interdependences between LM and GM. Dües et al. (2013) try to identify potential areas in which companies can integrate Green into current business practices. Through the analysis of a number of papers published in the recent years in the field of LM and GM, the Authors find that the overlap of lean and green paradigms is in the following common attributes: waste and waste reduction techniques, people and organisation, lead time reduction, supply chain relationship, KPI. The main differences, instead, lie in: their focus, what is considered as waste, the customer and certain practices such as the replenishment frequency. According to the Authors, lean is beneficial for green practices and the implementation of green practices has a positive influence on existing green practices. Brasco Pampanelli et al. (2013) face the question by introducing an integrated lean and green approach that results in a reduction in production waste (lean goal) and a reduction of environmental impact (green goal). The model proposed by the Authors adopts a kaizen approach to improve mass and energy flow in a manufacturing environment. Results show that the implementation of the model can lead to a reduction of the use of resources from 30 to 50% and of the total cost of mass and energy from 5 to 10%. On the same research stream, Hajmohammad et al. (2013), based on a sample of Canadian manufacturing plants, provide the first evidence that the extent of environmental practices mediates the relationship between lean management and environmental performance. In other words, the model suggests that supply management as well as lean activities provide means by which environmental actions can be encouraged leading then to improved environmental performance. Also the recent works of Fercoq et al. (2016) and Verrier et al. (2016) confirm the existence of a synergic relationship between LM and GM. Fercoq et al. (2016) outline that Waste Reduction Techniques represent one of the main areas of the overlap between the Lean and Green Paradigms. Using the Design of Experiments tool, this study measures the influence of different methods, derived from both the Lean and Green approaches, on solid waste management performance. Based on these results, a hierarchy of progress factors for a waste minimisation program in manufacturing is outlined. Verrier et al. (2016) introduce in their work an original Lean and Green house in order to analyse the synergies between lean and green wastes and the tools that may eliminate them.

Despite LM and GM share a number of similarities, some differences exist. In particular, Johansson and Sundin (2014), through a systematic review of 102 journal publications, try to understand if lean and green practices are two sides of the same coin. Similarities between the two concepts were found but, at the same time, some important differences too. Main differences lie in their goal and focus, value construct and tool/techniques used. The Authors do not support that "green thinking is thinking lean", meaning that LM and GM are not two sides of the same coin. However, LM and GM belong to the same "currency" and this surely highlights the existence of a synergic relationship between them. The replenishment frequency is the main point of collision between the two practices (Verrier et al., 2013; Verrier et al., 2016; Venkat and Wakeland, 2006; Carvalho and Cruz-Machado, 2009; Bortolini et al, 2016a; Bortolini et al, 2016b). By considering the product manufacturing and distribution process from factories to customers, LM calls for a high replenishment frequency of small product quantities, according to JIT principles, to minimise the stock level in customer warehouses (Venkat and Wakeland, 2006; Ugarte et al., 2016). Conversely, GM calls for a low replenishment frequency of big product quantities to minimise the CO_{2eq} emissions generated by shipments. The distance between logistics actors plays a critical role (Manzini et al., 2013). In fact, LM calls for distances on a logistic network to be as short as possible. This means that a short lean supply chain, e.g. a regional network, may be green, but as distances increase lean and green may be in conflict. In this field, further research is needed since in this age of global trade, few supply chains can consist entirely of short transportation links. In addition, the low cost of labor in developing countries is an important factor in the choice of locating parts of the supply chain far from customers (Venkat and Wakeland, 2006).

The literature analysis performed up to now shows that the relationship between the two paradigms is investigated through qualitative analysis or case study applications. Some author faces the question from a mathematical point of view. Kainuma and Tawara (2006), by following the guide issued in 2000 by the Environmental Protection Agency called "The Lean and Green Supply Chain", propose the multiple attribute utility theory method to analyse, at first, the effect of information sharing in a supply chain. The Authors find that information sharing can decrease the average stock level in the supply chain as well as the out-of-stock ratio at a retailer at a certain level. Bergmiller and McCright (2009) conduct a statistical analysis to prove that Lean firms including elements of Green Operations Systems will have stronger Lean results than those that do not include Green elements. Using the green measures as independent variable and the Lean results measures as dependent variables in statistical analysis allows the testing of the hypothesis. Results show that GM drives Lean results, particularly improved cost performance. King and Lenox (2001) explore the relationship between LM and GM analysing the environmental performances of 17499 U.S. manufacturing establishments during the period 1991-1996. They conduct a mathematical analysis, setting the environmental performance and management as dependent variables and lean production as independent variable. Results show that the adoption of LM may lower the marginal cost of pollution reduction and that the adoption of ISO 9001 increases the probability that managers will adopt the ISO 14001 environmental management standard. Finally, the Authors state that LM is associated with lower emissions. Miller et al., in their study, present the example of a small furniture production company that has integrated lean tools and sustainability concepts with discrete event simulation modelling as

mathematical optimisation to make a positive impact on the environment and society. The Authors state that LM and GM can have a more significant and positive impact when implemented concurrently rather than separately.

3. Current research trend in lean and green supply chain management

From the in-depth literature analysis performed in the previous section, the most representative papers are selected to investigate the current research trend in lean and green supply chain management. Then, a two-step methodology is performed.

STEP I

In this phase, the selected papers (16) are analysed to assess the main topics and targets existing in the literature, driving the successful integration between LM and GM.

All articles find that a synergic relationship between LM and GM exists. Lean is beneficial for Green practices and the implementation of Green practices in turn also has a positive influence on existing Lean business practices.

11 papers state that collaboration, commitment and employee involvement are very important and strategic elements for a successful integration of lean and green practices as well as a close relationship with suppliers. In fact, collaboration enables information sharing across the chain and eases the implementation of waste reduction techniques.

2 papers underline the importance of a simultaneous implementation of LM and GM taking into account the ISO 9000 and ISO 14000 guidelines. In particular, according to the Authors, the adoption of ISO 9001 increases the probability that managers will adopt the ISO 14001 environmental management standard.

Other Authors, in their works (3), confirm the convergence of the concepts of LM and GM. Specifically, Waste Reduction Techniques (WRT) are considered one of the main areas of overlap between Lean and Green Paradigms. In fact, WRT of both paradigms are often similar, with a focus on business and production process practices.

Finally, a number of Authors suggests that, despite the similarities between the lean and green concepts, some differences exist, especially in the field of transport. In particular, there are short lead-times and frequent replenishment in the lean logic versus the reduction of greenhouse gas emissions. The other differences between the two paradigms lie in: their focus, what is considered as waste, the customer, product design and manufacturing strategy, end of product-life management, KPIs, the dominant cost and the principal tool used by each of them. A summary of these findings is shown in Table 1 and Table 2. In particular, Table 1 shows the main factors that drive the successful integration between LM and GM. Table 2 shows the papers included in the analysis and, for each paper, the association with a specific topic.

Table 1: Summary of the main research topics existing in the literature

	Research topics
I	Existence of synergic relationship between LM and GM
II	Importance of commitment, collaboration and employee involvment
III	ISO 9000 and ISO 14000
IV	Waste Reduction Techniques (WRT)
V	The Replenishment Frequency problem

STEP II

In this phase, references of each paper are analysed to assess the existing connections and research streams through the construction of a spider diagram. The diagram is shown in Figure 1.

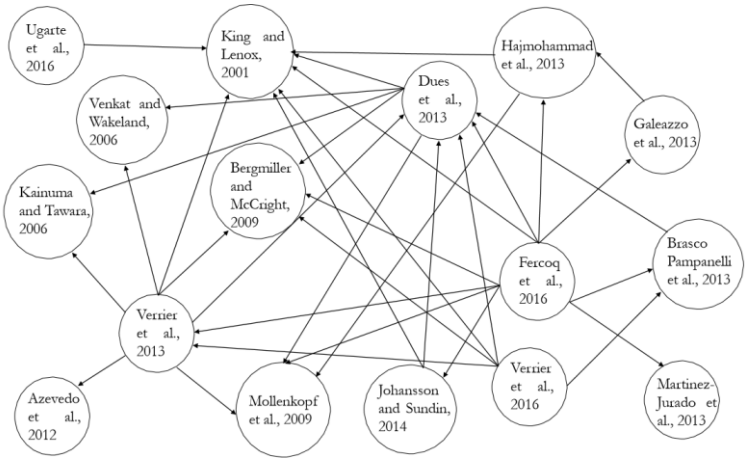

Figure 1: Literature spider diagram

Table 2: Association of the papers with the main selected topics

	I	II	III	IV	V
Ugarte et al. (2016)	✓		✓		
Venkat and Wakeland (2006)	✓				✓
Kainuma ad Tawara (2006)	✓	✓			
King and Lenox (2001)	✓		✓		
Bergmiller and McCright (2009)	✓	✓			
Dües et al. (2013)	✓	✓		✓	✓
Verrier et al. (2013)	✓	✓			✓
Verrier et al. (2016)	✓				✓
Azevedo et al. (2012)	✓	✓			
Mollenkopf et al. (2009)	✓	✓			
Hajmohammad et al. (2013)	✓	✓			
Galeazzo et al. (2013)	✓	✓			
Brasco Pampanelli et al. (2013)	✓	✓			
Fercoq et al. (2016)	✓			✓	
Martinez-Jurado et al. (2013)	✓	✓		✓	
Johansson and Sundin (2014)	✓	✓			

Each circle represents a paper. If an arrow connects paper A to paper B, it means that paper A cites paper B. The analysis shows that a strong connection between the articles exists. In particular, all the analysed papers share the common idea that Lean is synergic for Green and that lean practices can be used as a catalyst for greening the supply chain. The studies of King and Lenox (2001) and Dües et al. (2013) are the most cited papers. In fact, to date, the paper of Dües et al. has 199 citations while that of King and Lenox has 644 citations. This supports the conclusion that the two papers are pillars in the field of Lean & Green SCM and reference point for the development of further studies.
In their study, King and Lenox show how lean production is complementary to environmental performance and also that it is associated with greater source reduction, as pollution preventions. Dües et al. identify potential areas in which companies can integrate Green into current business practices through the analysis of the existing overlaps and differences between LM and GM.

The analysis highlights the main topics existing in the literature in the field of Lean&Green SCM and the main connections between the articles, to provide industrialist with an overview of the lean and green practices.

4. Conclusion

Nowadays environmental sustainability is one of the main goal of the industrial organisations to reduce the use of non-renewable resources, to eliminate toxic substances, to increase renewable energy penetration and to recover energy and matter from wastes.

This study collects the main works, published in the last years, analysing the possibility of simultaneously implementing lean and green practices in the field of Supply Chain Management (SCM). Starting from a review of contributions on the integration of LM and GM, this work outlines the current research trend existing in this field. A two-step methodology is followed. The former identifies five main topics and targets; the latter highlights the existing connections and research streams through the construction of a spider diagram.

The study proves that synergic effects between the two practices exist. A synergy is when 1+1=3, meaning that the integration of the practices produces great results, higher than the sum of the performances from their separate application. LM has positive effects on green practices, while GM can improve waste cut-off and the process quality. Then, the spider diagram shows that a strong connection among the articles exists. Starting from this scenario, this study also aims at providing industrialist and practitioners with an overview of the integrated lean and green practices to develop a richer knowledge on these paradigms and to stimulate new research currents.

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