Integrating lean and green management

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Abstract

Purpose – The purpose of this paper is to perform a literature review of peer-reviewed journal articles investigating the relationship between Lean and Green management in light of developing an integrated management model.

Design/methodology/approach – After an extensive search, 60 articles from 1996 to 2016 were identified as relevant to this study.

Findings – The evidence of successful integration of Lean and Green management has largely been weak. The strongest positive evidence between the two management philosophies has been for Lean implementation pushing Green outcomes through operational waste reduction, thus improving environmental performance. The majority of studies suggest highly optimistic outcomes from integrating Lean and Green, however, an integrated operating model of the firm relating Lean and Green is lacking.

Research limitations/implications – The literature review suggests the necessary elements for proposing an integrated operating model of the firm.

Practical implications – The paper offers interesting implications for managers. While most Lean implementations have resulted in some positive environmental outcomes, both management philosophies tend to be implemented independently. Integrating the implementation of Lean and Green offers the potential for synergistic returns.

Originality/value – The findings are derived from a systematic literature review of articles that have studied the relation between Lean and Green management, resulting in a proposed integrated model of firm performance.

Keywords Performance, Environment, Management, Manufacturing, Lean, Green

Paper type Literature review

1. Introduction

Lean management and Green management are two approaches to operations that companies have adopted and promoted over the past few decades. Many companies have implemented aspects of each approach, with the purpose of creating better value through quality products and services while at the same time attempting to reduce manufacturing and/or environmental wastes (Deif, 2011; Shah and Ward, 2003). Both management philosophies seek to identify and eliminate waste in related, albeit different ways (Dües *et al.*, 2013; Martínez-Jurado and Moyano-Fuentes, 2014). Historically, expectations of firm performance heterogeneity (Porter and Van der Linde, 1995; Yang *et al.*, 2011) and compliance with environmental laws (Florida, 1996) have been major drivers for adoption of these management philosophies. More recently, increased attention to corporate social responsibility (CSR) may be seen as fueling the adoption rate of Green management (Babiak and Trendafilova, 2011).

Lean management stems from the work of Taichi Ohno in the Toyota Production System (TPS) (Ohno, 1988). Popularized by the work of Womack *et al.* (1990), the purported outcome of applying a Lean management philosophy is better cost, quality, and time in product delivery while utilizing fewer input resources. Ohno categorized Lean wastes, or muda, into seven generic categories (Jasti and Kodali, 2014).

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Lean management is focused on continuously identifying these wastes and redesigning processes to reduce them (Gupta and Jain, 2013; Stentoft Arlbjørn and Vagn Freytag, 2013; Stone, 2012). By comparison, Green management looks at the potential deleterious environmental impacts of the firm and its processes, and seeks to reduce or eliminate them (Azzone and Noci, 1998; Rusinko, 2007). Green management actions can be undertaken as a result of regulatory requirements (Alfred and Adam, 2009) or from the adoption of increased CSR (Molina-Azorín *et al.*, 2009).

The focus on waste reduction with both philosophies suggests the two are not mutually exclusive (Dües *et al.*, 2013; Galeazzo *et al.*, 2014). Understanding the commonality in goals can lead to a better understanding of application of key management and process improvement tools. Understanding how the two philosophies push or pull (Chiarini, 2011) management requirements and tools within the firm is also important. The interdependence of the two philosophies suggests management strategies that capitalize on this interaction to help firms achieve simultaneous financial and environmental gains (Yang *et al.*, 2011). However, some have argued against this win-win scenario, promulgating the economic argument that expenses on environmental improvements detract from firm investment and performance (Albertini, 2013; Iwata and Okada, 2011). A model that integrates Lean and Green with firm performance would help frame this discussion, yet is currently lacking.

This paper examines the integration of these two management philosophies. A systematic literature review is used as a research method. The relationship between the two philosophies is studied to see evidence of push or pull, such as finding evidence that Lean implementation leads to Green outcomes, or Green objectives require Lean implementation. These findings are summarized and used to propose a model that relates the two management philosophies to each other, and to corporate performance. This proposed model leads to several practical suggestions on firm management and suggests interesting avenues for future research.

2. Background

2.1 Lean production

The term Lean has been promulgated with firms that utilize an underlying set of principles and practices that are expected to lead to a better state of operations (Womack and Jones, 1996). Originated in the automotive industry as a generalization of the practices observed in the TPS, Lean seeks to eliminate all forms of waste or "muda" as a means to lower costs and reduce lead times, while maximizing production efficiency based on customer demand (Roosen and Pons, 2013; James-Moore and Gibbons, 1997; Womack *et al.*, 1990). The literature on Lean suggests that firm activities can be defined as either value added (VA) or non-value added (NVA) (Womack and Jones, 1996). VA activities are defined as activities that transform a product or service for which customers are willing to pay. NVA activities are those activities for which the customer would not be willing to pay. The Lean management philosophy is based on a set of practices aimed at enhancing the whole value chain within an organization (Furlan *et al.*, 2011; Womack and Jones, 1996), and eventually external to the organization (Nightingale and Srinivasan, 2011). To attain these objectives, five tenets of Lean are promulgated, namely value, value stream, flow, pull, and perfection, which aim to align production capabilities with customer demand rate, or takt time (Womack and Jones, 1996). These tenets seek to guide Lean transformation by specifying customer value for each product, identifying the value stream, making the value flow

without interruption, and letting the customer pull value from the value stream. The final step of pursuing perfection acts as a reminder that the process of transitioning to Lean should never end. In this light, the improvement steps can be repeated to gain further improvements.

Within the concept of Lean thinking, waste is defined as everything that does not directly add value to a product based on customers' needs and requirements. In this framework, seven types of waste are recognized, namely defects, inventory, overprocessing, waiting, motion, transportation, and overproduction (Ohno, 1988). Overproduction means producing more than customers order and producing unordered materials/goods. Waiting refers to idle time when no value is added to the product, and includes queues, storage, and time in inventory. Transportation represents any handling of the material or information that is not a VA process step. Inventory is associated with unnecessary raw material stores, work in process, and finished stock storage. Motion is the movement of equipment or people that add no value to the product. Overprocessing results from unnecessary process steps, including such activities as redundant reviews and signatures (work carried out on the product which adds no value). Defects appear when producing parts that do not meet customer expectations and can be identified in rework cycles where additional resources are required to get the product to meet specs. Inability to do this rework results in scrapped product. As a strategy developed for improving operational performance, Lean management has expanded as a business practice and extended beyond manufacturing to succeed in service industries and product development operations with varying levels of success (Akugizibwe and Clegg, 2014; Bhamu and Singh Sangwan, 2014; Hallam and Keating, 2014; Stentoft Arlbjørn and Vagn Freytag, 2013).

2.2 Green production

More recently, sustainability has become an important issue within businesses, arising from concerns over natural resources depletion, wealth disparity, and social responsibility (Sezen and Cankaya, 2013). In this regard, organizations are rethinking their products and processes while implementing environmentally responsible management practices. This focus has led to the concept of environmentally conscious manufacturing, also referred to as Green manufacturing (Rao and Holt, 2005). Green manufacturing uses Green strategies and innovative techniques, including products and systems that consume less material and energy, utilize new input materials, and introduce processes to reduce unwanted outputs. These efforts also include programs to convert outputs into inputs (recycling), and discover novel uses for byproducts that result in secondary products. These strategies are targeted at reducing environmental wastes in delivering products and services to customers. From this perspective, environmental waste has been defined as the unnecessary use of resources, or the release of substances to the air, water, or land that could harm human health or the environment (Deif, 2011; Environmental Protection Agency (EPA), 2006). Different environmental metrics have been proposed to track environmental wastes, including but not limited to energy, material, and water consumption, solid waste creation, scrap, emissions, wastewater discharges, and hazardous waste generation (EPA, 2006).

Three different manufacturing approaches to reduce environmental wastes have been cited within the Green management field. These approaches include pollution

control, pollution prevention (also known as cleaner production), and product stewardship. Pollution control is an "end of pipe" approach and is related to the methods employed to trap, store, treat, and/or dispose of pollution after it is created (Rusinko, 2007). Pollution prevention is related to activities intended to eliminate emissions, affluent, and wastes, thus mitigating the need for pollution control. Viewed as a continuous improvement approach, pollution prevention may provide organizations advantages over their competitors when implemented. Pollution prevention may result in lower costs for raw materials and waste disposal. It may also help reduce cycle times by removing unnecessary steps in production and operations, which provide organizations benefits in terms of increased productivity, efficiency, reductions in costs, and enhanced cash flow (Hart, 1995; Rusinko, 2007). Finally, product stewardship extends the environmental perspective to the entire value chain, including other internal and external stakeholders such as R&D, product designers, and suppliers (Rusinko, 2007).

2.3 Lean and Green relationship

Lean management and Green management have been considered compatible initiatives because of their joint focus on waste reduction, efficient use of resources, and emphasis on satisfying customer needs at the lowest possible cost (Duarte and Cruz-Machado, 2013). Lean production and Green environmental management practices are synergistic in terms of their focus on reducing waste and inefficiency (Yang *et al.*, 2011). One important aspect about this relationship is that Lean can enhance the benefits of pollution prevention approaches. According to the EPA (2006), environmental wastes are embedded in or related to Ohno's seven wastes. By expanding Lean theory to consider environmental wastes, new applications for Lean practices and tools may become apparent. Green management programs can maximize their gains when Lean methods are applied to specific pollution prevention activities. In other words, Lean tools may help pollution prevention approaches be more competitive (EPA, 2006). Table I provides examples of environmental wastes associated with the Ohno's seven wastes.

Lean and Green management also share the goal of enhancing firm performance indicators. Both approaches seek to improve quality and time as well as to reduce costs, with the end goal of generating greater value (Deif, 2011; Gupta and Jain, 2013; Shah and Ward, 2003). According to Deif (2011) the use of Green manufacturing reduces material wastes and energy consumption, which diminishes production costs and improves production time. It will also improve the quality of the production process which will, in turn, improve product quality (Gupta and Jain, 2013).

While both approaches share waste reduction as an objective, Green and Lean management philosophies may also work against each other. In the case of Green manufacturing, organizations may require the use of less harmful raw materials at a higher input or processing cost. Likewise, Lean manufacturing could negatively impact the environment when more greenhouse gases are emitted by using just-in-time delivery processes (Martínez-Jurado and Moyano-Fuentes, 2014; Rothenberg *et al.*, 2001). Understanding the interaction of these management philosphies on firm performance is important, yet potentially complex in relationship and behavior. Forrester's (1961) work suggests the use of systems dynamics for exploring such problems, and we propose an initial use of causal relationship diagrams to start the modeling process based on this literature review (Parunak *et al.*, 1998; Sterman, 2000).

Lean waste	Impact	Benefit
Overproduction	Overproduction leads to excessive consumption of raw materials and energy resources in making unwanted parts; excessive hazardous materials resulting in extra emissions and waste disposal	If organizations do not overproduce they consume fewer raw materials, use less energy to operate, and eliminate the risk associated with not selling the excess inventory and eventually disposing of it as waste
Overprocessing	Overprocessing leads to additional consumption of parts and raw materials per unit of production, increased waste, energy usage, and emissions	Improving processing to just what is needed allows organizations to cut down on waste and lower their environmental footprint
Waiting	Waiting leads to damage of potential materials components; energy waste from heating, cooling, and lighting during production time	Reducing waiting can cut down on production downtime, which means organizations have less wasted energy
Transportation	Transportation leads to extra energy usage and emissions for transport	Minimizing transportation reduces the energy used and the costs associated with the product
Inventory	Inventory adds waste from deterioration of work in process (WIP) products as well as from the replacement of damaged WIP by alternate materials	By having less product inventory sitting around, organizations can use their plant space more efficiently (saving heating and cooling demands) while also consuming less packaging and raw materials. Lower levels of inventory also reduce the risk of waste due to obsolescence and undiscovered defects
Defects	Defects leads to consumption of raw materials and energy in making defective parts, recycling for defective components, space for rework	Minimizing product defects means organizations are using fewer raw materials to manufacture products, which equals less energy consumption
Motion	Motion requires more space increasing heating, cooling, and lighting demands. It can also increase the time to produce a product resulting in increased energy requirements	Reducing any effort of lifting things unnecessarily or the needing to walk an excessive distance back and forth to find tools or complete a task means organization will use less energy

Table I. Relation of reduction in seven Lean wastes on environmental performance

3. Research methodology

This study aimed to create a detailed review of previous work assessing the relationship between Lean and Green using systematic literature review as a research method. Literature review is a method that helps identify, synthetize, and evaluate the existing work published by scholars and researchers (Tranfield *et al.*, 2003; Onwuegbuzie *et al.*, 2012). In order to provide a high-quality analysis, the literature review was focused on peer-reviewed journal articles, representing scientifically validated knowledge (Machi and McEvoy, 2012; Moher *et al.*, 2009). To obtain the most relevant peer-reviewed journal articles, we used the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist method as proposed by Siddaway *et al.* (2015). First, we searched the major research databases (Emerald Insight, Google Scholar, Science Direct, IEEE, Springer, Taylor and Francis, Wiley Online) by using specific keywords. Next, we reviewed the references in the articles that we considered relevant to our study, and identified additional articles that we were not able to identify through electronic database searches. A series of keywords such as

"lean manufacturing/management," "green manufacturing/management," "lean and green," "lean and environment," "pollution prevention," "CSR," and/or "cleaner production" were used. Each keyword was searched individually, resulting in hundreds of articles, most not relevant to the study. Combinations of these keywords were used to narrow the search.

The narrowed search yielded 126 articles, 116 of which were identified in electronic databases and ten from a review of their references. Of the 126 articles, one was rejected as a duplicate. Limiting the study to peer-reviewed journal articles, 50 articles were excluded for being either conference proceedings or book chapters. Our detailed review thus focused on the remaining 75 articles. We reviewed the full text of these articles and rejected an additional 15 as not applicable to our study. Thus we focused our detailed review on the remaining 60 relevant peer-reviewed journal articles published between 1996 and 2016. From the 60 articles selected, 30 articles (50 percent) were classified as case studies, 20 articles (33 percent) were conceptual papers, and ten articles (17 percent) were surveys.

The articles were analyzed for evidence of Lean push or pull with respect to Green implementation (Hopp and Spearman, 2004). By definition we categorized "Lean Push" as articles stating positive environmental, or Green, outcomes associated with a Lean implementation. We defined "Lean Pull" as articles that described Green implementation seeking the use of Lean tools to achieve better environmental outcomes. Furthermore, in an effort to start building a more comprehensive model relating Lean and Green to firm performance, we identified key management model parameters from the articles (Sterman, 2000). To be identified as relevant to the model, these parameters had to be included in the paper as either a cause or outcome of firm Lean or Green transformation (Forrester, 1994). The major parameters identified include Ohno's seven wastes, Lean tools, profit, brand value, cost, corporate performance, sales, growth, pricing, firm value, human resources (HRs), quality, and environmental impact. The presence of these model parameters are tabulated in Table II.

4. Results

A total of 60 relevant articles were identified from the systematic literature review process. These articles represent the most relevant peer-reviewed journal publications covering the integration of Lean and Green management. The articles are presented in Table II and include a summary of the findings and a tally of the management model parameters identified. These results are described in greater detail in the following four sections, including push vs pull, management synergies and firm performance, the supply chain perspective, and competitive advantage and growth. A management model integrating these findings is developed in the discussion section of this paper.

4.1 Push vs pull

We observe that the tenets of Lean and Green are fairly well established as independent efforts within firms. All of the articles in this literature review mention the seven wastes and environmental impact. Of these articles, 45 percent (27) describe some form of a push relationship between Lean and Green. None of the articles discuss evidence of a pull relationship between Green and Lean, highlighting a gap in the literature. The results show that many firms implementing Lean seek to reduce the seven types of wastes, and as a consequence, have observed improvements in Green performance (Florida, 1996; Miller *et al.*, 2010). For example, Sobral *et al.* (2013) point out that

Author(s)	Pull relation	Push relation	Ohno's seven wastes	Lean tools	Profit	Brand value	Costs	Corporate performance	Sales	Growth	Pricing	Firm value	Human resources	Quality	Environmental impacts	Article findings/focus
	Management model parameters															
Florida (1996)		X	X				X	X	X	X		X	X	X	X	Efforts of firms to improve manufacturing processes and increase productivity create substantial opportunities for environmental improvement
Maxwell *et al.* (1998)		X	X	X				X					X	X	X	Waste minimization through Lean manufacturing motivates environmental activities
King and Lenox (2001a)		X	X				X	X						X	X	Lean production is complementary to waste reduction and pollution reduction
Rothenberg *et al.* (2001)		X	X	X			X	X					X		X	The relationship between Lean manufacturing and environmental performance depends on the measure of environmental performance being examined
Soltero and Waldrip (2002)			X	X											X	Kaizen in connection with Lean manufacturing supplies organizations with tools to accomplish its pollution prevention goals
Simons and Mason (2003)		X	X	X				X							X	Lean and Green thinking helps remove waste from the whole supply chain process

(continued)

Table II.
Summary of Lean and Green management articles included in the study

Table II.

Author(s)	Management model parameters: Pull relation	Push relation	Ohno's seven wastes	Lean tools	Profit	Brand value	Costs	Corporate performance	Sales	Growth	Pricing	Firm value	Human resources	Quality	Environmental impacts	Article findings/focus
Pil and Rothenberg (2003)			X	X				X						X	X	Highlights the synergistic and reciprocal nature of environmental and broader manufacturing improvement efforts
Zhu and Sarkis (2004)		X	X	X			X	X		X				X	X	Investigates how quality management and Lean manufacturing influence the relationship between Green supply chain management practices and performance
Larson and Greenwood (2004)		X	X					X							X	Lean manufacturing produces substantial resource productivity improvements that contribute directly to environmental performance gains
Simpson and Power (2005)			X					X						X	X	Supply relationships may present a key way for business to influence the sustainability of their products and services
Tice *et al.* (2005)		X	X	X				X					X		X	Lean production and environmental management systems contribute to business objectives when aligned together

(*continued*)

Author(s)	Pull relation	Push relation	Ohno's seven wastes	Lean tools	Profit	Brand value	Costs	Corporate performance	Sales	Growth	Pricing	Firm value	Human resources	Quality	Environmental impacts	Article findings/focus
								Management model parameters								
Kainuma and Tawara (2006)			X					X				X		X	X	Presents a Lean and Green supply chain methods to evaluate the performance of a supply chain
Vais *et al.* (2006)			X	X				X						X	X	Lean and Green production implemented at Petrocart S.A. improved Bistrita River environmental conditions
Sawhney *et al.* (2007)			X	X				X					X		X	Presents a model intended to analyze the relationship between environmental concerns and Lean principles for specific processes
Mason *et al.* (2008)			X	X				X							X	Studies the link between being Lean and Green using value stream mapping
Carvalho *et al.* (2010)			X	X	X	X	X	X	X			X		X	X	Identifies the conceptual relationships among Lean and Green supply chain practices and performance
Yang *et al.* (2010)		X	X	X			X	X			X			X	X	Companies must integrate supplier management and continuous improvement with environmental strategies to improve manufacturing performance

(*continued*)

Table II.

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Author(s)	Management model parameters: Pull relation	Push relation	Ohno's seven wastes	Lean tools	Profit	Brand value	Costs	Corporate performance	Sales	Growth	Pricing	Firm value	Human resources	Quality	Environmental impacts	Article findings/focus
Miller *et al.* (2010)		X	X	X	X		X	X							X	Lean and Green manufacturing have a positive impact on operational performance and environmental performance
Esmemr *et al.* (2010)			X	X				X							X	Analyzes the Lean and Green dimension within a container terminal
Carvalho *et al.* (2011)			X		X	X	X	X	X	X		X			X	Provides links between Lean, agile, resilience and Green paradigms and the supply chain performance
Yang *et al.* (2011)		X	X	X	X		X	X	X	X		X	X	X	X	Analyzes the relationships between Lean manufacturing practices, environmental management, and business performance
Vinodh *et al.* (2011)		X	X	X			X	X							X	Presents strategies/ techniques that enable an organization to acquire environmental performance using Lean initiatives
Besseris (2011)			X	X				X							X	Demonstrates how process efficiency and environmental waste may be minimized in a Lean-and-Green project driven by Six Sigma tools

(*continued*)

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Author(s)	Management model parameters: Pull relation	Push relation	Ohno's seven wastes	Lean tools	Profit	Brand value	Costs	Corporate performance	Sales	Growth	Pricing	Firm value	Human resources	Quality	Environmental impacts	Article findings/focus
Jasti *et al.* (2012)		X	X			X	X	X			X				X	Lean can be an important pillar to accomplish Green goals
Cabral *et al.* (2012)			X				X	X						X	X	Proposes an integrated Lean, Agile, Resilient and Green model to support decision making in choosing the most appropriate practices and key performance indicators to be implemented in an supply chain
Azevedo *et al.* (2012)			X	X		X	X	X							X	Lean and Green contribute to improve economic, social, and environmental performance
Aguado *et al.* (2013)			X	X	X		X	X			X				X	Companies that introduce improvements in a Lean system through environmental innovation may get a competitive position
Hajmohammad *et al.* (2013)		X	X	X				X							X	The impact of Lean management, and to a lesser extent supply management, on environmental performance is mediated by environmental practices
Diaz-Elsayed *et al.* (2013)			X	X			X		X						X	Lean and Green strategies help reduce production costs

(*continued*)

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Author(s)	Pull relation	Push relation	Ohno's seven wastes	Lean tools	Profit	Brand value	Costs	Corporate performance	Sales	Growth	Pricing	Firm value	Human resources	Quality	Environmental impacts	Article findings/focus
	Management model parameters															
Dües *et al.* (2013)		X	X		X		X	X					X	X	X	Lean environment serves as a catalyst to facilitate Green implementation bringing benefits to companies
Duarte and Cruz-Machado (2013)			X	X		X	X	X					X	X	X	Presents a Lean-Green transformation model as well the connections between them at the strategic, tactical, and operational levels
Wiengarten *et al.* (2013)			X	X				X						X	X	The synergetic effects between traditional practices such as Lean and quality and environmental practices are possible
Jabbour *et al.* (2013)			X	X			X	X		X				X	X	Lean has a positive influence on environmental management
Sobral *et al.* (2013)		X	X	X				X					X		X	Lean manufacturing practices can bring environmental benefits
Martínez-Jurado and Moyano-Fuentes (2014)		X	X				X	X					X	X	X	Evaluates the literature related to Lean manufacturing, supply chain management, and sustainability

(continued)

Table II.

Author(s)	Management model parameters: Pull relation	Push relation	Ohno's seven wastes	Lean tools	Profit	Brand value	Costs	Corporate performance	Sales	Growth	Pricing	Firm value	Human resources	Quality	Environmental impacts	Article findings/focus
Kurdve *et al.* (2014)			X	X			X	X						X	X	Examines the integration of operations management, specifically production system models with environmental management
Banawi and Bilec (2014)			X	X				X							X	Lean-Green-Six Sigma framework offers an approach for process improvement and minimization of environmental impacts
Pampanelli *et al.* (2014)		X	X	X			X	X					X		X	Proposes a Lean and Green Model, where the Green concern for environmental sustainability is integrated with Lean thinking
Dhingra *et al.* (2014)		X	X	X	X		X	X		X			X		X	Examines the interrelationships among Lean, Green, and sustainability
Besseris and Kremmydas (2014)			X					X						X	X	Presents a concurrent optimization case study based on Lean and Green indicators
Verrier *et al.* (2014)			X		X			X							X	Proposes a framework for Lean and Green management aimed to help companies to benchmark their Lean and Green practices

(*continued*)

Table II.

Author(s)	Management model parameters: Pull relation	Push relation	Ohno's seven wastes	Lean tools	Profit	Brand value	Costs	Corporate performance	Sales	Growth	Pricing	Firm value	Human resources	Quality	Environmental impacts	Article findings/focus
Galeazzo *et al.* (2014)			X	X			X	X						X	X	Lean and Green practices may be implemented either sequentially or simultaneously
Johansson and Sundin (2014)		X	X					X					X		X	Lean and Green share a number of similarities that indicate a synergistic relationship
Chiarini (2014)		X	X	X				X							X	Lean practices implementation, in general, brings benefits to environmental management
Duarte and Cruz-Machado (2015)			X	X	X	X	X	X		X		X	X	X	X	Investigates how to evaluate Lean and Green supply chain performance through a traditional Balanced Scorecard
Govindan *et al.* (2015)			X	X		X	X	X							X	Presents a relationship model among Lean, Green, and resilient practices
Ugarte *et al.* (2015)			X	X				X							X	Presents a simulation to investigated the environmental performance impact of three Lean logistics practices
Ng *et al.* (2015)		X	X	X				X						X	X	Implementation of Lean and Green practices can bring improvement in production

(*continued*)

Author(s)	Pull relation	Push relation	Ohno's seven wastes	Lean tools	Profit	Brand value	Costs	Corporate performance	Sales	Growth	Pricing	Firm value	Human resources	Quality	Environmental impacts	Article findings/focus
	Management model parameters															
Garza-Reyes (2015)			X	X				X							X	Reviews the existing literature on Lean and Green identifying six streams of research
Hartini and Ciptomulyono (2015)		X	X	X			X	X	X			X		X	X	Presents a positive impact of Lean and sustainable manufacturing on operational, environmental, economic, and social performance
Mollenkopf *et al.* (2010)		X	X	X	X		X	X						X	X	Presents drivers, barriers, converging, and contradictory points between Lean and Green
Banavara *et al.* (2016)		X	X	X			X	X							X	Identifies factors that contribute to the evolution of Green Supply Chain initiatives framework as a result of sustained Lean strategies
Sagnak and Kazancoglu (2016)		X	X	X				X							X	Emphasis the need for six sigma methodology to overcome limitations within the Green Lean approach
Belayutham *et al.* (2016)			X					X							X	Assesses how to improve administrative inefficiencies through the use of Causal Loop Diagram, Lean and Cleaner Production concept

(*continued*)

Table II.

Table II.

	Management model parameters															
Author(s)	Pull relation	Push relation	Ohno's seven wastes	Lean tools	Profit	Brand value	Costs	Corporate performance	Sales	Growth	Pricing	Firm value	Human resources	Quality	Environmental impacts	Article findings/focus
Verrier *et al.* (2016)		X	X	X	X	X	X	X				X		X	X	Develops a Lean and Green maturity model in order to help organizations to manage their Lean and Green performance
Kumar *et al.* (2016)			X	X											X	Identifying barriers in Green Lean Sigma Product Development implementation
Prasad *et al.* (2016)			X	X				X							X	Lean and Green practices are moderately applicable for implementation to Indian foundry industry
Vinodh *et al.* (2016)			X					X		X		X	X		X	Presents a structural modeling approach for identifying the relationship among factors influencing the integrated Lean sustainable manufacturing system
Zhan *et al.* (2016)			X	X	X		X	X	X			X	X		X	Shows how Green and Lean practice affects organizational performance and how this association is affected by guanxi
Mittal *et al.* (2016)			X				X	X				X	X		X	Identifies the barrier for Lean, Green and Lean-Green Manufacturing System implementation
Total	0	27	60	44	12	8	31	57	7	8	3	11	17	25	60	
%	0	45	100	73	20	13	52	95	12	13	5	18	28	42	100	

Note: X, indicates the article addressed the specific management parameter listed at the top of the column

environmental benefits in terms of efficient use of resources, such as reductions in water or energy use, can result from process improvements that flow from adopting Lean manufacturing practices.

From a theory development standpoint, the literature has highlighted that the two concepts share the objectives of value creation, waste elimination in operations, and the involvement of supply chain actors in achieving business success, yet the majority of articles show a "push" of Lean practices that cause some Green benefits (Dües *et al.*, 2013; Florida, 1996; King and Lenox, 2001a; Johansson and Winroth, 2009; Larson and Greenwood, 2004; Tice *et al.*, 2005). Evidence of Green management successfully "pulling" from the Lean management toolkit is lacking. By sharing management attributes, Lean may help boost the efficacy of Green practices, and Green implementation may have a positive influence on sustaining existing Lean business practices (Dües *et al.* 2013; Mollenkopf *et al.*, 2010; Tice *et al.*, 2005). The literature suggests that Lean and Green can work together (Simons and Mason, 2003; Simpson and Power, 2005; Soltero and Waldrip, 2002; Upadhye *et al.*, 2010) and that Lean and Green may develop a complementary or synergistic relationship (Galeazzo *et al.*, 2014; Johansson and Sundin, 2014; King and Lenox, 2001a; Yang *et al.*, 2011).

4.2 Management synergies and firm performance

The compatibility of the two management philosophies and their combined effect on corporate performance has been identified in terms of operational, financial, and environmental metrics. Our study found that 95 percent (57) of the articles discuss corporate performance as a result of Lean and Green implementations. The implementation of specific Lean tools is described in 73 percent of the articles (44), with improved cost performance described in 52 percent (31), and improved quality in 42 percent (25). Organizations that are capable of simultaneously implementing Green and Lean practices may improve business performance while creating economic, social, and environmental benefits (Azevedo *et al.*, 2012). According to Mollenkopf *et al.* (2010), understanding the complementary and conflicting relationships between Lean and Green is vital since organizations may be missing synergies available through improved concurrent implementation, or may be failing to address important trade-offs that may arise between conflicting management objectives. Galeazzo *et al.* (2014) contend that Lean and Green should be implemented simultaneously instead of sequentially since such organizations could achieve the best operational fit between Lean and Green practices.

Ng *et al.* (2015) purport that companies that are able to integrate and implement Lean and Green practices simultaneously can achieve quantitative benefits in terms of lead-time reductions, value-added time improvements, and carbon footprint reductions, suggesting management synergism. Similarly, Pampanelli *et al.* (2014) identify that the integration of Lean and Green practices may result in reduced environmental impacts, increased productivity in the use of resources, and direct cost savings above and beyond what is achievable individually. Diaz-Elsayed *et al.* (2013) found through a simulation study that the implementation of both management systems together can result in reductions in production cost. Similarly, Miller *et al.* (2010) found through a case study that Lean and Green manufacturing can have a more significant, positive impact on multiple measures of operational performance (lead time, costs savings) and environmental performance (energy consumption, waste generation) when implemented concurrently rather than separately. This is consistent with Yang *et al.* (2011) finding a positive relationship between Lean manufacturing practices, environmental management, and business performance.

4.3 The supply chain perspective

Consideration is given to the relationship between Lean and Green approaches within the supply chain. According to Jasti *et al.* (2012), the integration of Lean and Green creates a new class of supply chain management. In this context, the authors suggest a strong correlation due the integration of Lean principles with Green supply chain management, targeting space use optimization, better material utilization, reduced fuel consumption and wastes, increased operating efficiency, and improved response time. Following this research path, Hajmohammad *et al.* (2013) found that the impact of Lean management, and to a lesser extent supply chain management, on environmental performance is mediated by firm environmental practices. Carvalho *et al.* (2010) propose deploying Lean and Green practices in a manufacturing supply chain context. They propose a measurement system that could be used to evaluate the influence of these practices on supply chain performance, categorized by economic measures (operational cost, environmental cost, and inventory cost), environmental measures (business waste, CO_2 emission, green image or brand), and social measures (corruption risk, supplier screening, and local suppliers).

Research in this area has expanded to focus on models or methods intended to provide evidence supporting the benefits of Lean and Green on supply chains performance (Kainuma and Tawara, 2006; Sawhney *et al.*, 2007; Verrier *et al.*, 2014, 2016). However, the level of case or industry evidence still remains low. This finding highlights another potential gap in the literature that is ripe for investigation. Furthermore, the extensive body of literature on supply chain management, and the subset on Lean supply chain management, covers many aspects of coordinating management best practices with suppliers (Dyer and Nobeoka, 2000; Matos and Hall, 2007; Rebolledo and Nollet, 2011; Marksberry, 2012). This area of inquiry requires further investigation to establish the overlaps and gaps between the existing supply chain literature and the Lean and Green supply chain relationship.

4.4 Competitive advantage and growth

Successful businesses continuously seek competitive advantage to outperform their rivals (Porter, 1985). The data from our study shows that while many authors propose integrating the two management philosophies, the study of causal relationships with firm (and industry) performance remains weak (Garza-Reyes, 2015; Martínez-Jurado and Moyano-Fuentes, 2014; Hartini and Ciptomulyono, 2015;). Less than 20 percent of the articles link Lean and Green to branding (13 percent), sales (12 percent), and firm value (18 percent). Furthermore, less than 15 percent of the articles link Lean and Green to pricing (5 percent) and growth (13 percent). The articles that do discuss the relationship are more likely to propose theoretical relationships and not case or industry-level evidence of heterogeneity.

When an organization achieves sustainable improvements in a Lean production system, including processes of environmental innovation, they may create a competitive advantage (Aguado *et al.*, 2013). Companies that continually implement Lean practices expect to improve environmental performance through good housekeeping practices, such as general waste reduction and minimizing hazardous waste, reducing lead times, and material and staff costs, while simultaneously increasing production activity and enhancing quality (Duarte and Cruz-Machado, 2013). Larson and Greenwood (2004) support this point of view, finding that Lean manufacturing produces substantial resource productivity improvements that

contribute directly to environmental performance gains. In this regards, Maxwell *et al.* (1998) highlight that waste minimization through Lean manufacturing motivates positive environmental activities. Yang *et al.* (2010) expand on this, pointing out that firms with close supplier partnerships and solid continuous improvement practices are more likely to develop a proactive environmental management program, which enhances competitive advantage through cost savings, quality improvement, and process/product innovation. We have only seen a marginal exploration of sources of competitive advantage and firm growth in the literature we reviewed related to Lean and Green. Part of this may be due to the management actions and performance metrics being measured at local operating scales, while growth and competitive advantage are measured at the firm level. This gap in literature suggests the need for developing a causal model to form the basis for understanding, coordinating, and measuring the effects of Lean and Green management on firm performance.

5. Discussion

The articles reviewed in this paper generally focus on the potential benefits of implementing Lean and Green practices to achieve gains in operational and environmental performance. They suggest that the adoption of Lean practices have a positive effect not only on environmental performance but also on organizational performance. This positive opinion stems from the perspective of eliminating the seven wastes, whereby the reduction leads to a lowering of input resource utilization and thus environmental wastes. While little evidence of a combined Lean and Green implementation exists in the literature, the purported synergy between Lean and Green manufacturing is evident in the postulate of several articles. Most authors professed that when implemented together, organizations may achieve greater benefits. However, an integrated model of how these firm activities relate to one another, and to firm performance, is lacking.

5.1 Causal system model of firm performance

To establish a starting point for this integrated management model, we take direction from the system dynamics discipline (Forrester, 1961) and causal relationship diagrams (Parunak *et al.*, 1998; Sterman, 2000). In this context, we are developing a representation of an external system whose structure is considered analogous to the perceived structure of the system (Doyle and Ford, 1998). This process is designed to help managers and policy makers dealing with changing environments and complex information feedback structures (Forrester, 1961). The benefit from this technique is not only generated by the outcome of (potentially) running equation-based models, but by considering systems modeling as an activity that leads to further thought discussion and inquiry (Forrester, 1968; Pidd, 2009). In doing so, it leads to a common understanding among individuals and groups of what is really happening, fosters conversation, and helps people to think about the consequences of management decisions (Forrester, 1994, 2007; Morecroft, 2007; Richardson, 1999). Causal loop diagrams describe variables and their relationships by linking them with arrows (Sterman, 2000; Pedercini, 2006). Each relationship is marked with either a positive or a negative polarity, which is an indicator of the influence of one variable on another (Richardson, 2011). The typical benefits of soft models like these arise in getting both internal and external stakeholders involved in the process and driving willingness to adopt and carry out management changes (Pidd, 2009).

Based on the literature review, we propose a model that traces back from firm performance to the two management philosophies in question, as shown in Figure 1. The causal model is based on the management model parameters identified in the literature (Table II), namely Ohno's seven wastes, Lean tools, product quality, operating costs, product pricing, sales revenues, environmental impact, HRs, green branding, and firm performance. Firm performance in this model can be defined as any measure of corporate returns that lend themselves to analysis, such as return on equity, return on assets, warranted equity value, book value, or stock price (Molina-Azorín *et al.*, 2009). While we did identify profit, growth, and firm value as parameters in Table II, we do not explicitly include them in the model (Figure 1), but rather group them in the overall parameter of firm performance. We see from this model that operating costs negatively affect financial performance while sales revenues positively affect financial performance. Neither Lean nor Green management directly impact these two measures, but rather affect antecedents of these calculated values.

5.2 Lean management impact

Tackling the Lean side of the model first, we see that adopting a Lean management philosophy will drive the use of Lean tools (Womack and Jones, 1996; Hallam *et al.*, 2010) which in turn leads to a reduction in Ohno's seven wastes. We introduce a variable in the model called productivity to capture these reductions in waste as operating efficiencies, and thus productivity gains. The productivity variable will also link the Lean side of the model with the Green side of the model as discussed in the next section. The productivity improvements reduce operating costs for an equivalent unit of output. The sign of the causal relationship indicates the direction of effect of the antecedent on the variable, thus we see that a decrease in operating costs drives an

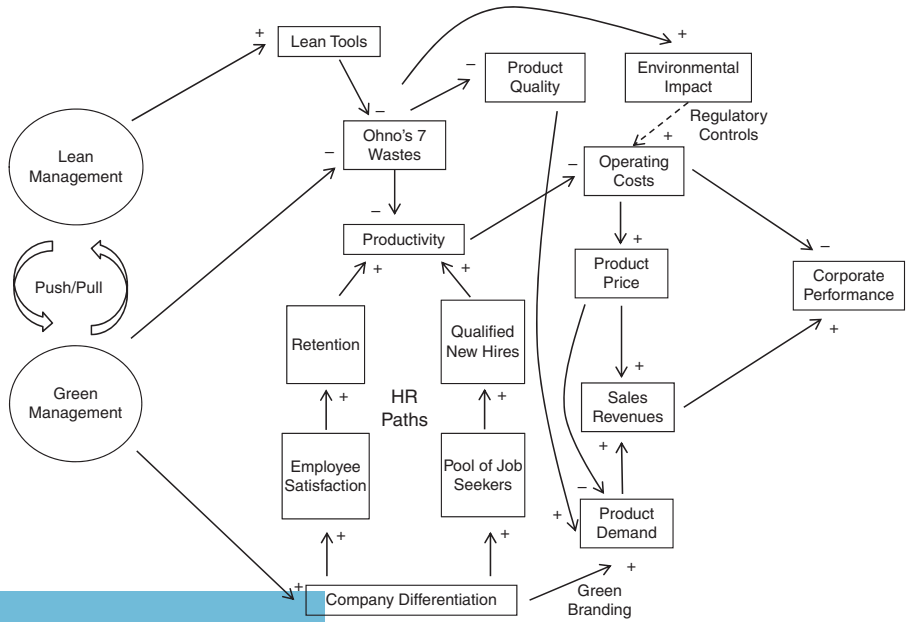

Figure 1.
Proposed management model integrating Lean and Green with firm performance

improvement in corporate performance (i.e. increased profit). While an increase in product pricing increases sales revenues (i.e. quantity times price) and hence corporate performance, the price elasticity of demand acts to counter this effect. The model shows this relationship as an increase in product pricing driving a decrease in product demand. The reduction in Ohno's seven wastes also result in a net improvement in product quality via fewer defects (Ohno, 1988; Liker and Morgan, 2006; Fullerton and Wempe, 2009). The improved quality of product resulting from Lean implementation acts to increase the demand for the product, thus driving the revenue path in the model through increased sales, and thus increased corporate performance.

5.3 Green management impact

As we look at the Green side of the model, the path connected to the seven wastes results in the use of fewer input resources for a given quantity of output resources. If we consider environmental impacts as negative, then this decrease in Ohno's seven wastes causes a reduction in environmental impact. The result of environmental improvement, or decrease in environmental impact, on operating costs includes the reduced burden of regulatory and compliance expenses associated with environmental wastes (such as emissions taxes). These are represented as a dashed line as they vary from state to state and country to country (Xing and Kolstad, 2002).

The second path from Green management has to do more with CSR and its effects on company differentiation or branding. With a focus on Green, the firm establishes a key HR influence that has two distinct reinforcing paths in the model, an employee retention path and a new hire path. The improvement in these paths has been highly touted in the CSR literature (Turban and Greening, 1997; Bhattacharya *et al.*, 2008; Turker, 2009). In our proposed model, both of these paths improve firm productivity. The retention path results in a lower turnover rate for the firm, thus keeping productivity high. The new hire path results in a larger pool of qualified applicants seeking the Green differentiated firm, also resulting in higher productivity. While the Lean path drives productivity through waste reduction and operating efficiency gains, the HR paths drives productivity through increased capability of human capital (Black and Lynch, 1996; Koch and McGrath, 1996; Firer and Mitchell Williams, 2003). The productivity path then affects form performance as previously described. The company differentiation path also increases the potential for sales due to Green branding of products or of the firm itself (Carroll, 1991; Lantos, 2001; McWilliams and Siegel, 2001). This path drives more product demand, thus sales revenue and growth, and ultimately firm performance.

5.4 Integrating management philosophies

From the proposed management model (Figure 1), we see that Lean efforts creating operational improvements can help reduce costs, drive demand through quality improvements and price reductions, and create environmental benefits if they are tracked by the company. The Green efforts can capitalize on Lean tools to achieve some of the performance objectives, but require the use of company differentiation as a potential path for sustainability and growth (Hayes and Pisano, 1996; Kleindorfer *et al.*, 2005; Yang *et al.*, 2011). We have not addressed the mathematical formulation of these relationships, and as such are not proposing a simulation model for testing management strategies. However, the causal relationships do provide a means for

management to consider where and how their Lean and Green implementations affect the overall performance of the firm.

From a management perspective the implementation of Lean creates a Green side effect by reducing waste – essentially Lean pushes Green. However, evidence of successful Green implementation requiring, or pulling Lean is remarkably thin. Furthermore, Lean implementation does not address all Green objectives, but rather those directly associated with operations. For example, choice of technology or process materials for Green, CSR or regulatory reasons may increase costs or production time. These may be partially offset by Lean improvements, but are essentially independent actions. The model highlights the cross-disciplinary nature of the efforts affecting different elements of the firm, such as production, HRs, marketing, compliance, and strategic planning. A holistic view of the firm is needed to understand how the improvements in one area will affect (positively or negatively) another, thus informing management decision making. In this light, our model can be used to frame key management strategies that drive the use of Lean and Green to improve firm performance.

5.5 Theoretical contribution

From a research perspective we have found that Lean is pushing Green, and little case evidence exists of the successful integration of the two management philosophies. An interesting research question can be proposed about the evolution of the two management philosophies from different disciplines. While Lean has largely been promulgated from the manufacturing and production disciplines, and eventually flowing into broader process management and improvement tools (Bhasin and Burcher, 2006), Green management has roots in the environmental regulatory and compliance domain (Florida, 1996; Baines *et al.*, 2012). As a result, managers in these disciplines bring to bear different lenses and language about firm operations, which lead to different actions (Simon, 1991). Investigating this aspect of Lean and Green may help explain why the integration of both management philosophies has been slow.

The international footprint of many global firms offers the opportunity to look at how geographic, cultural, and diverse regulatory environments can affect the integration of Lean and Green, and should be considered a potential source for comparative cases. The magnitude of the impact on firms can be largely affected by the cost of environmental impacts (Hart and Ahuja, 1996; King and Lenox, 2001b; Klassen and McLaughlin, 1996) and is a source of differences in firm performance among countries with differing regulatory frameworks (Christmann, 2004; Grossman and Krueger, 1991; Xing and Kolstad, 2002). The model we propose can be used for testing these differences qualitatively, and offers the potential for creating a quantitative systems dynamics model for simulation purposes. This would enable the study of firm-level management decisions on performance.

5.6 Limitations of research

As with other studies we recommend that our results be considered within certain limitations. We applied a PRISMA approach to the literature search (Moher *et al.*, 2009) focusing on both qualitative and quantitative articles. While we found a limited number of articles germane to our topic, the growth in the field may allow for more advanced quantitative meta-analyses (Lipsey and Wilson, 2001) or enable a mixed methods approach (Creswell and Clark, 2007) in the future. We anticipated finding evidence of

both push and pull relationships between Lean and Green, however, we only found evidence of Lean push relationships. This does not imply the pull relationship does not exist, but the relative few number of case studies we found did not provide any examples. Finally, we identified parameters in the relevant literature that lead to a proposed management model integrating Lean and Green. This model is neither exhaustive nor fully complete, but does offer a starting framework for linking Lean and Green management actions with firm performance in a causal mechanism (Senge and Sterman, 1992; Sterman, 2000; Forrester, 2007). As a proposed model, follow on studies are necessary to validate the model. Furthermore, the application of the model to supply chain management is not fully defined at this time and requires further work.

6. Conclusions and future work

The documented relationship between Lean and Green management has largely been weak. The strongest positive evidence between the two management philosophies has been for Lean implementation pushing Green outcomes through operational waste reduction, thus improving environmental performance. The majority of studies suggest highly optimistic outcomes from integrating Lean and Green, however, an integrated operating model of the firm relating Lean and Green is lacking. Our literature review suggests the necessary parameters for proposing an integrated operating model of the firm that links Lean and Green management antecedents with firm performance.

The general findings of our work also suggest that the two management philosophies have been implemented within firms as independent efforts. Understanding this gap in more detail may bring to bear a deeper understanding of the requirements for their integration. The emergence of Lean within the manufacturing, quality and continuous improvement functions of companies, vs the implementation of Green through environmental compliance and regulatory functions would suggest different organizational cultures and management lenses. Expanding on our work in this area could provide new knowledge and lay the foundation for successful Lean and Green change management.

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