



## Approach of the Two-way Influence Between Lean and Green Manufacturing and its Connection to Related Organisational Areas

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**Abstract:** Initiatives toward Lean and Green Manufacturing are given mainly due to organisational response to current market's economic and environmental pressures. This paper, therefore, aims to present a brief discussion based on a literature review of the potential two-way influence between Lean and Green Manufacturing and its role on the main organisational areas with a closer relationship to such approaches, which were observed to be more extensively discussed in the literature. Naturally lean practises seem more likely to deploy into green outcomes, though the other way around can also occur. There is some blur on the factual integration of both themes, as some authors suggest. Notwithstanding, they certainly present certain synergy. Thereupon, further research is needed to unveil the real ties, overlaps and gaps between these approaches.

**Key words:** Lean & Green, Manufacturing, Lean, Green, Sustainability.

### 1. Introduction

The Lean & Green approach has been considered in the search for environmental and economic enhancement of production systems (Kainuma and Tawara, 2006) and this topic has been gaining special interest since 2010 (Garza-Reyes, 2015). The economic characteristics of the market have been forcing organisations to tighten their belts and lean their processes in order to save resources and drop waste production. So then, Lean Manufacturing starting point was marked by the need for maximising the use of resources and minimising waste (Sundar, Balaji and SatheeshKumar, 2014) and later, as it developed, it started to grow and ramify, deriving similar approaches on diverse spheres, such as Green Manufacturing.

Besides market pressure, governments also play a certain role in an organisation's performance,

regulating industrial activities (Salvador *et al.*, 2014), aiming to prevent them to thrive on either the nature's or the population's expenses, environmental and economy-wise. For those reasons, an integrated approach seems to be an easier and better option in the path to leaner and greener practises. Therefore, this paper aims to present a brief discussion based on a literature review of the potential two-way influence between Lean and Green Manufacturing and its role on the main organisational areas with a closer relationship to such approaches, which were observed to be more extensively discussed in the literature.

Such organisational areas were Product Planning and Design, Supply Chain and Quality Management, Organisational Culture and Performance and Logistics. The novelty of this piece of research lies exactly on the identification of the main areas within an organisation where the connection between the

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discussed approaches can be observed more often and densely, though there might be other areas with a weaker relationship, which are not addressed.

This paper, thus, is structured as follows: firstly, the concepts of Lean Manufacturing and Green Manufacturing are presented. In the sequence, the main considerations about their influences on each other are briefly discussed. Then, their influence on each of the aforementioned organisational areas is pointed out, followed by some considerations from controversial literature. Lastly, the final considerations with regard to this piece of research are drawn and the references used are listed.

## 2. Lean Manufacturing

Developed in Japan (Rohani and Zahraee, 2015), this business strategy has been discussed since the 1950s. There is no one definite Lean Manufacturing definition, as it has been constantly developing (Jabbour *et al.*, 2013). Pioneers (Womack, Jones and Roos, 1990) consider it, though, as “making more with less”.

It originated from Total Productive Maintenance (TPM) practises, in the automobile industry (Roosen and Pons, 2013). The main objectives of Lean practises are reduction of costs and defects (Ohno, 1998) and customer focus (Jabbour *et al.*, 2013). Its principles lie on minimising various forms of waste throughout the entire value chain, reducing variability (Shah and Ward, 2007).

The 7 forms of waste considered by Womack, Jones and Roos (1990) are: transport, inventory, motion, waiting, over-processing, overproduction and defects.

It can be considered, thereafter, as a starting point to similar production approaches, such as the Green Manufacturing, as presented in the next section.

Moreover, the Lean Manufacturing presents five principles in order to achieve the reduction of those 7 forms of waste, being them: value, value stream, flow, pull and perfection (Womack and Jones, 1996). Such principles aim to specify value, through the customers' perspective, identify the value flow, make the value flow with no interruptions and allow costumers pull the value along the product's value stream (Hallam and Contreras, 2016).

## 3. Green Manufacturing

Also referred to as Sustainable Manufacturing, Green Manufacturing has as a major concern the consequences of production activities and the entire product life cycle on the environment. Even though it is hard to find a “one” definition for Green Manufacturing (Paul, Bhole and Chaudhari, 2014) the concept has been widening (Silva, Silva and Ometto, 2015) and the convergent idea is that it is the set of strategies, practises and behaviours, which aims to prevent, reduce and/or eliminate negative impacts on the environment.

The main approaches found in the literature used to cope with environmental issues are control, prevention and product stewardship (Hallam and Contreras, 2016). The first approach considers “end-of-pipe” treatment to emissions of all sorts, concerning with the problem after it has been created (Rusinko, 2007). The second one, prevention, focus on eliminating pollution/emissions (Hart, 1995). Product stewardship, though, involves other parties and stakeholders (such as internal [research and development, designers] and external [such as suppliers]) and their influence in the search for improvement of the environmental profile (Rusinko, 2007).

Moreover, there are tools to assist the application of the concept and keep practises and activities on a green track.

The main tool is the Life Cycle Assessment (LCA) (Dües, Tam and Lin, 2013; Piekarksi *et al.*, 2013), which is considered the most complete and complex tool for environmental assessment (Bocken *et al.*, 2012), allowing to identify and manage the impacts of any considered system.

## 4. Two-way influence: Lean ↔ Green

The alongside adoption of Green and Lean Manufacturing, besides appearing to present a positive effect on all dimensions of organisational performance (Garza-Reyes, 2015), can lead to an increase in market share and organisational profit (Carvalho *et al.*, 2011).

Greinacher *et al.* (2015) imply that from a lean approach, the reduction of inputs' consumption

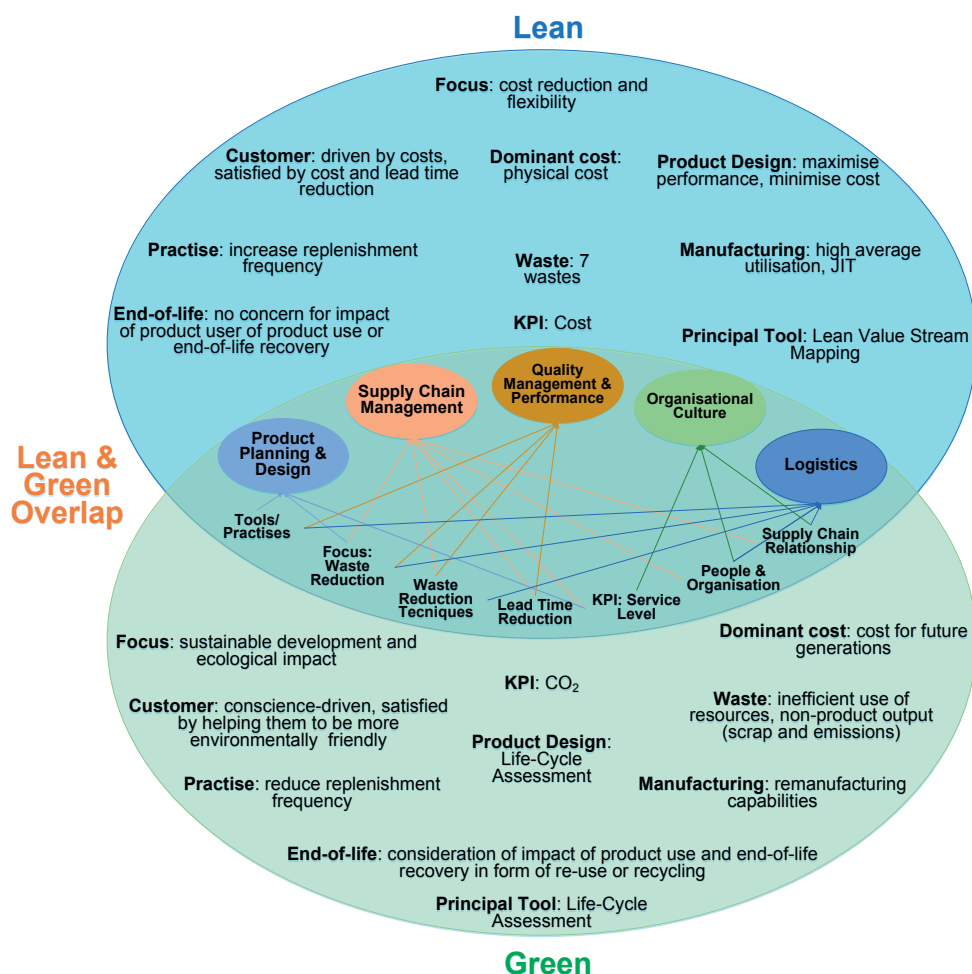
presents a logical continuation to reach “Lean + Green”, getting maximum efficiency and enhancing competitiveness.

Larson and Greenwood (2004) consider Lean Manufacturing and Green Manufacturing parallel universes, whereas Dües, Tam and Lin (2013) affirm that the adoption of Lean practises works as a catalyst for better Green practises. Additionally, overlapping environmental and operational practises get leveraged (Yang *et al.*, 2010; Carvalho and Cruz-Machado, 2009). Galeazzo, Furlan and Vinelli (2014) corroborate the idea suggesting that, based on previous studies, Lean and Green Manufacturing are complementary, as it can be observed in Figure 1. Thus, environmental practises would be able to help an organisation to become leaner and lean practises would help to greening the organisation (Ng, Low and Song, 2015).

Womack and Jones (1996), in turn, state that Lean production is environmentally friendly by nature, since it leads to reduction of energy consumption, wastes and by-products, which, according to Yang *et al.* (2010) might reflect on the organisational performance in a comprehensive way. Furthermore, EPA (2006) affirms that environmental wastes, somehow are related to or embedded in Ohno’s seven wastes, hence, tying once again Lean and Green.

Hallam and Contreras (2016) conclude that Lean practises tend to lead to greener outcomes, whereas evidence that Green pulls leaner outcomes is lacking, so what the latter does is to support existing Lean practises.

Nevertheless, it can be observed that they work together (Upadhye *et al.*, 2010) and have a synergistic relationship (Galeazzo *et al.*, 2014; Yang *et al.*, 2011).



**Figure 1.** Overlap of Lean & Green Paradigms and its Influence on Related Organisational Areas (source: Adapted from Dües, Tam and Lin (2013)).

The two aforementioned and discussed approaches seem to overlap in various areas within the organization, since early steps such as planning and design, as in processes and products, as presented hereafter. Figure 2 shows a set of pieces of research which approach the integration of Lean and Green in the areas approached in Figure 1. The filling colours of the bubbles indicate which organisational area they relate to and the connecting arrows point to the focus of the work, having been identified four main focusses within the papers analysed.

It can be seen that much attention has been given to the improvement of processes, which tends to lead to performance improvement, as well as to the development of new frameworks, which help to systematise and better understand the relations of Lean and Green within the organisation. Furthermore, Chart 1 shows the overall purpose of the papers presented in Figure 2.

The papers presented in Chart 1 approach a few implications of the alongside adoption (by diverse means) of Lean and Green. Such papers, together with the information provided in Figure 2, show potential research trends in organisational areas, which were mentioned earlier and are briefly addressed hereafter.

### 4.1. Product Planning and Design

Many organisations, as easily perceived, adopt Lean practises and worry about environmental issues of its processes only after certain period of activity. It might be due to lack of resources, knowledge, technical expertise and/or lack of interest. On this regard, Simons and Mason (2003) claim that such strategies should be adopted since the conception of the project of the business/product/system, thus, preventing potential environmental and/or economic damages.

In this sense, Kainuma and Tawara (2006) affirm that in product planning and design the lean approach aims the reduction of costs and maximisation of performance, while Green Manufacturing, through the principles of Life Cycle Assessment (LCA) aims to prevent impacts in each of the product life cycle phases. Hence, naturally, use of materials and diverse wastes are reduced, applying principles of Lean Manufacturing, evidencing, hereby, the interrelation between these two themes.

Anand and Kodali (2008) yet, point that product development plays an important role in an organisation's path to become Lean & Green.



Figure. 2 Main focus of research papers integrating lean and green and related organisational areas.

**Chart. 1** Overall research purpose of papers addressing lean and green integration.

Reference	Overall Research Purpose
Anand and Kodali (2008)	Development of a framework to reduce various forms of waste in New Product Development (NPD) process
Duarte and Machado (2017)	Development of a conceptual framework to asses the implementation of Lean and Green using some key-criterion to identify Green and Lean initiatives
Carvalho <i>et al.</i> (2017)	Propose a model to support decision making and to help identifying the best set of green and lean supply chain management practises to improve eco-efficiency
Kainuma and Tawara (2006)	Extend the range of the supply chain to include re-use and recycling throughout the life cycle of products and services
Galeazzo, Furlan and Vinelli (2014)	Using a case study methodology, the piece of research aims to discern how Lean and Green interact and how they yield maximum synergy in improving both operational and environmental performance
Hajmohammad <i>et al.</i> (2013)	Proposition of a conceptual model to help understand the roles of lean and supply management in regards to improving the firm's environmental performance. The model proposes that the magnitude of environmental practices mediates the relationship between lean and supply management with environmental performance
Mittal <i>et al.</i> (2017)	Identification and ranking of enablers of Lean and Green in the adoption of Leen-Green-Agile Manufacturing Systems
Kumar <i>et al.</i> (2017)	Literature review seeking to investigate the green impacts of Green on Lean, Six Sigma and Lean Six Sigma. Discussing the issues of energy management, global warming, pollution and usage of resources
Thani, Govindan and Thakkar (2016)	Applying AHP method, it seeks to investigate the impact of select lean and green practices on performance benefits, and to evaluate the influence of lean and green paradigms on overall performance of SMEs
Fercoq, Lamouri and Carbone (2016)	Quantitative study of Lean/Green integration focusses on waste reduction techniques in manufacturing processes. The study claims that the 3R Hierarchy must be preferred to a deadly waste approach on defining a waste minimisation program
Pampanelli, Found and Bernardes (2014)	Propose a model to integrate environmental sustainability into pure lean thinking, to improve mass and energy flows in manufacturing environments that already possess the necessary deployment level to apply lean thinking
Verrier <i>et al.</i> (2014)	Assess how Lean and Green actions could be enhanced when used together, proposing a framework for Lean and Green management, including Lean indicators, Green performance indicators and Green intentions indicators
León and Calvo-Amodio (2017)	Identify the building blocks of Lean for sustainability (environmental, social and economic spheres)
Salleh, Kasolang and Jaffar (2012)	Integrate Environmental Information Management practices are in a Lean Total Quality Management (TQM) framework in order to establish a Green Lean TQM system
Esmer, Çetin and Tuna (2010)	Analyse a Turkish container terminal performance both in terms of lean and green dimensions

## 4.2. Supply Chain Management

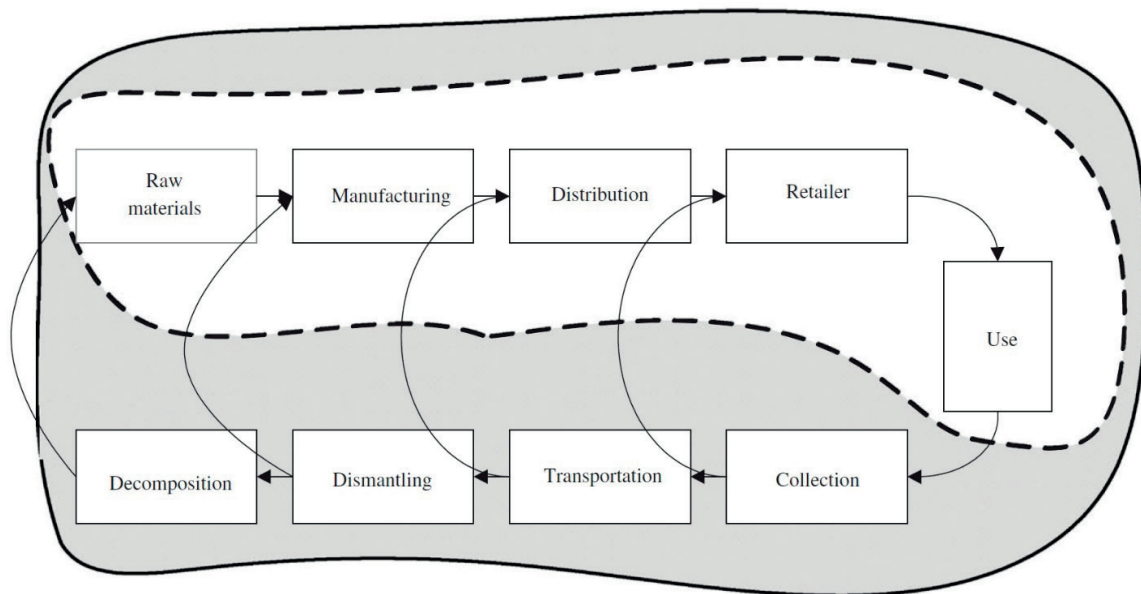
Lean & Green can also assist supply chain management. Kainuma and Tawara (2006) analysed different interaction models between the parties in the supply chain in order to identify the information flows, as showed in Figure 3, and the roles of these parties in management strategies.

The elements within the dotted line belong to a typical supply chain, whereas the Figure 3 as a whole

represent a Lean & Green supply chain management scheme. By such interactions, the chain encompasses a broader set of collaborators and in order to maintain its activities aligned with the pillars of both Lean and Green Manufacturing there is an extension of the aspects considered to the management of that supply chain, facilitating integration and collaboration of different areas and sectors.

Logistics strategies are to be considered seeking minimum motion, lower emissions, and a more





**Figure. 3** The range of the lean & green supply chain (source: Kainuma and Tawara (2006)).

responsive system (Dües, Tam and Lin, 2013), as well as reduced costs and lead-time (Esmer, Çetin and Tuna, 2010).

Additionally, as collaboration is of utmost importance within a supply chain (Dües, Tam and Lin, 2013), narrow, highly reliable and responsive relationships are necessary in order for the production activities to be conducted in time, with the required resources and within the required environmental-wise behaviour.

### 4.3. Quality Management and Organisational Performance

The Lean Manufacturing supports the Total Quality Management (TQM), whereas Green Manufacturing practises support the Environmental Management System as a whole (Salleh, Kasolang and Jaffar, 2012).

Regarding process' characteristics, reduction of variability will be supported by the rigor on the use of materials (Chugani *et al.*, 2017), there not being wastes of such, for instance energy and time for conducting low value-added activities, aside from a higher accuracy on the production activities,

preventing eventual rework (Pampanelli, Found and Bernardes, 2014). With regard to environmental characteristics, change begins with the reduction of wastes, through the Lean practises, being supported by a more rigorous selection of partnerships within the supply chain, requiring partners to bear the same concerns in mind and to prove it by obtaining the pertinent environmental certifications, hence, extending the environmental commitment.

With this regard, Hallam and Contreras (2016), claiming that there are no models to actually integrate these themes, proposed one model with such purpose, which is showed in Figure 4. The authors do not address the mathematical formulation of the elements' relationships, though.

As it can be seen in Figure 4, Green actions can avail themselves of Lean ones assisting on the achievement of performance objectives. It all reflects on the organisational performance and will persuade clients' and partners' standpoint toward the organisation. As Galeazzo, Furlan and Vinelli (2014) state, there can be both simultaneous and sequential benefits from the alongside implementation/practise of Lean and Green Manufacturing, which should, preferably, be applied simultaneously.

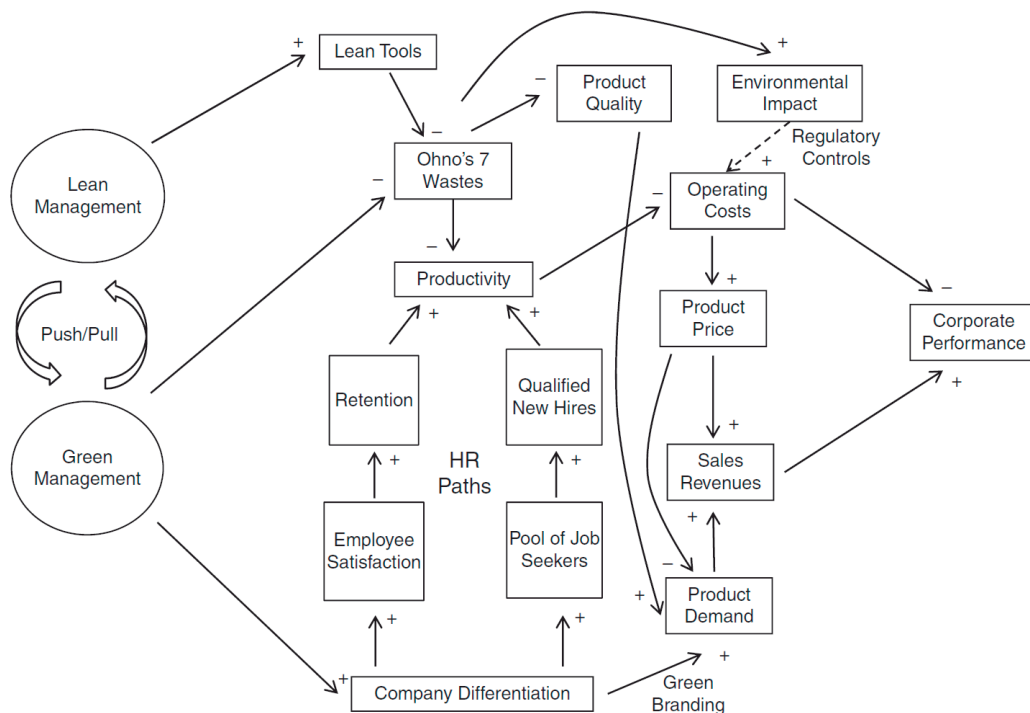


Figure 4. Proposed management model integrating Lean and Green with firm performance (source: Hallam & Contreras (2016)).

#### 4.4. Organisational Culture and Performance

As Dües, Tam and Lin (2013) imply, the integration between Green and Lean Manufacturing to the organisation's culture can bring about change to its core, adapting mission, vision and values, even revolutionising production practises, depending on the gap between the current and the desired (future) states.

Moreover, seeking cleaner products, the importance of this relation becomes evident, once the characteristics of the activities performed by suppliers have direct influence on the products and services offered by the core organisation (Hajmohammad *et al.*, 2013). Hence, there can often be imposition of requisites and environmental certifications, mainly by large corporate networks, to their suppliers and partners, thus guaranteeing continuity of the commitment put on to their activities and products.

#### 4.5. Logistics

To Verrier *et al.* (2014), environment and logistics are antagonic. A proper management of the environmental characteristics of logistics activities is, as well as a legal requirement, a users requirement

(Esmer, Çetin and Tuna, 2010); besides, more than transportation and distribution channels, many places of congruent negotiations of loads (such as ports, distribution centres) are also business centres and value-adding spots.

In what regards the characteristic emissions of the activities and cost management, such places need to deploy Lean and Green Manufacturing strategies (Esmer, Çetin and Tuna, 2010).

Furthermore, jointly, Lean and Green Manufacturing in logistics operations may result in minimum motion systems, so as to achieve lower emission levels, as well as reducing costs, besides bringing down waiting time and creating more responsive systems (Dües, Tam and Lin, 2013).

It is possible to drop the emissions levels by giving preference, where possible, to electricity driven equipment, replacing combustion motors, whereas simulation methods, from process modelling, can guide reductions of operations' time and costs (Esmer, Çetin and Tuna, 2010).

Moreover, as showed by Piekarski *et al.* (2017), replacing suppliers, choosing the ones located closer to the industrial facility may reduce greenhouse gas

emissions, on the Green side, and at the same time, contribute to a leaner system, diminishing delivery time and cost. Showing, this, a case of Green pulling Lean, opposite to what most of current literature claims. Furthermore, Cabrita *et al.* (2016) affirm that logistics is one of the key areas to seek collaboration in order to green a system.

## 5. Controversial Literature

Even though Lean and Green Manufacturing hold certain harmony, they differ in a few aspects, such as: main focus, process structure, construct value, performance measurements, type of consumers, definition of waste e techniques utilized (Johansson and Sundin, 2014). Under this light, Kleindorfer *et al.* (2005) state that Lean and Green Manufacturing practises are distinct and, therefore, they have different impacts on organisational performance.

Evidences of integrated approaches using Lean and Green can be extensively found in the literature. The links and the evidences proposed to successfully integrating them, however, are suggested by Hallm and Contreras (2016) to be largely weak.

Many authors corroborate the idea that Lean and Green Manufacturing are approaches that go alongside and have positive influence on each other. Johansson and Sundin (2014), however, affirm not to be possible to say that actions toward one directly lead to consequences on the other, being this area yet incipient (Garza-Reyes, 2015). Also, potential relations might have been neglected, being this investigation inconclusive (Jabbour *et al.*, 2013).

One example of a contradictory outcome out of the approached relationship is that Lean practises may impact negatively on Green ones by the use of a just-in-time delivery process (Martínez-Jurado and Moyano-Fuentes, 2014), due to the enlargement of the emissions of greenhouse gases in transportation.

On the one hand, according to Hallam and Contreras (2016), the majority of studies found in the literature corroborate a strong link and positive outcomes from the integration of both themes. On the other hand, the authors state that the area still lacks operating models of the firms to relate them.

With few attempts to, actually, integrate them both and that, according to the results of Biggs (2009),

both themes have developed independently. For Johansson and Sundin (2014), one of the main overlaps between Lean and Green Manufacturing is that they are both driven by the increase in competitiveness and, even though their constructs are different, these are not conflicting.

## 6. Final Considerations

It is possible to observe that the adoption and the joint use of Lean and Green Manufacturing can result in benefits and influences on various areas within an organisation, such influences might occur simultaneous or sequentially. Activities in a certain area can influence on another and, likewise, they can be potentialized, so then multiple single actions can result in a non-linear increase on the organisational performance ( $1+1 \neq 2$ ).

The organisational areas in the overlap region of Figure 1, Product Planning and Design, Supply Chain Management, Quality Management and Performance, Organisational Culture and Logistics, are the ones where current research is being conducted on the influence of Lean and Green on each other. So it can be noted that they have been being studied because of the perceived value of the joint use of the mentioned approaches on such areas. Therefore, future research lines should be drawn from those areas/fields to further explore and better assess the practical implications of actions and decisions addressing Lean and Green approaches on an organisation's outcomes.

Notwithstanding, this piece of research is not exempt from limitations. This review is not, by any means, exhaustive and it was limited to the particular topics approached. The authors believe, however, that it allowed to identify representative trends of the growing body of literature on Lean and Green.

Lean and Green efforts seem to be made independently on an organisation. It does not seem to be common agreement that they surely are or can be integrated, since their constructs might differ, however, it appears to be undeniable that they have certain synergy and have sharing features. Nevertheless, further research is needed to broadly investigate their relationship, unveil the real ties, overlaps and gaps between them.



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