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A CRITICAL REVIEW ON LEAN GREEN PRODUCT DEVELOPMENT: STATE OF ART AND PROPOSED CONCEPTUAL FRAMEWORK

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Abstract

The latent relationships between lean product development (PD) and green PD appear to be in its infancy in literature. Thus, the main objective of this research is to uncover the intersection of lean and green with PD issues, by building a conceptual framework of the field and proposing synergies among practices from these paradigms. A research design is proposed listing the lean and green practices in PD through a systematic literature review process. Firstly, papers were gathered from international peer-reviewed journal articles. Secondly, a total of 38 papers were assessed by quantitative indicators and evaluated using content analysis. This research contributes with an analysis of the main topics of lean and green paradigms revealed in the literature and provides a comprehensive list of lean PD and green PD practices, drivers, and barriers. Finally, lean and green synergistic propositions in PD field are discussed.

Key words: conceptual framework, green, lean, literature review, product development

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1. Introduction

The product development (PD) process is defined as an association of interrelated activities that work together to convert a market opportunity into a product or service that meets customer requirements and, at the same time, the firm's objectives (Krishnan and Ulrich, 2001; León and Farris, 2011). Recent studies point to the importance of PD in the competitiveness of companies (Gopalakrishnan et al., 2015; Marion et al., 2015). Thus, different approaches are employed in order to maximize the gains for organisations, for example Lean Thinking (e.g. Biazzo et al., 2017; Iamratanakul, 2017; Tortorella et al., 2016) and the green paradigm (e.g. Björkdahl and Linder, 2015; Chang et al., 2013; Inman and Green, 2018; Moreira et al., 2015; Rizzo et al., 2017; Zhao et al., 2018).

Lean thinking applied to manufacturing (also known as lean manufacturing) is considered well established by both the academic community and industry (Al-Ashaab et al., 2016; Baines et al., 2006), but lean applied to product development (PD) area is a more recent concern in the academia (Al-Ashaab and Sobek, 2013; Johansson and Sundin, 2014; Mund et al., 2015). The green paradigm aims to respond to

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growing customer demand for products and services that are environmentally sustainable and comply with government regulations. Thus, companies need to rethink their objectives and, therefore, rethink the way they manage their operations and processes (Garza-Reyes, 2015b). Many industries have benefited from the implementation of green practices not only in relation to environmental advantages, but also in regard to cost reduction (Comanita et al., 2018; Li et al., 2016), increased efficiency, increased productivity, and better product quality (Chiou et al., 2011; Jasti et al., 2015). In the area of PD, green product development (GPD) is acknowledged as a coherent pathway to reduce environmental degradation in order to provide economic and social benefits to the final customer, stakeholders, and companies (Fuller and Ottman, 2004; Gerboni et al., 2017).

The research fields in lean and green have evolved quite independently of one another (Johansson and Sundin, 2014). The lean-green junction is considered a new and emerging research topic and it is expected that publications in the area will grow in the next few years (Campos and Vazquez-Brust, 2016; Garza-Reyes, 2015b). Li et al. (2016) state that lean and green paradigms may be complementary and synergistic; however, studies combining both paradigms in PD subjects are more scarce (Galeazzo et al., 2014; Garza-Reyes, 2015b; Johansson and Sundin, 2014).

The integration of lean and green initiatives is motivated by both internal and external factors (Kumar and Rodrigues, 2019). However, the drivers or enablers for implementation of lean and green approaches have not been thoroughly uncovered in the past research (Gandhi et al., 2018). In addition, firms face difficulties in the implementation of both paradigms (Cherrafi et al., 2017), that is, literature suggests that green and lean practices, when applied to PD, are not easy to implement due to the existence of many impediments or barriers (Kumar et al., 2015; Kumar et al., 2016).

In this matter, this article intends to advance the body of knowledge related to the intersection of lean and green with PD issues by means of a systematic literature review process. Thus, this work aims at answering the following research questions (RQ):

RQ1: What are the main drivers and barriers for implementation of both paradigms in PD?

RQ2: What is the present state of art in the field of lean and green product development in terms of a conceptual framework?

Finally, yet importantly, this paper also aims at starting a discussion on the possible synergies that emerge from both paradigms when applied in PD.

The rest of this manuscript is organized as follows. Section 2 brings details on the research method, while Section 3 presents the literature review results and discussion, including the descriptive and content analysis. Section 4 organizes the information produced by this systematic literature review by presenting the conceptual framework and synergic propositions. At last, Section 5 closes the manuscript by addressing final remarks and future paths of research.

2. Research method

This research is based on a systematic literature review (SLR) method, following a precise and explicit approach, and it includes sequential phases that ensure rigor and transparency for the research questions (Tranfield et al., 2003). Systematic reviews support the expansion of concepts from a great number of previous related research and convert research questions into a bibliographical portfolio (Oliveira et al., 2018).

Literature reviews generally aim at three purposes (Bouzon et al., 2014; Meredith, 1993): (i) to summarize existing research, identifying issues and patterns; (ii) to provide an overview and critical evaluation of a bibliographic portfolio in relation to a research topic or problem; and (iii) to identify the conceptual content contributing to the theoretical development of the field.

This literature review utilizes Seuring and Müller (2008) and Bouzon et al. (2014) procedures, and includes the phases described in Fig. 1. The following paragraphs detail the topic delimitation and article portfolio definition phases. The remainder is presented in the following Sections of this paper.

The authors do not ignore the effort in previous research to integrate the traditional PD research with the triple bottom line (TBL) of sustainable development. Under TBL, products have to be profitable for the firm (economic), and, at the same time, they have to be equally relevant for the people's concerns (social) and the needs of the planet (green) (Thomé et al., 2016). However, as a delimitation of this research, only papers focused on the green pillar of sustainability were taken into account, as previously done in Lean – Green literature review by Reyes and Arturo (2015), that is, papers referring to environmental aspect of sustainability were collected by the search term "green."

Regarding the selection of papers dealing with lean issues, the term "lean" was combined with green or "product development" and similar terms. As the scope of this research was to uncover a portfolio of papers that focused on more than one lean practice, the authors decided to use the word "lean", since it embraces many practices and initiatives such as Kanban, just-in-time, value stream mapping, etc. This research outline has been already used in previous reviews (i.e. Reyes and Arturo, 2015; Salgado and Dekkers, 2018).

Thus, the articles included in this review are those that explicitly presented more than one lean and/or green PD practices. This study was carried out through a structured research with keywords determined comprehensively, in order to not artificially limit the field of research, and, at the same time, to avoid undesirable results. In view of this, two research groups were drawn, according to Table 1.

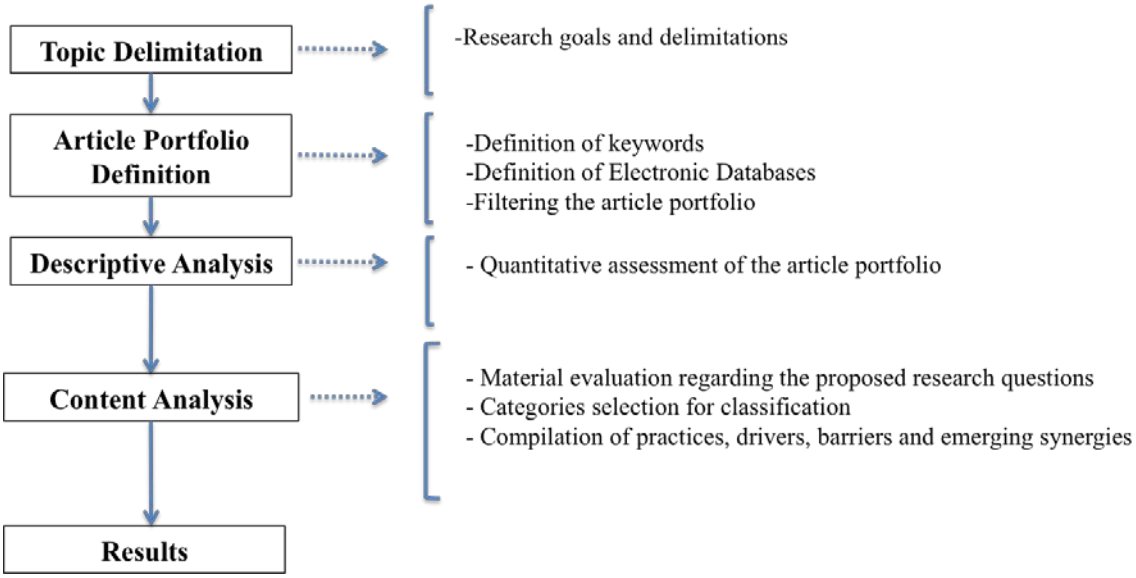

Fig. 1. Literature review procedure. Source: Adapted from Seuring and Müller (2008) and Bouzon et al. (2014)

Table 1. Keywords

Group A	("lean" OR "green") AND ("product development" OR "product design" OR "product introduction")
Group B	("lean green" OR "lean and green")

Only papers published in academic journals in English and with peer-reviewed articles were considered. The databases were chosen by relevance in operations management areas: Scopus, Web of Science, and OneFile Gale. After this step, the bibliographic portfolio containing 6124 articles was initially filtered. For this process, EndNote® bibliographic portfolio management tool was employed in order to eliminate occasional duplicate papers and to avoid manuscripts that did not fall into the category of peer-reviewed journal articles. Secondly, the articles were submitted to a filter considering the title and abstract. At the end of this selection, the bibliographic portfolio ended up with a total of 266 articles. From this point, the relevance of the articles was verified by means of an article classification index, taking into account three variables:

- Number of citations (NC): this indicator demonstrates the relevance and recognition of the work by the scientific community. According to Pagani et al. (2015), articles recently published generally have few citations, which leads to the conclusion that it would not be correct to determine the scientific relevance of a work based only on the number of citations of the paper. The number of citations of the articles in our portfolio was accessed on Google Scholar, as recommended by Harzing and Van der Wal (2008) and Harzing and Alakangas (2016).
- Journal Impact Factor (JIF): it indicates the relevance of the journal for the scientific community in which the article was published. For this work, we have considered the "previous year Journal Citation Reports" (JCR) metric, published by the Institute for Scientific Information and edited by Thomson.
- Year of publication/Paper age (A): a paper published recently increases the probability of presenting innovations in the research area, as well as using frameworks and methodologies already validated in the area (Pagani et al., 2015).

Taking the aforementioned indicators into account, the calculation proposed by Pagani et al. (2015) was adapted to select the most relevant papers in our portfolio, as presented in Eq. 1:

$$ACI = W_{JIF} * (JIF * K_{JIF}) + W_A * [1- (A * K_A)] * W_{NC} * (NC * K_{NC}) \quad (1)$$

where:

- *ACI* represents the individual Article Classification Index;
- *JIF* is the JCR index, normalised by the coefficient K_{JIF};
- *A* represents the age of the paper, calculated using the year of the research (2017) minus the publication year of the paper. This value was normalised as well by the coefficient K_A;
- *NC* represents the number of citations of the article, normalised by coefficient K_{NC}.

As aforementioned, in order to compare variables in different scales, we have used K_{JIF}, K_A, and K_{NC} coefficients to normalise data. We also used weights to depict the importance level of each variable of the classification index, represented by W_{JIF}, W_A and W_{NC}, respectively: 0.25, 0.25, and 0.5. The weight values were established during meetings between the

authors and tests carried out within the article portfolio. An example of the use of Eq. 1 for the article entitled "Eco-innovation and new product development: understanding the influences on market performance" authored by Pujari (2006) is provided: JIF = 2.243, A = 12, NC = 326, K_{JIF} = 2.017, K_A = 0.417, K_{NC} = 0.0175, W_{JIF} = 0.25, W_A = 0.25, and W_{NC} = 0.5, thus the final ACI = 3.19.

Eq. (1) was applied to the bibliographical portfolio containing 266 articles with the objective to prioritise papers and to select the most relevant manuscripts published up to 2014, since the articles published after this year were automatically taken to the next step because we believe that these recent articles had no time to be broadly cited. Besides that, this decision was made because the more recent the paper, the more likely it is that new developments have been attained, and the higher the probability of the research to contribute to some innovation in the knowledge area (Pagani et al., 2015). Thus, as the selection process of papers was performed in January 2018, the authors decided to include automatically articles from 2015, 2016 and 2017. This decision was also based on previous research, as in Lacerda et al. (2012), who indicates to gather directly articles published two years before or less from the date of the research. To avoid missing any important previous research, the authors decided to expand this time gap to 3 years.

Articles that presented a positive ACI were kept in the bibliographic portfolio, taking into account the three criteria discussed in Eq. (1). Finally, the last filter applied to the article portfolio aimed at converging articles that cite at least one of the LPD or GPD practices.

Thus, the full texts were accessed and the term "practice" and its synonyms were searched. The final bibliographic portfolio was then selected for full text reading and content analysis. Fig. 2 summarizes the procedure employed for selecting and filtering the articles. After reading 47 articles in full, 38 articles were selected to compose the final bibliographic portfolio.

3. Results and discussions

3.1. Descriptive analysis

Descriptive analysis consists of quantitatively measuring the article portfolio. In order to identify the research evolution on the studied field, a timeline was built. The 38 selected articles were distributed according to their publication year. Articles were arranged into two groups: lean and green. Fig. 3 shows a growing trend of publications in recent years in both fields of study. However, it is worth noting that the method used to select papers have prioritised articles from 2015 and beyond. Nevertheless, an increasing trend may be perceived until 2014. "All publications" represented by the red bar in Fig. 3 does not denote the sum of lean and green publications because articles that dealt with both lean and green paradigms were counted in both categories, that is, twice.

The second analysis aims to find out the recurrent journals in the article portfolio. 21 journals were identified, and the most frequent ones were Journal of Cleaner Production with 13 papers and EMJ - Engineering Management Journal with 3 articles. It is also worth noting that 42% of the journals included in the article portfolio presented only one publication.

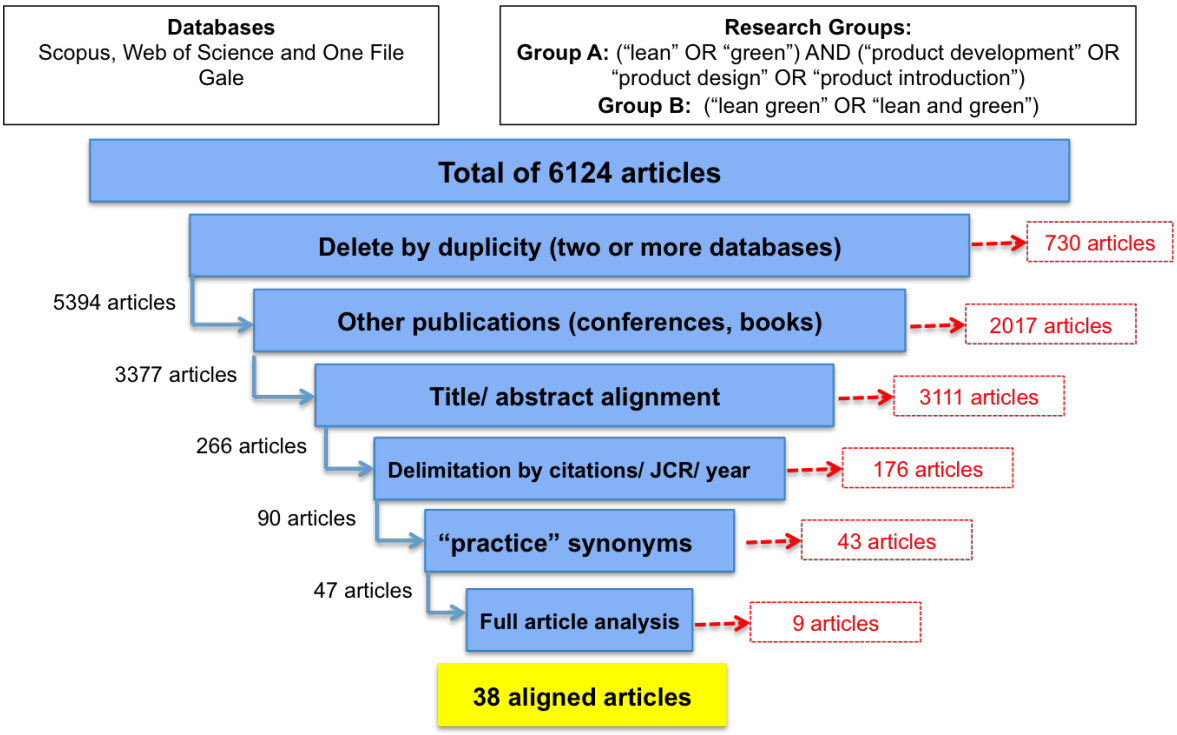

Fig. 2. Article portfolio selection and filtering process

3.1. Analysis

This topic aims at consolidating the body of knowledge uncovered by this literature review. To accomplish that, this section is organised in order to uncover definitions and practices and answer RQ1 (drivers and barriers).

3.2. Content analysis

3.2.1. Concept definition

The Toyota Motor Company introduced the lean product development (LPD) concept in the early 1990s (Womack et al., 1990). There is no consensus on how to define Lean Product Development (Hoppmann et al., 2011). As highlighted by Johansson and Sundin (2014), LPD literature has evolved in the sense of identifying the elements that consolidate the philosophy through frameworks rather than finding a clear definition for the LPD concept. This fact indicates that there is still room for research linking lean thinking to product development, unlike its application in manufacturing, where studies are already in an advanced state (Schulze and Störmer, 2012).

The resulted sample of the SLR retrieved a certain number of papers, from which the authors proposed a LPD definition. Lean product development, also referred to as Lean Product Introduction (LPI) (Haque and James-Moore, 2004), can be viewed as a methodology aimed at applying the five principles of lean thinking (value, value flow, continuous flow, pull production, and perfection) to process and product development (Haque and James-Moore, 2004; León and Farris, 2011). LPD is value-focused PD (Khan et al., 2013). Value is a broad term used to define stakeholder needs and desires (Khan et al., 2013). LPD can be used (but not limited to) to maximize value and eliminate waste in PD (Galeazzo et al., 2014; León and Farris, 2011; Letens et al., 2011; Siyam et al., 2015).

The concept which relates PD to environmental benefits has several designations, such as environmentally conscious design, ecodesign, design for environment (DFE), sustainable product development, and green product development (GPD) (Johansson and Sundin, 2014). The last terminology was chosen to designate this concept throughout this article. As in the LPD literature, there is no clear and widely accepted definition for the GPD paradigm. In fact, many tools are proposed to support environmental product development teams, but little is used in practice. It is still an incipient area of research with limited impact on industry (Baumann et al., 2002; Deutz et al., 2013).

Even considering the importance of the topic, the literature regarding GPD or associated terms is still in a developing phase and not structured (Jasti et al., 2015). GPD is generally viewed as a philosophy that seeks to reduces the impact of the product's life cycle industrial growth on the environment (Baumann et al., 2002; De Medeiros et al., 2014; Jabbour et al., 2015; Jasti et al., 2015; Pigosso et al., 2013; Pujari et al., 2003), without compromising performance and cost (Gmelin and Seuring, 2014; Johansson and Sundin, 2014; Pigosso et al., 2013; Pigosso et al., 2016). It focuses on practices friendly to the environment (e.g. reducing resource consumption/ waste generation) (Dangelico and Pujari, 2010; Jabbour et al., 2015).

At last, concerning the topic Lean and Green, Garza-Reyes (2015a) presented the term Green Lean "as an effective tool to improve processes and reduce costs, by not only reducing non-value-added activities but also physical waste created by system".

3.2.2 Practices

Practices are central elements for the consolidation of both the lean and the green paradigm. According to PMI (2008), practice is a specific type of professional or managerial activity that contributes to the execution of a process and which employs one or more techniques and tools.

Table 2 lists the main lean practices identified in the article portfolio. Practices were classified based on Morgan and Liker (2006), who used the following dimensions: people, processes, and tools and technology. Table 3 lists the main green practices using the classification described by Pigosso et al. (2013), which separates practices into managerial and operational groups.

From the LPD practices side, the retrieved papers present practices from different perspectives. Hoppmann et al. (2011) argue that the literature on the topic focuses on specific categories and this fact has resulted in a high fragmentation of the field. The authors use the word "components," and their list of components are covered in our LPD practices list. The difference between the elements from their study and ours essentially lies in the fact that elements from the aforementioned study are organized towards a more operational perspective. For instance, some of the components listed by Hoppmann et al. (2011), such as "Set-based Engineering" and "Rapid Prototyping, Simulation and Testing," are included in our list of practices in LPD 09 - Tools and technology selection and integration. León and Farris (2011) present a list of LPD practices, but the tools and technology perspective is not considered. Siyam et al. (2015) and Tortorella et al. (2016) have concentrated their lists in the knowledge aspects concerning LPD practices. Letens et al. (2011) exhibit two perspectives ('People' and 'Tools and Technology'), although in the first one, just one aspect is considered.

Another research on the LPD topic, from Khan et al. (2013), names these LPD practices as "enablers" or "building blocks," and, similarly, their enablers are concordant with our list. While Mund et al. (2015) cover all the perspectives, these authors do not contemplate every practice presented here. In this sense, Table 2 represents an overview of the different lean practices presented in the literature review in a structured way.

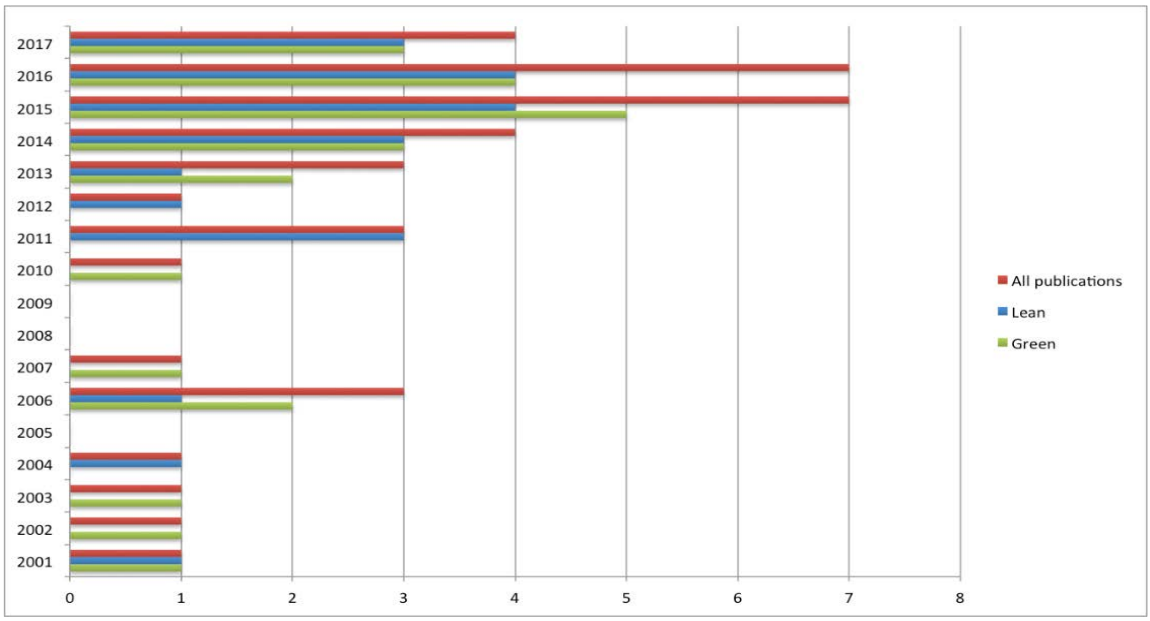

Fig. 3. Publications timeline

Table 2. Lean practices in product development

Category	***Code***	***Practice***	***Description***	***Sources***
People	LPD-01	Company Culture	Establish a company culture focused on product development and, meeting the stakeholders' expectations.	(Caldera et al., 2017; Khan et al., 2013; León and Farris, 2011; Schulze and Störmer, 2012)
	LPD-02	Technical Competencies	Programme manager translates value into measurable product attributes and performance specifications.	(Hoppmann et al., 2011; Khan et al., 2013; León and Farris, 2011; Mund et al., 2015)
	LPD-03	Learning and Training	Structured methodology for selection, mentoring and development of new engineers.	(Khan et al., 2013; Mund et al., 2015; Schulze and Störmer, 2012; Siyam et al., 2015)
	LPD-04	Cross-functional Teams	Cross-functional teams ensure the cooperation and intensive communication.	(Khan et al., 2013; León and Farris, 2011; Letens et al., 2011)
Process	LPD-05	Customer value definition	Customer requirements should be assessed in the early stages of the PD process.	(Khan et al., 2013; León and Farris, 2011; Mund et al., 2015)
	LPD-06	Standardization	Standardization as the basis for continuous improvement and innovation.	(Hoppmann et al., 2011; Khan et al., 2013; Siyam et al., 2015)
	LPD-07	Knowledge Management	Promote cross-project knowledge transfer to foster a more robust decision-making process and reduce development time.	(Hoppmann et al., 2011; Khan et al., 2013; León and Farris, 2011; Tortorella et al., 2016)
	LPD-08	Supplier Integration	Close and cooperative relationship with suppliers involving them in the early stages of PD process.	(Hoppmann et al., 2011; León and Farris, 2011)
Tools and Technology	LPD-09	Tools and technology selection and integration	Tools such as use of product platforms, modular design, value stream mapping, simultaneous engineering, visual control, rapid prototyping, simulation and testing.	(Khan et al., 2013; Letens et al., 2011; Mund et al., 2015)

Table 3. Green practices in product development

Category	*Code*	*Practice*	*Description*	*Sources*
Managerial	GPD-01	Strategic Management	Integrate environmental issues during the decision-making process.	(Jasti et al., 2015; Pigosso et al., 2013)
	GPD–02	Regulations and Laws	Formulate and monitor mandatory rules to comply with regulations and laws.	(Jasti et al., 2015; Pigosso et al., 2013)
	GPD–03	Learning and Training	Green-oriented learning for employees involved in the PD process.	(Jasti et al., 2015; Pigosso et al., 2013)
	GPD–04	Reverse Logistics	Define the reverse logistics strategy to be addressed according to the end-of-life phase of the product.	(Hartmann and Germain, 2015; Jasti et al., 2015; Pigosso et al., 2013; Ruiz-Benitez et al., 2017)
	GPD–05	Multidisciplinarity	Promote cross-functional integration processes.	(Dangelico, 2016; Hartmann and Germain, 2015; Pujari et al., 2003)
	GPD-06	Product and process planning and control	Include the environmental goals into the product target specifications.	(Jasti et al., 2015; Pigosso et al., 2013)
	GPD-07	Green Supply Chain Management	Involve the total value chain to improve the environmental performance of products.	(Dangelico, 2016; De Medeiros et al., 2014; Deutz et al., 2013)
	GPD-08	Customer Integration	Company should provide information on the environmental performance of the products and make recommendations for use and end-of-life phases.	(Deutz et al., 2013)
	GPD-09	ISO 14000 series	ISO 14000 series is a set of norms directed to the Environmental Management of companies.	(Campos and Vazquez-Brust, 2016; Jabbour et al., 2015; King and Lenox, 2001; Miroshnychenko et al., 2017)
Operational	GPD–10	Minimise energy and material consumption	During pre-production, production, transportation and storage.	(Jasti et al., 2015; Pigosso et al., 2013; D. C. A. Pigosso et al., 2016)
	GPD–11	Low environmental impact resources and processes	Select non-toxic and harmless energy resources and materials	(Jasti et al., 2015; Pigosso et al., 2013)
	GPD–12	Product lifetime optimization	Increase product durability and facilitate reuse, remanufacturing, and repairs.	(Jasti et al., 2015; Pigosso et al., 2013; D. C. A. Pigosso et al., 2016)
	GPD–13	Extending the lifespan of materials	Select materials with efficient recycling technologies. Minimise incompatible materials and facilitate end-of-life processes.	(Jasti et al., 2015; Pigosso et al., 2013; Pigosso et al., 2016)

By contrast, Table 3 depicts the GPD practices.

A final list of 13 practices is proposed, nine of them from the managerial perspective and the remaining four elements from the operational perspective. This classification complies with Pigosso et al. (2013), since the authors proposed an ecodesign maturity model classifying practices into two main groups: operational and managerial. Jasti et al. (2015) have presented a comprehensive framework with 11 pillars and 80 elements. Interestingly, their list of pillars includes what we have classified as practices and also classifies drivers for achieving GPD, as can be seen in the following section of this work. Although Pigosso et al. (2013) and Jasti et al. (2015) contemplate most of the GPD practices, integration between departments, supply chain members, and customers is neglected by the authors. We believe that practices concerning integration are important to the success of the GPD. Dangelico (2016) presented the importance of these practices and considered both internal and external integration. Deutz et al. (2013) focused on external integration, and Hartmann and Germain (2015) and Pujari et al. (2003) highlighted internal integration. Concerning the operational categorization, notice that only two papers of the sample present practices for GPD; instead, most of papers concentrate on the managerial perspective.

3.2.3. Drivers

The main motivation underscoring LPD is a search for competitiveness in the market, since the process of PD is considered a primary issue for

companies to remain competitive (Johansson and Sundin, 2014). Moreover, the application of the lean concept to the PD has the potential to reduce both cycle times and time to market (Johansson and Sundin, 2014; Letens et al., 2011).

Value-building in LPD is dependent on both end customers and on internal and external stakeholders and, in fact, there is a flow of useful information within the PD process to generate knowledge for the organisation (Haque and James-Moore, 2004; Johansson and Sundin, 2014; Schulze and Störmer, 2012; Siyam et al., 2015). Siyam et al. (2015) still show that the creation of knowledge in PD differs from manufacturing, from where lean thinking originates. The authors emphasise the lack of distinction between the identification of value and waste. Certain activities necessary for the process of PD may be considered waste since they do not add value to the final consumer, but they are required for the PD. In this sense, Schulze and Störmer (2012) point out "seek for waste elimination" as an important driver. The same authors bring a definition of waste for PD in order to contribute to the waste identification in the PD. Table 4 presents the compilation of LPD drivers retrieved from literature.

As seen in Table 4, LPD drives are related to value creation (Haque and James-Moore, 2004; Schulze and Störmer, 2012; Siyam et al., 2015), waste elimination (Johansson and Sundin, 2014; Letens et al., 2011; Schulze and Störmer, 2012) and time reduction (Letens et al., 2011). Although the literature presents the value creation connected to information creation (Johansson and Sundin, 2014; Schulze and Störmer, 2012), there is not a consensus about which activities and areas are responsible to value generation (Schulze and Störmer, 2012).

Table 4. Main LPD drivers

Driver	***Description***	***Internal/ External***	***Sources***
Competitiveness	LPD paradigm is a way to remain competitive.	External	(Johansson and Sundin, 2014)
Value generation	Companies adopted LPD to create knowledge and useful information to generate value for customer and stakeholders.	Internal	(Haque and James-Moore, 2004; Johansson and Sundin, 2014; Letens et al., 2011; Siyam et al., 2015)
Waste elimination	Companies seek to eliminate non-value-adding activities to reduce cost.	Internal	(Garza-Reyes, 2015a; Johansson and Sundin, 2014; Letens et al., 2011; Schulze and Störmer, 2012)
Cycle time reduction	The search for cycle time reduction may motivate the company to implement the LPD.	Internal	(Johansson and Sundin, 2014)
Time-to-market reduction	Time-to-market reduction can motivate the company to implement the LPD.	Internal	(Johansson and Sundin, 2014; Letens et al., 2011)

Table 5. Main GPD drivers

Driver	***Description***	***Internal/ External***	***Sources***
Competitive advantage	GPD implementation can lead to market expansion and competitive advantages (greater market share, higher profits, improved reputation).	External	(Baumann et al., 2002; Dangelico and Pujari, 2010; Dangelico, 2016; Johansson and Sundin, 2014)
Sustainability	With the increase on sustainability discussions, GPD has been adopted as a way to improve corporate image.	Internal	(Dangelico and Pujari, 2010; Dangelico, 2016)
Innovation	GPD adoption can drive innovation, since it extensive research and development.	Internal	(Dangelico and Pujari, 2010; Dangelico, 2016)
Top management commitment	Senior-level managerial commitment in supporting the company's environmental preservation and deployment of environmental practices.	Internal	(Casper Boks, 2006; Dangelico, 2016; Katsikeas et al., 2016)
Organisational policies	The existence of guidelines that address the green question is a success factor for GPD adoption.	Internal	(Baumann et al., 2002; Casper Boks, 2006; Dangelico and Pujari, 2010; Dangelico, 2016; Katsikeas et al., 2016)
Market demand and market stakeholder pressures	Companies face pressures from society and stakeholders towards adopting green initiatives.	External	(Dangelico, 2016)
Legislation and Regulations	Many countries are adopting legislations or guidelines that favor GPD implementation.	External	(Baumann et al., 2002; Casper Boks, 2006; Dangelico and Pujari, 2010; Dangelico, 2016; De Medeiros et al., 2014; Johansson and Sundin, 2014)

These drivers come from an operational perspective, since they concentrate on improvements in internal company processes. For the green perspective, the search for competitive advantage, as well as in the LPD paradigm, is also an important driver for the development of green products (Abdulrahman et al., 2014; Baumann et al., 2002; Dangelico and Pujari, 2010; Dangelico, 2016; Johansson and Sundin, 2014; Temea et al., 2016). Problems related to the environment and those associated with the implementation of GPD have increased in the last decades. In the same way, organisations search to maximise their profits and to gain competitive advantage through product differentiation and low production prices (Baumann et al., 2002). In a literature review conducted by Dangelico and Pujari (2010), GPD-related drivers were classified as internal or external to the organisation. According to the authors, six main internal drivers are identified in the literature. These drivers include obtaining competitive advantage, reducing costs, seeking greater market benefits (for example, increasing market share), improving corporate image, garnering opportunities to create innovations and, finally, implementing the existence of organisational policies that address the green issue in PD. Additionally, the commitment of top management and corporate policies in support of green paradigms are important factors (Dangelico, 2016; Katsikeas et al., 2016). Dangelico (2016) highlights as external drivers to the organisation: environmental policies, market demand, stakeholder pressure, and even media exposure of environmental impacts from the organisation. Thus, an important driver mentioned in the GPD literature is "compliance with policies and regulations" (Baumann et al., 2002; Casper Boks, 2006; Dangelico and Pujari, 2010; Dangelico, 2016; Johansson and Sundin, 2014). These drivers and others are compiled in Table 5.

Table 5 presents the main drivers for GPD. They appear from both tactical and strategic perspectives (e.g. Dangelico and Pujari, 2010; Dangelico, 2016) and, in this sense, the top management commitment (Dangelico, 2016; Katsikeas et al., 2016) and the existence of organisational policies (Baumann et al., 2002; Dangelico and Pujari, 2010; Dangelico, 2016; Katsikeas et al., 2016) are internal essential drivers. External drivers for GPD are represented by pressures from legislation and regulations (Baumann et al., 2002; Dangelico and Pujari, 2010; Dangelico, 2016; Johansson and Sundin, 2014), from market or stakeholders (Dangelico and Pujari, 2010; Dangelico, 2016; Katsikeas et al., 2016). It is noteworthy that competitive advantage is a driver for both LPD and GPD, although few papers, such as Johansson and Sundin (2014) articulate this perspective for LPD. Both GPD and LPD implementation can create commercial benefits coming from cost reductions and/or higher product quality, thus improving the competitiveness of the company (Johansson and Sundin, 2014).

3.2.4 Barriers

Several strategies for implementing LPD concept have been discussed in the literature, but organisations still face the challenge of choosing the most promising one, because depending on the PD structuring, different ways of implementing lean paradigm may work for different organisations (Dombrowski et al., 2014). Dombrowski et al. (2014) analysed LPD implementation models described in the literature and stated that the most recommended form of implementation starts with a pilot department.

Al-Ashaab et al. (2016) proposed a model to identify the status of the organisation related to the level of implementation of the lean principles, that is, to access the maturity of the companies in relation to the LPD model. The authors present a model that consists of the following key factors: value, knowledge, continuous improvement, chief engineer, and simultaneous engineering, which is considered the most important factor (Al-Ashaab and Sobek, 2013; Khan et al., 2013). Al-Ashaab et al. (2016) conclude that certain elements should be customized depending on the organisation, which leads us to believe that there is no model defined in the literature for LPD implementation, but rather tools and practices that can be used depending on the maturity level of the company's PD process. On the other hand, Dal Forno et al. (2016) propose a method based on a PD process benchmarking to identify the barriers and opportunities of a company's growth. The authors identify common problems during the PD and aim to reduce these through a model called "BenchPDP_Lean."

Regardless of the way in which organisations carry out the LPD paradigm implementation process, managerial problems may arise, such as: (i) waiting for actions pertinent to other people, (ii) excessive information, (iii) excessive processing of information, (iv) miscommunication of information, (v) accumulation of information, (vi) design of incorrect information, (vii) correction of information, and (viii) unnecessary movement of persons (Tortorella et al., 2016).

Although the implementation factors related to the LPD model have been addressed in the literature, there is much research to be done. Few examples of practical applications of the LPD model can be found, and this gap implies an initial literature regarding the factors that positively or negatively affect its implementation. For a model to succeed, organisations must undergo an extensive cultural change (Baines et al., 2006; Hoppmann et al., 2011). Besides that, the lack of formal management practices that assist the leadership and the non-inclusion of IT tools is another important issue related to the LPD process (Tortorella et al., 2016). Table 6 presents the main barriers to implement the lean paradigm in the PD.

The main barriers for LPD are related to its implementation process addressed by authors from different perspectives. In this work, the barriers were classified into four types, categorised as internal problems. The first barrier in Table 6 refers to the difficulty in the proper selection of a framework to implement LPD, as presented by (Hoppmann et al., 2011). The company maturity level influences the success of the implementation, since tools and practices need customisation to attend the company context and environment (Al-Ashaab and Sobek, 2013; Khan et al., 2013). Leadership and IT integration tools and information exchange are essential issues to the LPD implementation process and, hence, they must be considered (Tortorella et al., 2016). It is noteworthy that all the barriers must be understood and addressed before the implementation process starts.

Moving to GPD barriers, its implementation process has been widely discussed in previous literature (e.g. Caster Boks and Stevels, 2007; Dangelico, 2016; Jasti et al., 2015; Pigosso et al., 2013). However, there are few empirical results from the use of these tools that effectively contribute to GPD implementation. Successful modelling requires the involvement of organisations at a strategic level and integration at the corporate and product development levels (Baumann et al., 2002). In addition, for GPD implementation to succeed, multidisciplinary in team design, top management support, and supplier involvement in the PD are essential, as materials or components from suppliers will directly influence various product attributes, such as quality, design, cost or lead time (Hartmann and Germain, 2015; Pujari, 2006).

Among the challenges faced by organisations to implement GPD, the difficult integration between environmentally friendly and conventional attributes in products stands out, that is, firms struggle to develop products aiming at good quality and, at the same time, environmental attributes (Dangelico and Pujari, 2010).. Table 7 brings the main GPD barriers.

Table 6. Main LPD drivers

Barriers	***Description***	***Internal/ External***	***Sources***
Framework choice and statement point	Organisations face difficulty in choosing an LPD design that addresses their needs.	Internal	(Dombrowski et al., 2014; Hoppmann et al., 2011)
Maturity levels	Depending on the organisation's PD process maturity level, different LPD tools and practices can be implemented.	Internal	(Al-Ashaab and Sobek, 2013; Khan et al., 2013)
Management process and leadership issues	Organisations face difficulty during the implementation process, such as project leadership.	Internal	(Cherrafi et al., 2017; León and Farris, 2011; Tortorella et al., 2016)
Integration and communication	Problems in communication among areas and personnel, including issues with IT integration	Internal	(Letens et al., 2011; Tortorella et al., 2016)

Table 7. Main GPD barriers

Barriers	***Description***	***Internal/ External***	***Sources***
Excess of tools	There is an excess of theoretical models and tools with little empirical application.	Internal/External	(Baumann et al., 2002; Casper Boks, 2006; Caster Boks and Stevels, 2007)
Lack of involvement of strategic level	Implementing GPD often face lack of involvement of top management, and a lack of integration at the corporate and PD level.	Internal	(Cherrafi et al., 2017; Hartmann and Germain, 2015; Pujari, 2006)
Organisational complexities	Lack of appropriate infrastructure.	Internal	(Casper Boks, 2006; Caldera et al., 2017)
Cooperation	Lack of cooperation between departments.	Internal	(Casper Boks, 2006; Cherrafi et al., 2017)
Lack of industrial context in general	There is no connection between business and environmental considerations.	External	(Casper Boks, 2006; Garza-Reyes, 2015a)
Quality and environmental attributes trade-off	There is a challenge to create green products and quality at the same time at a competitive price.	Internal	(Dangelico and Pujari, 2010)
Customer awareness	Companies' investments in green products are conditioned by the customers' awareness which is still a challenge.	External	(Casper Boks, 2006; Dangelico and Pujari, 2010)
Competitive price	Firms may find difficulty to sell products with green attributes at a competitive price.	Internal/External	(Dangelico and Pujari, 2010)

Another challenge resides on the design of a green product that can be sold at a competitive price and valued by the consumer. This is because there is still a lack of consumer awareness about the benefits of green products, especially in developing countries (Dangelico, 2016). Companies may overcome these issues by popularizing environmental labels and third-party certifications, which increase the credibility of green products (Dangelico and Pujari, 2010)Barriers concerning GPD implementation process found in the literature are related to internal and external difficulties. The internal barriers highlight managerial and operational aspects. From the managerial aspect, it is possible to emphasise the need for strategic level involvement (Casper Boks, 2006; Hartmann and Germain, 2015; Pujari, 2006), cooperation between departments (Casper Boks, 2006) and the existence of an appropriate infrastructure to implement GPD (Casper Boks, 2006). Concerning operational aspects, there is a lack of empirical applications of GPD that could bring more practical information on the trade-off between environmental attributes and quality level, as well as to methods to produce green products at a competitive price (Dangelico and Pujari, 2010). The external barriers are associated with green product acceptance, since this should be a market demand (Dangelico and Pujari, 2010) and it must go beyond regulatory compliance. Another important barrier is associated with the disconnection between the company strategy and the environmental needs (Casper Boks, 2006). The greatest challenge for companies in this scenario is how to introduce green products with, occasionally, higher prices and, at the same time, to keep or to promote the product's acceptance level in the market (Dangelico and Pujari, 2010).

4. Conceptual Framework and Propositions

Based on the descriptive and content analysis, it is noteworthy that the theoretical and empirical studies that contemplate lean and green paradigms from a PD point of view are in the process of growing and acquiring relevance within the academic community and organisations. Through the descriptive analysis, it is possible to observe that publications in the area are progressively growing, indicating an increase in the importance of the topic. In order to respond to RQ2, this section presents the proposed conceptual framework, synergistic propositions emerged from the framework, and further discussions.

4.1. Conceptual LGPD Framework

From the analysis of the information extracted from the Tables 2 to 7, a lean green product development (LGPD) conceptual framework (Fig. 4) is outlined that shows the key terms within each of the categories aforementioned. The conceptual framework from Fig. 4 congregates and organises the information produced by this systematic literature review process, responding to RQ2.

Because research combining LPD and GPD is still in its infancy, this framework aims at grouping the findings and uncovering the interrelationships between its elements in order to serve as a foundation for future work on the subject and related topics. The synergic propositions (SP) displayed in Fig. 4 by dotted arrows are discussed in the following sequence.

4.2. Synergic propositions for future investigation

Johansson and Sundin (2014) argue that LPD and GPD are not exactly two sides of the same coin. However, both paradigms share a number of similarities that point toward a synergistic relationship. Considering this, the following propositions regarding LGPD synergy are suggested and discussed in relation to previous literature on the topic, as promised in the introduction of this manuscript.

(1) SP1: LPD–03 Learning and Training and GPD–03 Learning and Training

The suggestion of a relationship between LPD-03 and GPD-03 practices is noteworthy because the creation of a learning culture can be synergistic and bring benefits to organisations that promote it and thus favor the consolidation of both paradigms. Johansson and Sundin (2014), who state that learning and training are positively associated with implementation of both the LPD and GPD, already proposed this synergy. In a broader domain, Campos and Vazquez-Brust (2016) also conclude that employees' capacitation is a synergistic pathway for Lean Green development in the Supply Chain domain.

(2) SP2: LPD–04 Multidisciplinarity and GPD–05 Cross-functional teams

LPD-04 and GPD-05 practices refer to multidisciplinarity within the PD teams and in the different areas of an organisation. The focus on cross-functional teams can effectively contribute to the consolidation of both paradigms. In a broader approach, a similar result was proposed by Martínez-Jurado and Moyano-Fuentes (2014), who state that the advanced human resource management practices from lean manufacturing (e.g., versatile workers, teamwork, etc.) can facilitate the adoption of better environmental practices.

(3) SP3: GPD–04 Reverse Logistics and LPD–05 Custumer value definition

The GPD-04 practice can positively influence LPD-05 practice, since end-of-life product information contributes to product improvement and, thus, greater end-customer satisfaction. According to that, Campos and Vazquez-Brust (2016) posit that "reverse logistics is one of the green operational supply chain practices with more potential for synergies with lean" in the SCM domain.

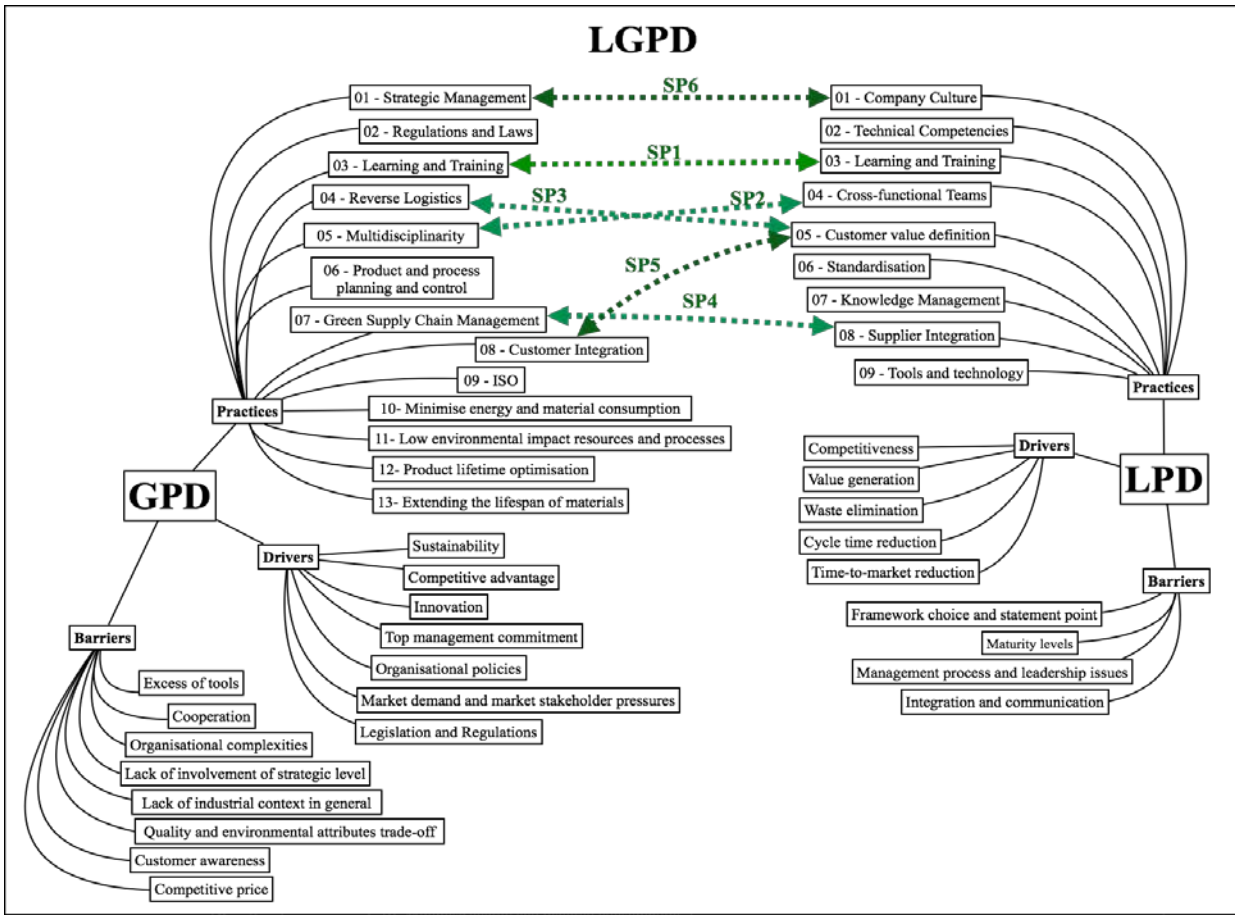

Fig. 4. LGPD conceptual framework

(4) SP4: LPD–08 Supplier integration and GPD–07 Green supply chain management

Practices LPD-08 and GPD-07 may be interrelated. The lean paradigm has the premise of maintaining a close relationship with suppliers to add value to an organisation's processes. This proposition is already commented as synergic by other authors (Campos and Vazquez-Brust, 2016; Dües et al., 2013) in the SCM domain. The authors posit that close collaboration with supply chain members is a synergic lean and green practice. In addition, Inman and Green (2018) suggest that managers struggling to improve both the economic and environmental sustainability of their firms should follow the implementation of lean supply chain practices with the implementation of green supply chain practices.

(5) SP5: GPD–08 Customer integration and LPD–05 Customer value definition

Although the key goal of LPD is to create value for customers by eliminating waste and the overall goal of GPD is to ensure the creation of products that have minimal impacts on the natural environment (Johansson and Sundin, 2014), we suggest that practice GPD – 08 and practice LPD – 05 are synergic. Knowing the real customer needs may serve as an input for developing products that add more value to end consumers. On the other hand, this integration may facilitate improved communication and negotiation on green improvements in product design, use of materials, etc. Supporting this proposition, Campos and Vazquez-Brust (2016) assert that communication with customers is the central issue leading to synergies between lean and green paradigms.

(6) SP6: LPD–01 Company culture and GPD–01 Strategic management

Finally, LPD - 01 and GPD - 01 may also show an interrelationship, since the management model of a company can impact the organisational culture, as well as the other way around. Johansson and Sundin (2014) have already discussed this issue when they state that the adoption of a holistic perspective that includes the process-people-tools dimensions is positively associated with successful implementation of both LPD and GPD. Inman and Green (2018) also reinforce this statement, by arguing that lean and green practices require strategic focus and culture modification.

4.3. Theoretical and managerial contributions

The overall theoretical contribution of this research is the development of a solid conceptual framework on LGPD, which outlines synergistic propositions between lean and green practices in PD. This paper answered two research questions by

consolidating information on concepts, practices, drivers, and barriers for both paradigms. For the paper portfolio filtering process, we have proposed an article classification index, which includes indicators such as number of citations, journal impact factor, and paper age. At last, the synergistic propositions uncovered by this work intend to pave the way towards a more solid and cooperative combination of lean and green paradigms for PD.

From the managerial perspective, manufacturing managers seeking to improve economic and environmental aspects should focus on synergistic lean-green practices revealed by this manuscript, as follows:

- Managers can obtain benefits, for instance, on lean and green paradigms by creating a learning culture in the organisation, as well as by investing in cross-functional teams.
- Managers can also expect progress in a better understanding of customer value when employing reverse logistics activities.
- The closer integration with suppliers and clients encouraged by both paradigms may favour the elimination of waste from the points of view of both lean and green.
- Managers can also benefit from an integrated perspective that includes the process-people-tools dimensions, which is positively associated with successful implementation of both paradigms.

Moreover, in general terms, this study holds, as a practical implication, a conceptual framework, which can be used by managers as a starting point to map practices, drivers, barriers and possible synergies between GPD and LPD in their specific industry context, in order to facilitate the deployment of strategies to enhance both environmental and financial outcomes.

5. Conclusions

Lean and green concepts are well established both in academia and industry, but there is little research to evaluate these paradigms together, especially in the PD area. Thus, there is a research gap on the relationship between LPD and GPD, which is surprising since PD is considered a key factor for business success. In this context, this work contributes to a better understanding of LPD and GPD paradigms, as well as their possible interconnections, by means of a comprehensive literature review.

While the research questions were completely addressed, some limitations did emerge and, hence, provide opportunities for future research. Firstly, the synergistic connections between LPD and GPD proposed by our research do not intend to be an exhaustive list, and therefore, we recommend conducting theoretical and empirical research to confirm these SP, as well as suggesting new ones. Thus, an important suggestion for future studies in this topical area is to measure empirically the synergistic relationship between lean and green paradigms in product development field. Beyond that, future works may explore the divergences between LPD and GPD practices and present options on how to overcome these issues.

Concerning barriers and drivers, it would be of great value to study the interrelationship of these elements for both paradigms. The application of multi-criteria decision-making tools to evaluate the causal and effect factors in the barriers system, for instance, is a recommended path of research.

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