RESEARCH PAPER

Lean Green Tendency: A Systematic Literature Review

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ABSTRACT

Lean philosophy and Green practices have been identified as management approaches that allow organizations to reach better economic and environmental results. Nevertheless, some authors argue that results can be enhanced with the integration of the Lean and Green practices. This synchronous effort has led to the developing a new Lean philosophy branch, the Lean Green.

Goal: This work aims to deepen the Lean Green state of the art, as well as to understand how companies have adopted it.

Design / Methodology / Approach: The methodology was supported by a systematic literature review following three steps: Planning, data collection, data analysis throughout content analysis.

Results: The results showed that Lean Green is still an emerging theme in scientific research, with an increasing trend of publications worldwide in the last six years, adopting distinctive research strategies. Companies' main motivations and barriers to adopting Lean Green were also identified. Finally, were identified the key factors that could help organizations to adopt Lean Green, namely critical implementation factors, facilitator models and tools, and the main results and advantages obtained.

Limitations of the investigation: The main work´s limitation is that it was considered only the Scopus database.

Practical implications: Help companies find solutions that enhance their performance and competitiveness, reduce their environmental impact, and improve their social responsibility.

Originality/Value: The originality of this work is defended by crossing the results at the academic and practical levels. This allows the usefulness of academic research results by bringing them into a practical organizational context.

Keywords: Lean; Lean Green; Systematic Literature Review.

INTRODUCTION

Nowadays, environmental concerns and the importance of sustainability are becoming increasingly relevant and the target of the whole society's attention. Since then, it has become a key societal issue, deserving much attention from academics, government entities, and organizations (Ershadiv et al., 2021). Furthermore, as a response to climate change and the challenges inherent to it, companies are committed to finding solutions to combat these environmental concerns through business management, interactions with stakeholders, thus

enhancing the development of green practices and their social responsibility (Candrianto et al. , 2023).

The Lean Philosophy arises from the need for change and the desire to improve the entire process of an organization, based on the "Toyota Production System" (Ohno, 1988). which aims to provide better product quality to the customer, at the lowest cost and in the shortest time delivery, by reducing waste. Subsequently, with the publication of the revolutionary book "The Machine That Changed the World", the term Lean Methodology spread as a management way to achieve continuous improvement and optimization of production processes (Womack and Jones, 2003).

Also, Green and Sustainable Goals are increasingly part of the work agendas of manufacturing companies, having developed different types of efforts (Cherrafi *et al.*, 2018). Therefore, adopting Lean and Green practices could boost sustainable organizational performance (Kovilage, 2021)). However, several authors argue that implementing Lean and Green methodologies should follow an integrated and synchronous methodology. In this way, organizations can achieve a greater competitive advantage than when Lean and Green are implemented separately (Mittal *et al.*, 2017). As a result of this integration, an emerging branch of Lean philosophy appears called Lean Green (LG). As explained in Figure 1, this integration has the main objective to improve processes at the operational level, reducing costs not only by reducing and limiting non-value-added (NVA) activities but also physical waste derived from the system, which consequently ends up reducing the organization's ecological footprint (Cherrafi *et al.*, 2018; Kovilage, 2021).

Figure 1 - Problem Statement
Source: The authors themselves.

To summarize, the main motivations for carrying out this research are relating to:

- customers begin to demand green products and services, made with processes that don't harm the environment, manufacturing companies must adapt their operations to meet these new customer requirements (Green et al., 2015).

- Increasing customer sophistication, environmental concerns and global competition are driving the industry towards new manufacturing strategies in 21 st century;

- Besides eliminating wasteful or non-value-added activities, companies look for management models that improve the environmental aspect and ecological consciousness on systems;

- Furthermore, some research suggest that lean companies integrating green practices simultaneously, achieve better results, justifying that lean practices can lead to positive environmental contributions, also environmental practices often lead to improved lean practices (Bergmiller et al., 2009).

However, implementing these integrated strategies is complex, and some barriers must be overcome for these practices to be successfully implemented (Singh *et al.*, 2013). In addition, most organizations have neglected this symbiosis, and these approaches have been implemented separately by the different sections or departments. As a result, the efforts and costs associated with the individual implementation of each approach increase, meaning that companies can jeopardize their competitiveness and environmental performance. While separate research streams on best practice efforts on lean and green, the overlap between these principles has received little attention (Wiese *et al.*, 2015). Thus, the main work´s aim is to contribute to deepen the LG knowledge at two distinct levels:

Aim 1 - academic research: to characterize the state of the art of LG in the scientific research field, namely, to identify trends, types of publications, and the most prevalent research methodologies and strategies;

Aim 2 - Practical perspective: To deepen the knowledge about LG from a company's implementation perspective, such as understanding the motivations for its adoption, identifying the tools implemented, critical success factors, barriers to its implementation, results, and advantages achieved.

To this end, a mixed research methodology was followed, with quantitative and qualitative data analysis supported by the development of a systematic literature review.

This paper is organized into five sections. The first section is the introduction, followed by a presentation of the systematic literature review methodology performed. In the third section, we find the literature review, analyzing the themes of Lean and LG as well as how they are associated. Finally, section four presents the result analysis and discussion, then the conclusion with the research's limitations as well as proposals for future work.

METHODOLOGY

A concrete methodology is essential for research success, allowing for achieving the proposed objectives more effectively. Initially, we proceeded with a narrative literature review to support the conceptual foundation for understanding and framing the topic: LG.

Then, a systematic literature review was developed based on the guidelines of Denyer and Tranfield (2009), which define three main stages:

Stage 1- Planning the review allowing a discussion of the objectives and the main Research Questions (RQ) as described in Figure 2:
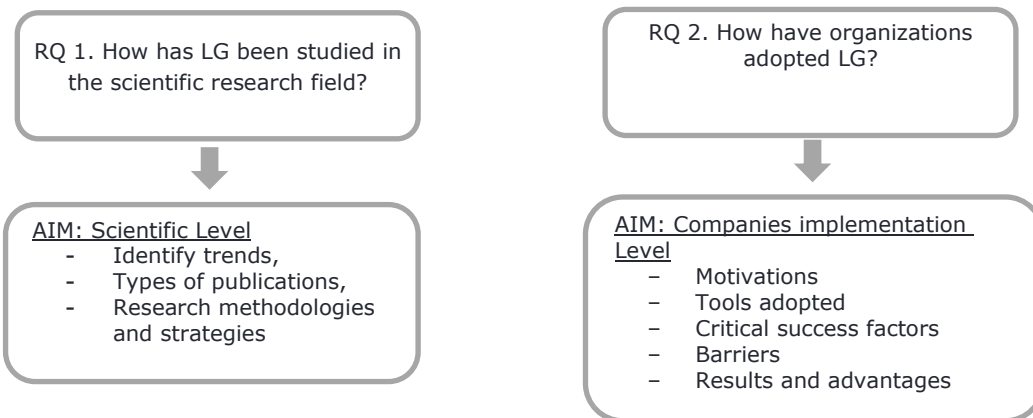

Figure 2 - Research Question and aims
Source: The authors themselves.

Stage 2 – Data gathering: identifying, selecting, and synthesizing data from the relevant literature using an explicit and replicable criterion for the inclusion and exclusion of documents. This step was performed at two levels, a broader one to answer the first research question. The documents were collected in the Scopus database since it is globally recognized for covering multidisciplinary fields. It should be noted that this database is made up of many different publications, such as articles, reviews, book chapters, etc. Therefore, Scopus is a database with a selective approach to indexing documents (documents from a pre-selected list of publications). This database also offers advanced search and filtering features, allowing the development of more complete systematic literature reviews (Martín-Martín *et al.*, 2021). To better substantiate the criteria for choosing the Scopus database, the authors replicated the search process in the Web of Science ™. The database obtained was significantly smaller, with only 60% of the number of Scopus database, and 92% were duplicated. Therefore, only the Scopus database was selected, simplifying the data collection process, and thus guaranteeing the study's replicability criteria.

The Table 1 describes all the steps for the first document-gathering database.

Table 1 - Steps for first level of data colleting

Steps	Total of Documents	Excluded	Selection criteria
1st – Location on Scopus database	212	--	Title, Abstract and Keywords: "Lean Green"
2nd – Period	210	2	By 2022, as it is the intention to analyse complete years

			for a comparative analysis
3rd – Scientific areas	178	32	We selected the three most representative areas and the areas most related to the topic: Engineering; Business, Management and Accounting; Environmental Science
Document Type	155	23	Considering the first research question, the documents were limited to articles, conferences and review
Specific keywords	113	42	Limited to the following specific keywords; "Sustainable Development"; "Lean"; "Sustainability"; "Green"; "Green Manufacturing"; "Lean Production"; "Lean Manufacturing"; "Lean Green"; "Lean and Green"; "Lean Management"; "Lean-Green"; "Lean-Green"
Source	103	10	We considered only documents from Journal and Conference proceeding
Idiom	103	0	All in English
Publication Stage	102	1	One "article in press" was excluded

Source: The authors themselves.

Subsequently, a more refined selection was made, adopting additional selection criteria to answer the second research question since its focus is on a microanalysis context directly linked to companies. At this level, we considered only the period previously demarcated as a growth trend, i.e., from 2016 to 2022, gathering 95 documents as the second research question focuses on the business context, the following subject areas were excluded: Decision Sciences Computer Science Mathematics Economics, Econometrics and Finance Earth and Planetary Sciences Agricultural and Biological Sciences, Materials Science Medicine, building a database with 25 final documents.

Stage 3 – Data analysis: The LG state-of-the-art was supported in the bibliometric analysis. Then, a content analysis of the document's abstracts was also performed to understand the research methodologies applied in the LG area. Finally, concerning how companies have adopted and implemented LG, two authors analyzed the selected documents 'abstracts, and only those that directly contributed to identifying motivations, models and tools, barriers, critical factors, results, and advantages were selected. The document selection stage was carried out individually, then the results were grouped, and situations of divergence were discussed, resulting in a database of 25 articles. Then, this database was read and analyzed in detail, supported by the content analysis technique, which advocates using categories, often derived from theoretical foundations, or extracted from them (Bogdan and Biklen, 2013). The levels of the two categories were defined, as illustrated below in Figures 5 and 6. The first level categories were defined according to the specific objectives, such as Scientific Level - Research methodologies, and Strategies and Companies implementation Level - motivations; models and tools; barriers, critical factors, results, and advantages. The sub-categories were extracted by analyzing the documents collected. According to Bogdan and Biklen, (2013), the analysis involves working with the data, its organization (categories), division into simple units of text (references), synthesis, looking for patterns, discovering essential aspects that should be learned, and the decision of what will be transmitted to others. Some led to the "snowball" effect selecting other publications that have contributed significantly to the second research question of this work, in other words, were included articles that meet the research´s inclusion criteria after screening. "Snowballing could benefit from not only looking at the reference lists and citations, but to complement it with a systematic way of looking at where papers are actually referenced and where papers are cited" (Wohlin, 2018). Specifically, the backward snowballing technique was used since the reference lists of the articles that had already been selected were used to include new articles. The data analysis and discussion are described in section 4.

THEORETICAL FOUNDATIONS

Sustainability and Green

Sustainability was introduced by the World Commission on Environment and Development to respond to social and environmental impacts, helping reduce the planet's damage caused by human intervention. This led to the Brundtland Report (Brundtland, 1987), which defended a consensual and generalized definition of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Linked to the concept of sustainability was the Triple Bottom Line (TBL), based on the idea that organizational performance cannot be measured solely in terms of economic results but also in terms of social and environmental results (Norman and MacDonald, 2004). The term became popular with the publication of John Elkington's "Cannibals with Forks: The Triple Bottom Line of 21st Century Business" (Elkington, 1998). In this book, the author introduces the concept of responsible management, arguing that organizations should consider the three dimensions of sustainable development: environmental, social and economic (Figure 3). He also states that these three aspects need to be operationalized based on the principles of transparency and the main stakeholder's involvement. The author shows how traditional financial management can be reconciled with environmental quality and social justice, using specific examples.
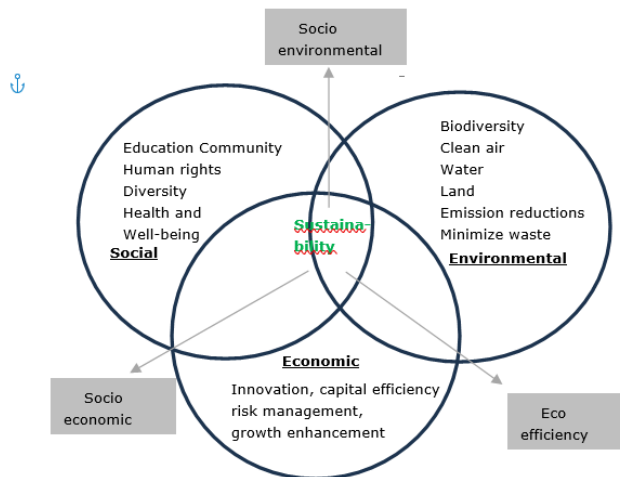
Figure 3 - Triple Bottom Line
Source: Adapted from (Elkington, 1998).

Due to pressures such as environmental regulations and customer demand for greener products and services, companies are being forced to rethink their objectives and consider the environmental impact of their operations. In this way, green and sustainable objectives are increasingly part of the manufacturing agenda of companies that have been developing different types of efforts (Cherrafi *et al.*, 2018; Kovilage, 2021).

In this sense, the integration of sustainability and innovation has been the focus of analysis in several research studies. The Ali *et al.*, (2024) study confirms a positive and consistent relationship between green innovation and organizational competitive advantage. This strategy makes it possible to align investments in green resources and strengthen the organization's image as a leader in implementing environmental practices. To this end, the same authors highlight the role of organizational green culture as an important driver of the interaction between green innovation and competitive advantage.

Organizations are currently making different types of efforts to achieve sustainable business performance. However, there needs to be more focus on sustainability management from an operational point of view, regarding value creation for companies, and even more so in terms of communication and corporate image. Sustainability initiatives are often dealt with in a fragmented way, under different management standards, as ad hoc projects rather than as programs rather than programs. A sustainability approach requires that all elements of sustainability are addressed simultaneously and not individually (Silva *et al.*, 2020).

Lean Philosophy

After the Second World War, due to the scarcity of resources such as workforce and materials, Toyoda, the president of the automobile company Toyota, and Taiicho Ohno (Ohno, 1988), developed a system named "Toyota Production System" (TPS). Over the last few decades, the Lean concept has been extended to other production companies as well as the service industry. Its main objective is to eliminate wastes detected across the production process. By waste, it means all activities that do not add value to the final product (Womack et al., 1990; Taj and Berro, 2006; Zenchanka and Malchenka, 2018; Kovilage, 2021). Therefore, the following types of waste are identified: defects, waiting timing, excessive movements, excessive production, inventory, excessive processing, and transportation (Singh *et al.*, 2013; Mittal *et al.*, 2017; Kovilage, 2021) .

At a management level, the Lean philosophy supports several types of industries, through

maximum waste reduction, intending to increase product value via optimizing production processes (Danese et al., 2018). The objective is to reduce waste while attending to the client's request with minimal costs and time (Bhamu and Singh, 2014).

Lean, as a management philosophy, is based on the following five principles (Womack and Jones, 2003): 1-Value creation: product/service value is defined by the client; 2 - Value flow: identification of all actions, requirements, or necessities that the product requires to reach the client; 3- Optimization of value flow: bring fluidity to all steps of the company's production flow; 4- Pull system: the order to start the production is only given with the quantities that the final client wants; 5- Search for perfection: always do more and better. Afterward, with the changes in organizations' necessities, two more principles were identified: 6- Stakeholders identification; 7- Continuously innovate.

The Lean philosophy also considers a set of tools and techniques that look for waste elimination, contributing to the organization's continuous improvement (Womack and Jones, 2003; Mittal *et al.*, 2017; Ahmad et al., 2021; Kovilage, 2021). Adopting Lean practices allows the reduction of human effort, stock quantity, and product development time, also allowing the increase of energy efficiency. One can mention as the positive results of implementing the Lean philosophy: the consumption of fewer resources, the implementation of quality improvement programs, and the reduction of reworks (Zhu et al., 2018; Ershadi *et al.*, 2021).

Despite the unquestionable benefits of the lean philosophy, research shows there is still potential for the lean philosophy to have applications beyond large-scale manufacturing, and there are still many challenges to overcome in the implementation process. These challenges determine the success of Lean Management, especially in SMEs, since there is a lack of top management training in these companies capable of disseminating a culture of continuous improvement (Pereira and Tortorella, 2018). So, SMEs need a different approach than larger enterprises. Furthermore, applying lean needs to be considered from the perspective of corporate strategy and environmental sustainability (Rymaszewska, 2016). A descriptive case study was conducted on Toyota South Africa Motors (TSAM) where companies are encouraged to implement an integrated, environmental best practice business model as a strategy to reduce costs and sustainably increase profitability and competitiveness (Wiese *et al.*, 2015).

Lean Green (LG)

The Lean and Green practices contribute to managers reaching better economic, social, and environmental performance for the organizations. Green practices include the integration of ecological thinking in supply chain management, including product design, the search, and selection of materials, production processes, the final delivery of the product to the consumer, and the product's end-of-life, considering all product life cycle (Mittal *et al.*, 2017).

LG´s concept was created to address the problem of integrating Lean and Green. The benefits of this integration are better environmental quality, lead-time reduction, production cost reduction, and improved relationships between customers and suppliers. LG works as a tool to reach the maximum exponent of sustainability once it allows the interaction between all sustainability components, bringing several organizational benefits. As a result of integrating Lean and Green systems, a strategy emerged, that may help companies reach better economic and environmental performance. Recent studies have advocated that this integration benefits companies implementing Green and Lean practices (Mittal et al., 2017). Green production can be characterized as reducing waste and increasing the efficiency of production processes. Therefore, this consists of a shared objective between the economic side, where Lean focuses on production, and the ecological side, where we can find the sustainability approaches (Dieste et al., 2020). To summarize, the main objective of LG is to improve operational activities while simultaneously improving environmental efficiency (Kuppusamy et al., 2017).

Still, implementing these integrated strategies is complex, and some barriers must be overcome for these practices to be successfully implemented(Singh *et al.*, 2013).

RESULTS ANALYSIS AND DISCUSSION

Concerning the main goals set, in the first place, we present the results of the Leen Green state of the art, trying to identify trends, types of publications, and the most prevalent research methodologies used to investigate this emergent concept. Then, in point 4.2, we discuss the second goal regarding practical perspective, namely identifying the main tools adopted, critical success factors, barriers, and advantages achieved by LG implementation.

How has LG been studied in scientific research?

Based on the criteria for gathering documents in Scopus, a list of 102 articles was compiled,

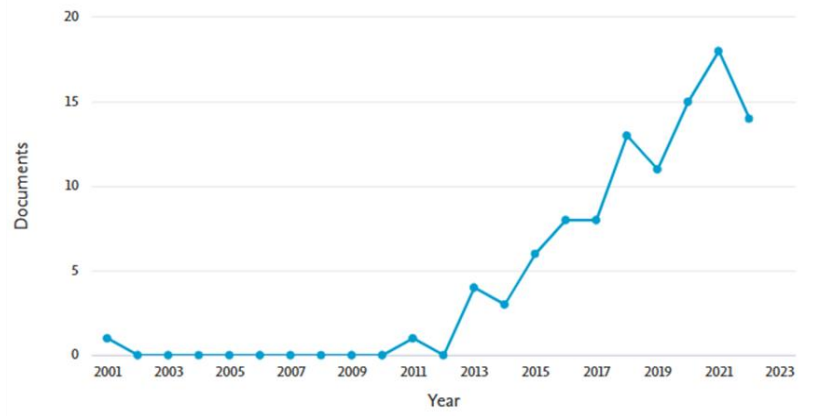with publishing evolution throughout time as shown in the Figure 4.

Figure 4 - Nº of publications per year in the Scopus
Source: The authors themselves.

The first publication was in 2001 to investigate the relationship between Lean Manufacturing (LM) practices and environmental performance in the automobile assembly industry (Rothenberg et al.,2001). In the subsequent decade, there were no publications on the LG subject, with a slight increase in interest by the end of the first decade of 2000. However, the exponential growth in LG publications emerged from 2016 onwards.

Considering the areas classified in Scopus, it was found that "Engineering" leads the list with 26.3% of total selected publications, after Business, Management and Accounting, and Environmental Science.

The subject has also aroused interest worldwide, with publications in Asia, Europe, and America. However, with a more significant number of works developed in India. It is also interesting to highlight Portugal's 3rd position, which is relevant to the current economic development context.

To analyze the trends associated with Lean-Green symbiosis further, a study of keyword co-occurrences was carried out using Vosviewer® software (version 1.6.19 https://www.vosviewer.com/). For this purpose, the 102 selected documents were considered, with the cut-off criterion being keywords mentioned at least four times. Four main clusters of keywords were grouped according to the highest frequency of co-occurrences, as described in Table 2 and Figure 5.

Table 2 - Key-words clusters

Cluster	Keywords
1	Lean - green SMES Supply chain management Sustainability Sustainable development
2	Eco-efficiency Environment Industry 4.0 Lean green Systematic literature review
3	Barriers Green manufacturing Lean manufacturing Six-sigma
4	Green Lean Social Supply Chain

Source: The authors themselves.

The concept of "lean-green" as an integrated way stands out in clusters 1 and 2, focusing on sustainable development, eco-efficiency, and Industry 4.0. This result reinforces the association of "lean-green" as an approach to be further developed to help organizations with their sustainable development challenges also considering their need to improve competitiveness and efficiency. These results, therefore, reinforce the trend toward integrating lean and green to

maximize these benefits.

In turn, clusters 3 and 4 contain the keywords "lean" and "green" individually and are linked to manufacturing, supply chain, and social areas. Therefore, Lean and Green, when implemented isolated, focus on the micro level rather than contributing to organizational performance.
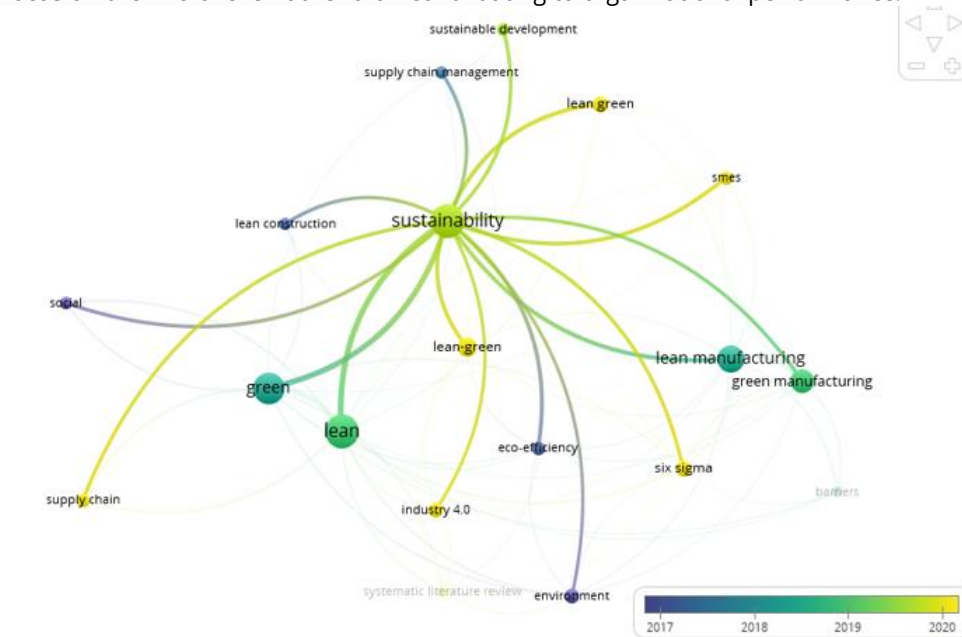

Figure 5 - Academic Research level: Research Strategies
Source: The authors themselves.

From the results obtained, it is evident that the central keyword with the highest number of co-occurrences is "Sustainability," and it is very promising to recognize that "Lean" and "Green" are identified as approaches that contribute to the organizations 'sustainability. From figure 5, both "green", "lean," and "lean-green" show a significant intensity of connection with sustainability. Looking at the chronological evolution, the "Lean-Green" approach has been a more recent research topic (represented in yellow in figure 5) along with emerging themes such as Industry 4, SMEs, six-sigma. This trend could resolve some of the gaps identified in the literature review, such as the need for Lean to be better adapted to SMEs and from the perspective of corporate strategy and environmental sustainability.

As structured in Figure 6, the research strategies around the subject LG have been developed through different strategies, namely literature review, case study, focus group, and surveys.
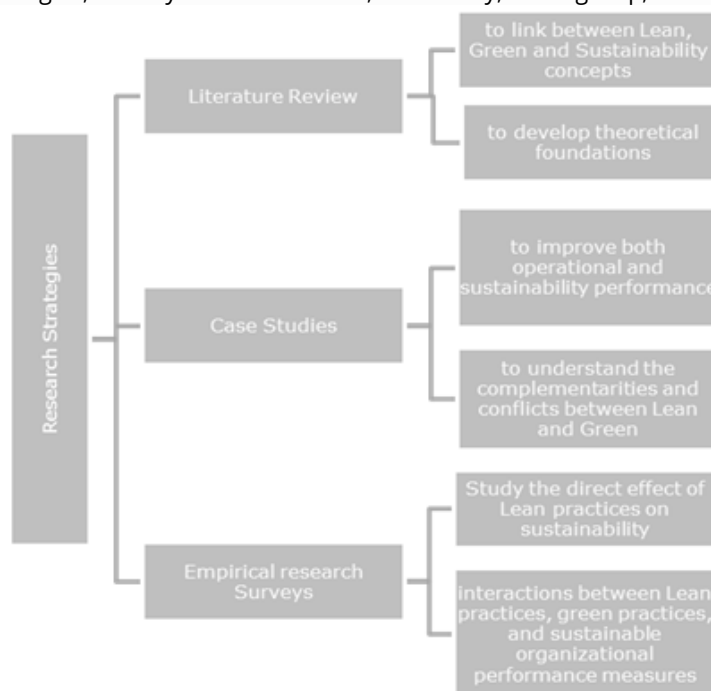

Figure 6 - Academic Research level: Research Strategies
Source: The authors themselves.

Several authors (Marques et al. 2021; Teixeira et al. 2021; El et al., 2022; Queiroz et al. 2022; Zekhnini et al., 2022) have developed theoretical foundations through literature reviews with different objectives and strategies. For example, Queiroz et al. (2022) extracted documents through latent Dirichlet allocation (LDA), and the main results revealed that digitization is a facilitator for Lean and Lean-Green. Other authors seek to identify the contributions of the Internet of Things (IoT) to sustainable supply chain management (SSC) through a systematic literature review. El et al (2022); Zekhnini *et al.* (2022) review the relationship between digital technologies, Lean, Green, Sustainability, and supply chain performance. Teixeira *et al.*, (2021) performed a structured bibliometric literature review focused on the link between Lean, Green, and Sustainability concepts. Malesios et al., (2021) conducted a systematic literature review of 58 articles published between 2005 and 2018 in leading journals.

The development of case studies has proven to be a strategy adopted by several authors. Martinho et al., (2022) developed a case study contributing to a gap in integrating the Internet of Things in Continuous Improvement processes, especially to facilitate diagnosis and problem-solving activities concerning manufacturing workstations. Thekkoote (2022) conducted a case study in a multinational retail company to improve both operational and sustainability performance. Marques, et al (2021) developed a pioneering case study, one of the first publications concerning the application of Lean management in the food retail sector to improve both operational and sustainability performance. Schmitt et al., (2021) aimed to understand the complementarities and conflicts between Lean and circularity throughout a case study.

In the empirical research supported by surveys, the authors Waqas *et al.*, (2021) measured green total factor productivity (GTFP) based on panel data for 68 provincial-level cities in China from 2006 to 2019. In addition, Fatima et al., (2022) collected data from 210 manufacturing organizations and relied on the structural equation modeling technique to examine the direct effect of Lean practices on sustainability with green production as a mediating variable.

Kovilage (2021), through a focus group of 15 experts, used the interpretive structural modeling (ISM) technique to explore the interactions between Lean practices, Green practices, and sustainable organizational performance measures.

How have organizations adopted LG?

In this section, we are looking for a more comprehensive understanding of the practical application of Leen Green, trying to highlight motivations, tools, critical success, barriers, and advantages for organizations. Figure 7 summarizes the main results, followed by a detailed characterization of each element.
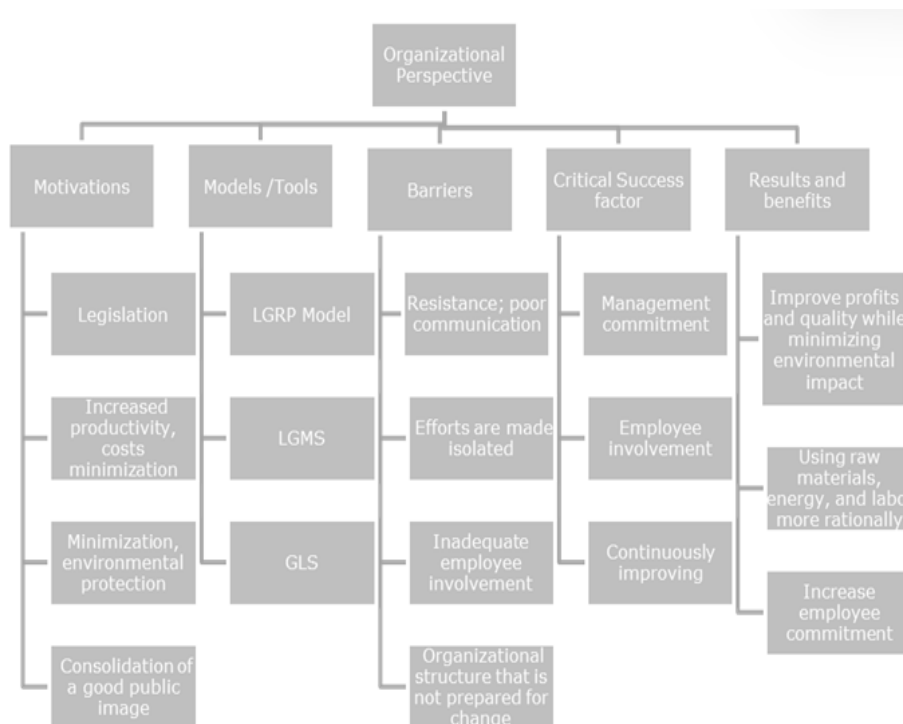

Figure 7 - Organizational Perspective
Source: The authors themselves

Motivations for LG implementation

Currently, companies are increasingly aware and fulfilling ecological measures, some imposed by legislation, others of voluntary decisions that come from their social responsibility, client, and market pressures. As a result, companies are increasingly looking to implement "greener" management strategies, reducing waste, and opting for more ecologically efficient processes (Al-Swidi *et al.*, 2022). Organizations that implemented Lean and Green practices achieved better results than if they focused on just one initiative. This is because the integration of Lean and Green practices has a greater impact on organizational performance when implemented together (Cherrafi et al., 2018).

It is also evident that companies have been opting to be pro-environmental since this option presents several advantages to the organization, such as: increased productivity, cost minimization, environmental protection, consolidation of a good public image, and improvement of the long-term financial performance (Al-Hakimi *et al.*, 2022).

The awareness raising on sustainability management (its benefits and consequences) is fundamental since management commitment is the central pillar for any management practice's implementation and success (Candrianto et al., 2023). Companies ' agendas have emphasized the necessity to improve environmental performance due to rising energy costs, pollution, and global warming (Thekkoote, 2022). Moreover, in this era of fast technological improvements, growing environmental awareness, and depletion of resources, there is an urgent necessity to improve the use of raw materials and available services, so that the main objectives, such as the cost-benefit ratio and quality improvement, may be accomplished (Ahmad et al., 2021). Integrating Lean and Green suggests a new approach to economic and environmental issues. In this way, an innovation process is required to maximize the impact of the effects of this LG synergy and allow companies to be more competitive and economically sustainable (Cherrafi et al., 2018).

LG Manufacturing is a philosophy to be followed by small industries to define a strategy focused on sustainable development since the Green aspect allows the organization to fit into fields more directed towards the sustainable aspect, such as legislation, certificates, and conscious use of raw materials. In turn, Lean stands out in the operational aspect, and process optimization since it reduces waste, which also falls under the Green aspect. Thus, Lean and Green, when implemented together, potentialize positive organizational productivity impacts (Sumant and Negi, 2018).

Different studies show that the integration of Lean and Green practices implies benefits in terms of profits, quality, while at the same time reducing the environmental impact (Schmitt et al., 2021). Lean and Green, when integrated, increase revenue and improve company image by combining Lean production with a "green" manufacturing strategy. Companies can thus decrease costs and risks, increase revenue, and enhance brand image (Pérez et al., 2022) This information is summarized in Table 3.

Table 3 - Sum of Motivations for LG implementation

Sub - Categories	Publications
Legislation	Al-Swidi et al., 2022
Increased productivity, costs minimization	Cherrafi, A., Garza-Reyes, J. and Kumar, V., 2018; Al-Hakimi et al., 2022)
Minimization, environmental protection	Candrianto, Aimon and Sentosa, 2023; Thekkoote, 2022
Consolidation of a good public image	Pérez, P., Pérez, R. and Paz, M., 2022

Source: The authors themselves.

Models/Tools/practices adopted for LG implementation

LG practices become essential for organizations looking for competitiveness and environmental sustainability (Zhu and Zhang, 2020).

From the analysis of the selected documents, we identified several recommendations and contributions at different levels so that organizations may understand how to adopt LG, from more holistic and integrated models focused on Lean principles and sustainability issues.

The authors Kuppusamy *et al.*, (2017) developed the Lean-Green Resourced Person (LGRP) model, which focused on integrating Lean and Green practices to help organizations study and implement Lean-Green strategies in their operations. This model will lead the organization to adopt Lean-Green practices, reducing consumption time. In addition, the integration and implementation of the Lean-Green techniques have a unique and original approach, since they defend that Lean-Green practices begin with identifying employees and their influence area

(Kuppusamy *et al.*, 2017).

A hybrid implementation model for LG with LM, denominated Lean–Green Manufacturing System (LGMS), was proposed by the authors Mittal *et al.* (2017). This system will lead to holistic improvements in the existing productive efficiency models, since it will be possible to reduce more waste compared to a single methodology.

Implementing practices that relate LG to the supply chain allows the organization to achieve better economic, social, and environmental performance. It is important to emphasize that the benefits of implementing these practices in the supply chain include cost and lead time reduction, and better relationships with stakeholders, which also leads to improved environmental quality (Cherrafi et al., 2018).

Another tool was Green Lean Six Sigma (GLS), referenced as a comprehensive method that aims to reduce waste and process variation, decreasing the negative environmental impact during the life cycle product (Thekkoote, 2022). In LG, the employees use fewer natural resources and follow the 3R principle (reduce, reuse, recycle), leading to moderate waste emissions (Chan *et al.*, 2016; Ahmad et al., 2021).

It is also important to mention that the Lean approach is explained through the standard ISO 14001: Environmental Management System (EMS) in the vast universe of ISO standards. This standard consists of an environmental normalization that assists in more efficient business management while keeping the commitment to protect the environment. Therefore, it ensures that a company utilizes its resources and energy sustainably, allowing it to reduce costs through Green practices (Ahmad et al., 2021; Kovilage, 2021).

Several studies have shown evidence that the quality management systems' practices (QMS) are facilitators of the environmental management systems to obtain greater returns from these practices. The synergies between quality and environmental objectives have contributed to evolutions in both these fields (Garza-Reyes *et al.*, 2018). These results are synthesized in table 4.

Table 4 - Sum of Models/Tools/practices adopted for LG implementation

Sub – categories	Publications
LGRP Model – Lean-Green Resourced Person	Kuppusamy et al., (2017)
LGMS – Lean–Green Manufacturing System	Mittal et al. (2017)
LG in supply chain	Cherrafi et al., 2018
GLS – Green Lean Six Sigma	Thekkoote, 2022
3R principle (reduce, reuse, recycle)	Chan et al., 2016; Ahmad et al., 2021
ISO – ISO 14001: Environmental Management System	Ahmad et al., 2021; Kovilage, 2021

Source: The authors themselves.

Barriers to LG implementation

Although both philosophies, Lean and Green, provide a competitive advantage to organizations, companies with little experience in management tools present resistance to implementing these practices. In this case, the top management's role is crucial to its implementation's success. Coordination problems between the departments and poor communication present significant barriers when implementing the practices mentioned above (Singh *et al.*, 2013).

However, in many companies, efforts are made isolated, justified by the need for more communication in their various departments, which implies a considerable overlap of efforts and expenses. Therefore, it is possible to overcome this obstacle by cross-synchronously the implementation of measures and practices (Kovilage, 2021). Poor employee training and their low ability to learn new techniques and work methods are also barriers. Therefore, the organization's Human Resources (HR) involvement is crucial to implementing Lean and Green practices (Singh *et al.*, 2013). It can also be presented as a limitation, the result of Lean and Green approaches being time-consuming. Sometimes, it may take years before significant results can be found.

The LG Management system analysis detected barriers that prevented it from being fully implemented. Some examples include reluctance to interrupt production, low consumer consistency, limited resources available for production, inadequate regulatory framework, resistance to change, and inadequate employee involvement and organizational structure that is not prepared for change (Kumar et al., 2016)

The organization's maturity presents itself as a challenge in implementing Lean and Green practices since, in some instances, there needs to be a better understanding of the concepts by the organization elements (Sumant and Negi, 2018). The main ideas are listed in Table 5.

Table 5 - Barriers to LG implementation

Sub - categories	Publications
Resistance; poor communication	Singh et al., 2013
Isolated efforts	Kovilage, 2021
Inadequate employee involvement	Kumar et al., 2016
Organizational structure that is not prepared for change	Sumant and Negi, 2018

Source: The authors themselves.

Critical success factors for LG implementation

Ahmad et al., (2021) attempted to identify the drivers of green innovation implementation by studying the relationship between organizational performance and company competitive advantage, considering the impact of management commitment and Human Resource (HR) practices. They also found that the interest and purpose of implementing the Integrated LG System increased surprisingly with employee involvement, as both approaches lead to reduced waste and product cost, while continuously improving the quality of products and processes (Ahmad et al., 2021).

HR is a key resource for achieving sustainable development of companies. The employee's management efficiency and validity is an index for measuring sustainability (Zhu and Zhang, 2020).

Resource constraints, such as energy or water in small and medium-sized businesses, have proven to be a critical factor in developing Lean and Green practices more systematically and continuously (Sumant and Negi, 2018), as described in Table 6.

Table 6 - Critical success factors for LG implementation

Sub - categories	Publications
Management commitment	Ahmad et al., 2021
Employee involvement	Ahmad et al., 2021; Zhu and Zhang, 2020
Continuously improving	Ahmad et al., 2021
Resource constraints	Sumant and Negi, 2018

Source: The authors themselves.

LG results and benefits

Green production is characterized as a method that minimizes both waste and pollution. It aims to modify conventional production practices to make them greener and more energy efficient. Several studies show that the integration of Lean and Green practices in production implies that companies obtain benefits in terms of profits and quality while minimizing environmental impact (Sumant and Negi, 2018).

Green production is an integrated method that targets all waste streams related to the design, manufacturing, use, and disposal of products and materials. Additionally, LG practices are considered a comprehensive method to reduce the negative environmental impact and produce standardized products simultaneously. A well-designed system can reduce operating costs and increase product value by using raw materials, energy, and labor more rationally (Thekkoote, 2022).

As a result, when applied together, Lean and Green techniques can provide companies with better results than would be possible if they were being applied individually.

The coordination of LM and Green practices can bring benefits to organizations, such as reduced costs, reduced lead time, improved process and environmental quality, and increased employee commitment. Thus, LM practices could positively impact sustainable performance (Thekkoote, 2022).

Lean and Green, when integrated, increases revenue, and improves the company's image by combining Lean production with a "green" manufacturing strategy.

Implementing Lean and Green thinking practices in the supply chain is also noted as an advantage. As a result, the Product- Services - System (PSS) is developed to drive both business excellence and environmental sustainability. A brief sum is presented in Table 7.

Table 7 - LG results and benefits

Sub - categories	Publications
Improve profits and quality while minimizing environmental impact	Sumant and Negi, 2018
Using raw materials, energy, and labor more rationally	Thekkoote, 2022
Increase employee commitment	Thekkoote, 2022

Source: The authors themselves.

CONCLUSION

Companies should be responsible and aware of their environmental implications and, in parallel, enhance their competitiveness. In this respect, LG management can be a valuable tool for achieving environmental objectives by mitigating the environmental impacts of industrial activities (Dieste et al., 2020).

The results from the systematic literature review revealed that the integration of Lean and Green is an emerging topic, with significant growth in the last six years, from a worldwide perspective. It was further verified that the research has been carried out mainly in Engineering, Business, Management and Accounting, and Environmental Science. This research area has been developed through different strategies (literature review, case studies, surveys), each providing different contributions. The literature review emphasizes the importance of the digital era, attempting to understand the role of Information Technology (IT) in consolidating of the LG approach. Case studies were developed to demonstrate the relationship between Lean management and sustainability performance in several sectors. In turn, research surveys have contributed to the definition of indicators that allow evaluation of the impact of green practice on productivity, as well as the role and impact of LG on organizational sustainability performance.

From the practical lens, the results showed that not only legal requirements and market pressures are motivating organizations to implement LG. Additionally, there is also a pro-environmental attitude that fosters the awareness that LG, when implemented simultaneously, leads to better organizational performance. To consolidate this integration, several holistic and hybrid models were identified, namely: LGRP (Kuppusamy *et al.*, 2017); LGMS (Mittal *et al.*, 2017); GLS (Thekkoote, 2022). Notably, some studies point to EMS and QMS as facilitators of Leen-green integration.

However, in this LG journey, organizations face obstacles due to a lack of experience, coordination, and communication between departments. Thus, it is important to develop strong top management support, cross-synchronous implementation measures, as well as LG management training.

This paper's main limitation is that it was considered only the Scopus database, as it proved to be a more complete database. Even so, we intend to deepen this research, expanding the scope to other databases to explore the potential value of the remaining contribution. It is also intended to develop the LG state-of-the-art further, considering the main trends shown in the results: lean-green, Industry 4.0, SMEs

So, as a future research path, it would be interesting to deep LG in Industry 4.0, to better understand the role of IT in this paradigm. To address some of the gaps identified in the literature review, one line of future work is to develop a better adaptation of Lean-Green for SMEs.

In summary, lean manufacturing practices and green practices improve the company's performance with the environment, so Lean and green together increase the organization's efficiency and competitiveness (Ahmad et al., 2021).

ACKNOWLEDGMENT

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