

Article

Integrated Lean-Green Practices and Supply Chain Sustainability for Manufacturing SMEs: A Systematic Literature Review and Research Agenda

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Abstract: While it is understandable that lean and green practices are mostly sensible for large companies, it is also important to bring these practices to small and medium enterprises (SMEs), as they are the dominant players in various industry sectors. SMEs are part of larger supply chains and contribute substantially to the economy, and thus perhaps there is a need for a workable model that attracts them to the lean and green practices. This study aims to find gaps in the lean-green research area that require development in future studies, especially for SMEs. This study uses an analysis of systematic literature reviews (SLR) and involves carefully selected articles from different databases or sources. This SLR was conducted in an effective and structured way using keywords entered into the search engine and found as many as 157 peer-reviewed journal articles, which were studied further using quantitative and qualitative approaches. The bibliometric analysis carried out made it possible to observe research trends on lean and green from 1996 to 2022. To find different research dimensions on lean and green topics, an in-depth evaluation was carried out on the linkage between lean, green, supply chain management, sustainability, and other management approaches. This study finds a lack of empirical research studies that comprehensively focus on investigating the impact of lean and green practices on the supply chain sustainability performance of manufacturing SMEs and involve all three aspects of the triple bottom line (3BL). Our review suggests such a robust and workable model for SMEs is not currently available. A limitation of our review is the use of keywords or “terms” to select articles, as well as the subjectivity of the researcher. Finally, we identify the research streams, criteria, findings, limitations, and enablers or challenges of 17 selected published journal papers on lean-green studies in SMEs and propose a number of research questions for future research directions.



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Keywords: lean; green; sustainability; supply chain; small and medium enterprise

1. Introduction

In recent times, more companies have become increasingly aware of environmental concerns and are adapting their operations to develop socially and environmentally responsible products, services, and processes [1,2]. At the same time, regulations, high competition, and public pressure require companies to balance environmental, economic, and social performance [2–4]. In response, on the one hand, many companies consider the management of environmentally friendly and more sustainable operations as an integral part of economic development and value creation in order to remain competitive [5]. On the other hand, the company is under tremendous pressure to increase productivity, flexibility, and quality while reducing its costs. The triple bottom line (3BL) of sustainability, which consists of three dimensions, i.e., profit (economy), planet (environment), and people (social), has become a strategic requirement for companies to align with more traditional profitability and efficiency priorities [6]. Therefore, it is necessary to develop a fit strategy

to meet sustainability requirements by exploring the best practices currently in use and how they can be adapted and applied.

Over the last few decades, many studies have shown that there has been a shift towards lean practice as a major part of the sustainability answer [7,8]. Beginning in the mid-1990s, a research survey conducted by Florida [9] involving US manufacturing companies indicated that company efforts focused on reducing waste in the manufacturing process resulted in increased productivity, which could create substantial opportunities for environmental improvement.

King and Lenox [10] surveyed the facilities of 17,000 US manufacturing companies during the period of 1991–1996 regarding the integration of Lean-Green practice initiatives, and their results showed that the adoption of ISO 9001 [11] increases the likelihood that management will adopt the ISO 14001 [12] environmental management standard. The empirical evidence supports the claim that “Lean is Green”, which means that lean production is associated with lower emissions. The finding was confirmed by Yang et al. in their research, who surveyed 309 diverse manufacturing companies located in European and non-European countries. Yang et al. [13] proved that Lean is an essential precursor to environmental management practice. The focus of lean manufacturing on internal and process waste reduction to increase efficiency should be extended to reduce environmental waste for improved environmental performance. Furthermore, Lean and Green practices simultaneously serve as catalysts to reduce negative environmental impacts on operations and processes [14].

Correspondingly, the synergy of both Lean and Green practices has been emerging as an operational strategy to help companies improve their sustainability performance while still achieving their economic goals [15]. Research conducted by Verrier et al. [16] facilitates understanding and practical implementation of sustainable Lean-Green integration through emphasizing the existing correlations between the respective Lean and Green wastes and tools that can help eliminate them. The results of the study also recommend integrated Lean-Green practice tools that are easily accessible and used by companies with less experience.

Several studies, such as Pampanelli et al. [17], investigated empirical evidence that lean-green synergy can enhance sustainability performance (both economic and environmental dimensions) at the operational level or production cell. However, today’s business concept does not represent an isolated entity due to a shift in the nature of competition from inter-company to inter-supply chains [18]. Hence, recently, there has been an increasing emphasis on measuring supply chain sustainability performance. Thus, a study should be conducted to establish the sustainability impact of integrating these two practices into an integrated system or supply chain.

Furthermore, the adoption of Lean-Green into supply chain sustainability has become a current trend practice for businesses, especially large companies, with evidence of its benefits [14]. However, the role of small and medium enterprises (SMEs) as one of the supply chain players cannot be counted out, as many SMEs supply materials or other types of inputs to large companies. In order to win the competition, all players in a supply chain have to possess the same “one frequency”. Likewise, SMEs are one of the main economic pillars and play an important role in national economic growth. According to Das and Rangarajan [19], SMEs contribute almost 90% of global business and create 50–60% of total employment worldwide. Moreover, according to Parker et al. [20] and Luthra et al. [21], SMEs worldwide are responsible for 60–70% of hazardous emissions. When looked at separately, SMEs have a negligible effect on the environment, but when taken collectively, SMEs have a significant effect [22–24]. This implies that SMEs also need to adopt Lean Green as part of the whole supply chain effort toward better sustainability. Therefore, efforts are required to encourage SMEs to successfully and effectively adopt it.

To the best of our knowledge, only a few empirical studies have comprehensively investigated the impact of lean and green practices on supply chain sustainability performance and involved all three aspects of the 3BL. In particular, empirical research focusing on lean and green practices in manufacturing SMEs is also limited. An extensive literature

review conducted by Siegel et al. [6] identified a number of challenges for SMEs and their implications for Lean-Green and sustainability. The study points out some reasons why most SMEs have not yet integrated Lean, much less Green-Lean, and sustainability. A robust and workable model for SMEs is not currently available. This study aims to find gaps in the lean-green research area that require development in future studies, especially for manufacturing SMEs. Hence, this article aims to answer two research questions in order to provide a more comprehensive understanding of Lean-Green practices for SMEs:

RQ1. *What are the current trends in lean and green practices and their link with the different aspects of sustainability?*

RQ2. *What are the main paths for further research in developing the integrated lean-green practices and supply chain sustainability for SMEs?*

This article is then structured as follows: Section 2 describes the methodological process of a systematic literature review, including the determination of keywords, criteria, and bibliometric analysis. Section 3 presents and discusses the results of the bibliometric analysis, research gaps, research streams, challenges, and other findings to determine future research directions related to integrated lean-green practices and supply chain sustainability for SMEs. Finally, Section 4 concludes this study.

2. Research Method

This study uses an analysis of the systematic literature review, as illustrated in Figure 1, by tracing research studies from 1996 to 2022 that discuss and consider synergies, synchronization, and integrated approaches of Lean and Green practices. We found various articles on different aspects of the two practices, such as their drivers, benefits or/and barriers, or obstacles to synergies, applications, methodologies, and integration of both widely across various industry sectors. The transition to green operations has compelled organizations to seek ways to combine “traditional” measurements of profitability, efficiency, customer satisfaction, quality, and responsiveness with green goals and initiatives. This combination produces green lean. When considering what lean and green signify, their synchronization appears to concentrate around their emphasis on waste reduction. However, the reality is far more complex. Lean-green seeks more efficient systems to reduce overproduction and the environmental impact of their conception along the supply chain and the organization’s internal operations [25].

Systematic literature review (SLR) involves rigorously disaggregating and selecting articles collected from different databases or sources, such as Scopus, ScienceDirect, Elsevier, Emerald, Wiley, Springer, Taylor & Francis, etc. This literature review was carried out in an effective and structured manner, with keywords used in the search including “lean”, “lean manufacturing”, and “lean practice” combined with “green”, “green manufacturing”, “environmental”, “green practice”, “sustainability”, “sustainable”, “performance”, “supply chain”, “SMEs”, and “small and medium enterprises”. Thus, the following search string was used: (lean OR lean manufacturing OR lean practice) AND (green OR green manufacturing OR environmental OR green practice) AND (sustainability OR sustainable) AND (performance) AND (supply chain) AND (SMEs OR small and medium enterprises). To maintain the quality of the review, this study did not include articles published in conference proceedings. A number of selected papers were found in the search domain. Then, the papers were analyzed descriptively and quantitatively based on the distribution of the year of publication, the journal and publisher, the research method used, the geographic area, the industry sector, and the number of citations. Furthermore, these papers were reviewed and analyzed based on the criteria category of the research method used, the intersection of the relationship between lean, green, sustainability, supply chain and other approaches.

A number of relevant literature reviews were studied. For example, Farias et al. [26] reviewed 65 selected articles from 1996 to 2018. However, not all selected articles presented clear performance criteria regarding their relationship to Lean and Green. This relationship was found in 18 articles that are used as references in establishing the basis for developing

a conceptual framework. Siegel et al. [6] explored 45 selected articles published between the period of 2000 and 2018 to analyze and study the literature related to the discussion of the Lean-Green integration approach and sustainability in small and medium enterprises.

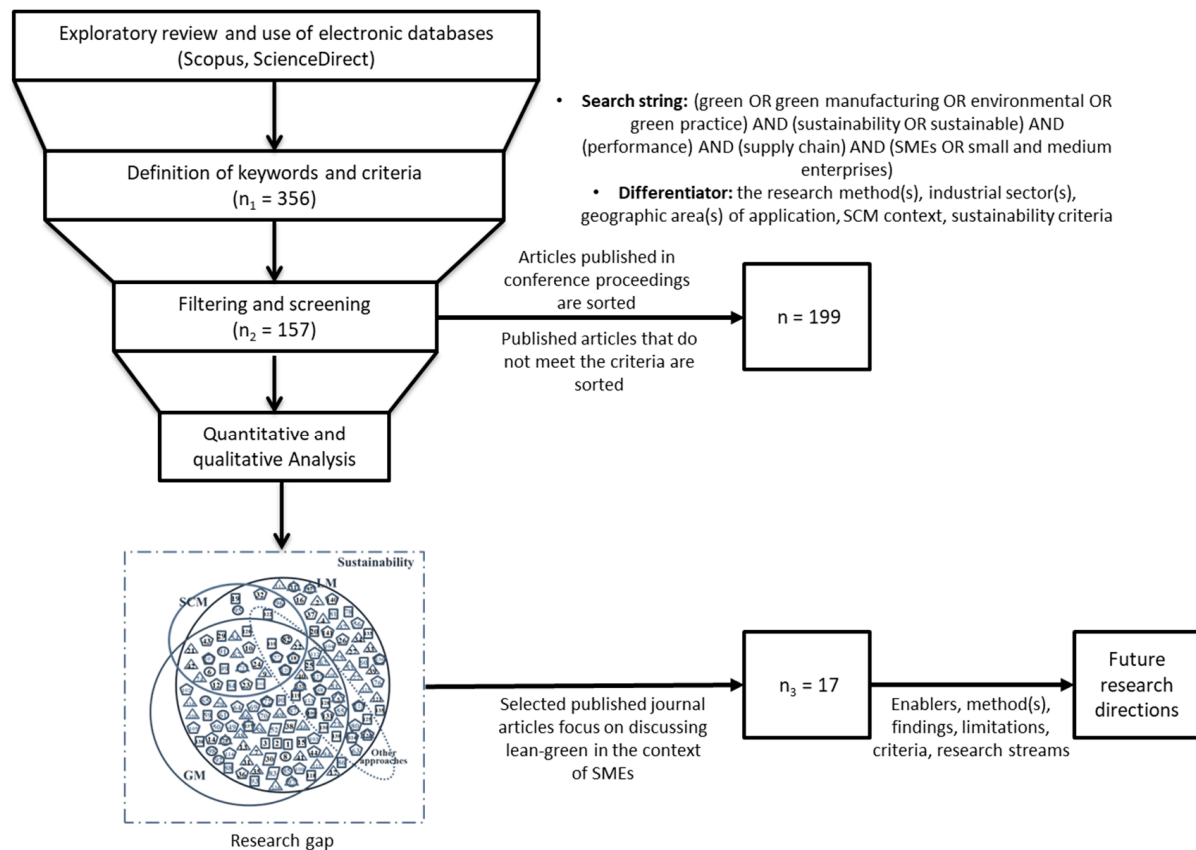


Figure 1. The phases of a systematic literature review.

At the beginning of the exploratory search in terms of title-abstract as well as using keywords on search engines, a total of 356 articles were found. Not all of these articles discussed lean or/and green sustainability and were then filtered, which ended up with 157 peer-reviewed journal articles that will be analyzed and studied further using quantitative and qualitative approaches. These articles were published and distributed in various journals, as shown in Table 1. Finally, we identify the research streams, criteria, findings, limitations, and enablers of 17 selected published journal papers on lean-green studies in SMEs and propose a number of future research directions.

Table 1. Article distribution in journals.

Journal	Number of Articles	Cumulative Frequency
Journal of Cleaner Production	46	29.3%
International Journal of Lean Six Sigma	9	35.0%
International Journal of Production Economics	9	40.8%
Sustainability	9	46.5%
Production Planning and Control	8	51.6%
International Journal of Production Research	4	54.1%
Journal of Manufacturing Technology Management	4	56.7%
Resources Conservation and Recycling	4	59.2%
Benchmarking: An International Journal	4	61.8%
Supply Chain Management	3	63.7%

Table 1. Cont.

Journal	Number of Articles	Cumulative Frequency
International Journal of Productivity and Performance Management	3	65.6%
Business Strategy and the Environment	3	67.5%
International Journal of Sustainable Engineering	3	69.4%
Clean Technologies and Environmental Policy	2	70.7%
Environmental Quality Management	2	72.0%
International Journal of Operations and Production Management	2	73.2%
Journal of Supply Chain Management	2	74.5%
TQM Journal	2	75.8%
Journal of Industrial Engineering and Management	2	77.1%
Asian Journal of Shipping and Logistics	1	77.7%
British Journal Management	1	78.3%
Production and Operations Management	1	79.0%
Built Environment Project and Asset Management	1	79.6%
China Foundry	1	80.3%
CIRP Annals	1	80.9%
California Management Review	1	81.5%
Computers and Operations Research	1	82.2%
Energy	1	82.8%
Environmental Impact Assessment Review	1	83.4%
International Journal of Automation Technology	1	84.1%
International Journal Business Performance and Supply Chain Modeling	1	84.7%
Journal of Manufacturing Technology Management	1	85.4%
Journal of Technology	1	86.0%
Journal of Transport and Supply Chain Management	1	86.6%
Journal of Green Building	1	87.3%
Management Decision	1	87.9%
Management Research Review	1	88.5%
International Journal Enterprise Network Management	1	89.2%
International Journal of Fashion Design Technology and Education	1	89.8%
International Journal of Contemporary Hospitality Management	1	90.4%
Progress in Industrial Ecology	1	91.1%
International Journal of Physical Distribution and Logistics Management	1	91.7%
International Journal of Value Chain Management	1	92.4%
IEEE Transactions on Engineering Management	1	93.0%
International Journal of Construction Management	1	93.6%
International Journal Agricultural Resources Governance and Ecology	1	94.3%
International Journal of Management Science and Engineering Management	1	94.9%
International Journal of Environment Science and Technology	1	95.5%
Sustainable Cities and Society	1	96.2%
Research in Transportation Economics	1	96.8%
Journal of Purchasing and Supply Management	1	97.5%
Journal of Open Innovation: Technology, Market, and Complexity	1	98.1%
Transportation Research Part E: Logistics and Transportation Review	1	98.7%
Sustainable Production and Consumption	1	99.4%
Environmental Science and Pollution Research	1	100.0%

3. Results and Discussion

In this section, a more in-depth discussion of the evolution of Lean-Green practices and Sustainability is presented. For an overall view, one hundred and fifty-seven selected articles are listed. All articles are described by author(s), year of publication, research method used, geographic area(s) of application, and sustainability aspect(s).

3.1. Descriptive Analysis of Findings

Based on the number of selected articles published, research on Lean and Green practices and Sustainability has begun to receive special attention from the research community since 2010, and the number increased significantly in 2020, as shown in Figure 2. This

confirms the statement in the paper published by Farias et al. [26]. As mentioned earlier, the first research on Lean-Green practices in the concept of sustainability was carried out in Florida [9]. He surveyed manufacturing companies in the US and found that, in addition to increasing productivity, reducing waste in manufacturing processes also creates substantial opportunities or impacts on environmental improvements. At that time, the term sustainability was more focused on environmental factors without involving all of the 3BL, including economic, environmental, and social aspects.

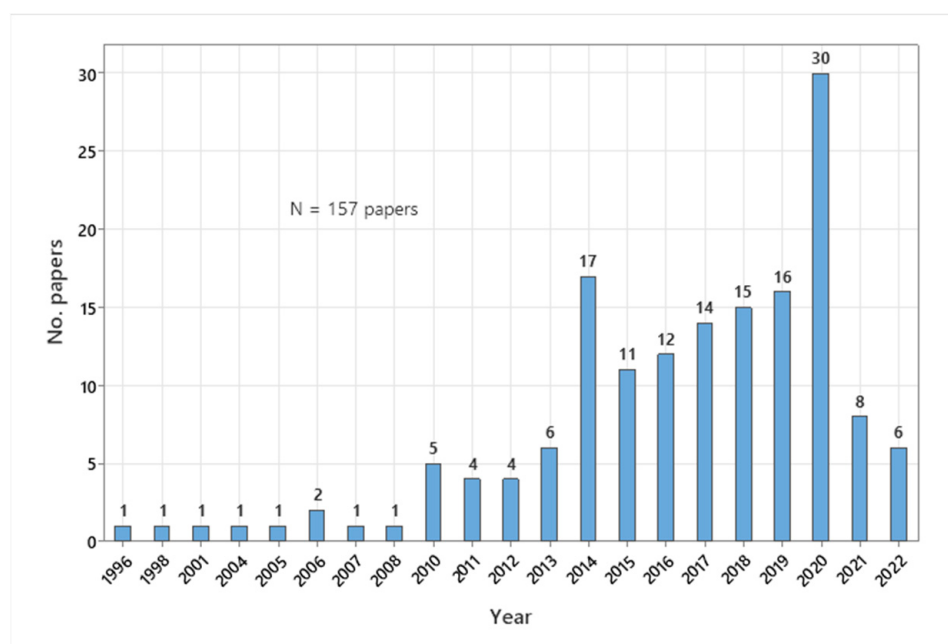


Figure 2. Year of publication.

In the late 1990s and early 2000s, these two practices were mostly applied at the operational level of a company and not yet linked to the supply chain context. In 2006, Kainuma and Tawara [27] published a paper entitled “A Multiple Attribute Utility Theory Approach to Lean and Green Supply Chain Management”, discussing these two practices from the perspective of supply chain management to improve operational performance and environmental performance. Over the past two decades, the SCM literature has increasingly addressed the need for sustainability criteria [28]. Supply chain sustainability does not only measure business profits, but also measures the impact on the environment and social systems. However, our observation reveals that only a small number of Lean-Green studies have really addressed their relationships with supply chain sustainability. Figure 3 shows the difference in the cumulative frequency of the number of articles discussing Lean or /and Green practices in and not within the supply chain context. Although a select number of articles discuss lean and green practices in the supply chain function, there is a lack of research that addresses the impact of these two practices on sustainable supply chain performance, especially for SMEs.

In general, the research methods used consist of surveys, literature reviews, modeling and simulation, case studies, and action research. It is interesting to highlight that the case study method was the most used (26.8%) in this Lean-Green research studies and the distribution is as illustrated in Figure 4. It was followed by literature review (21.7%), survey (21.7%), a combination of literature review and other methods (12.7%), modeling and simulation (7.6%), a combination of case study and other methods (5.1%), action research (2.5%), and the rest are a combination of survey and other methods (1.9%).

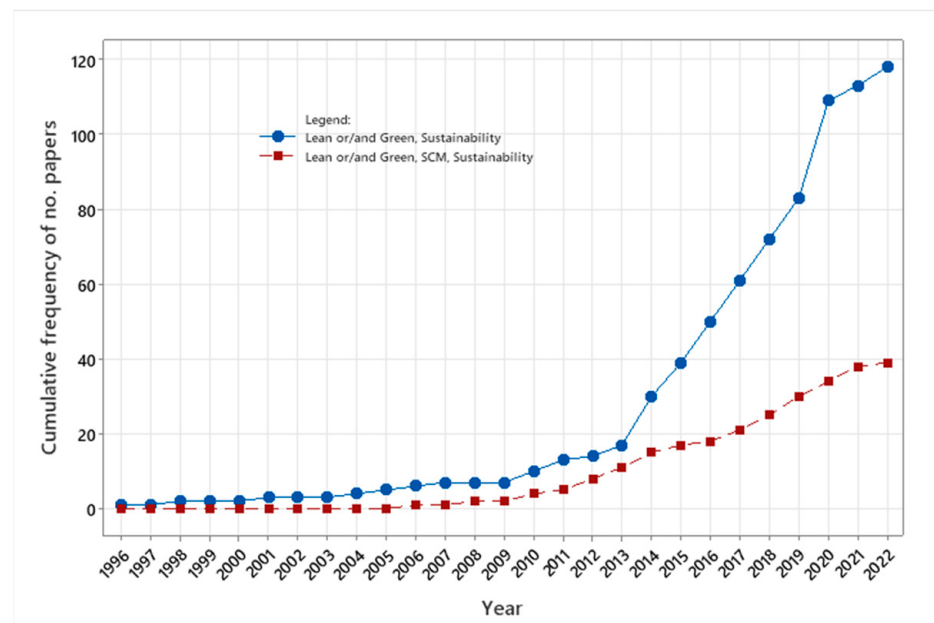


Figure 3. Cumulative frequency of the number of articles published by research topic.

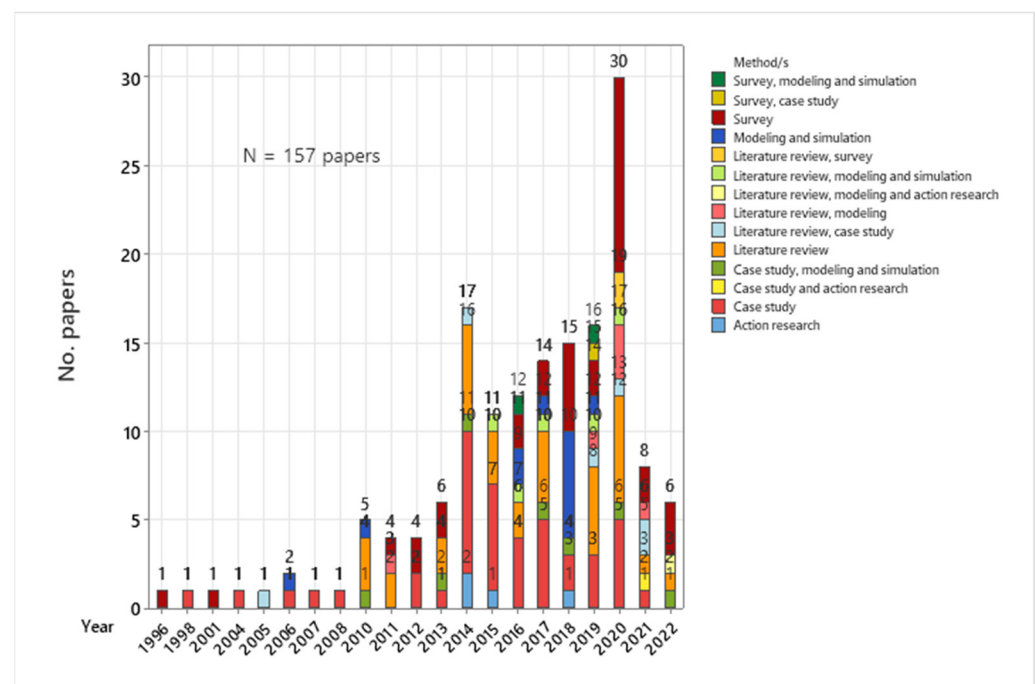


Figure 4. Research methods per year (from 1996 to 2022).

In terms of the area of application, the Lean or/and Green studies were mostly carried out in the manufacturing industry (i.e., 55.7%), followed by multisectoral (12.1%), construction (4.5%), services (2.4%), metal working (2.5%), foundries (1.3%), agriculture (0.6%), mining (0.6%), and others (20.3%). More details can be seen in Figure 5. The distribution of manufacturing industry applications includes automotive, food and beverage, electronics, furniture, aerospace, tube, paper and board mill, textile, manufacturing SMEs, water pumps, apparel, and so on. A small number of the above studies addressed Lean or/and Green practices in the context of SMEs (17 papers, or about 10.6%).

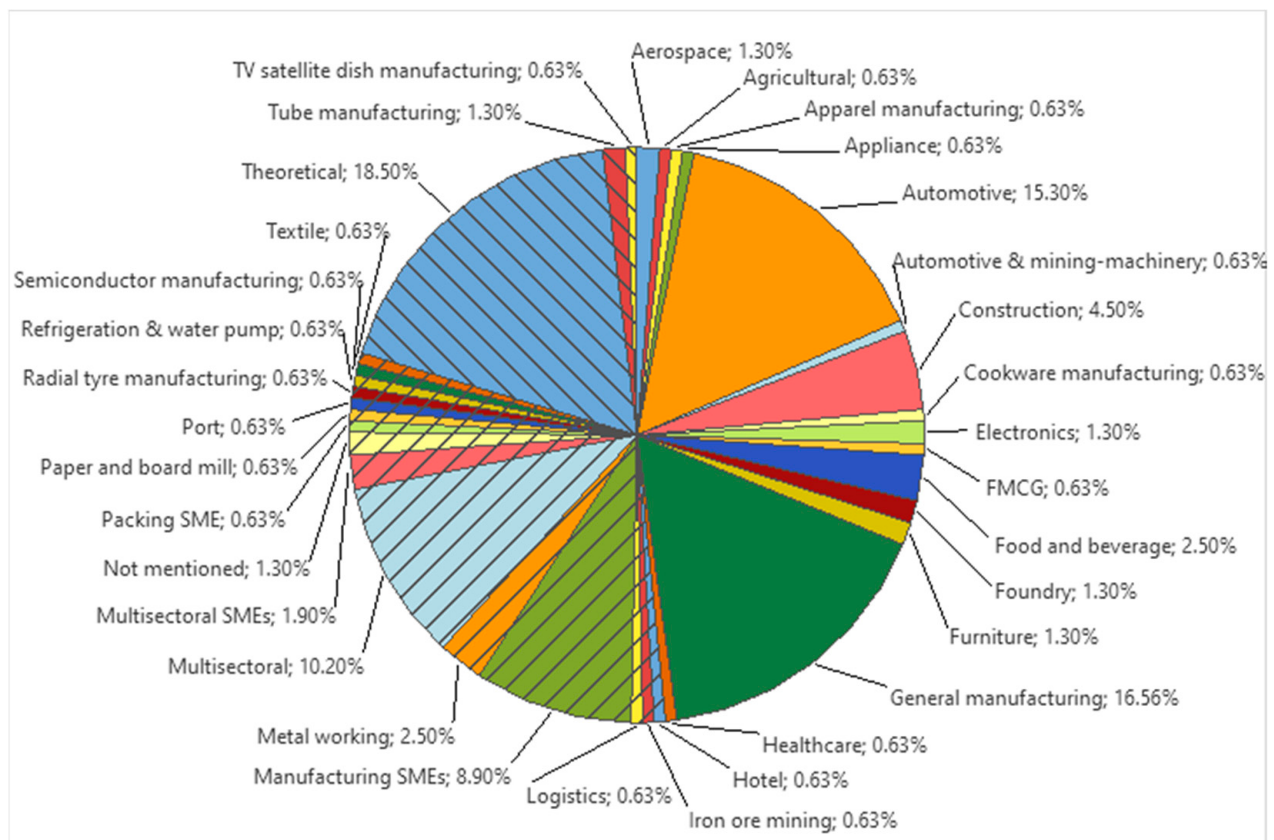


Figure 5. The industrial sector(s) application.

Research on Lean-Green practices for Sustainability has been carried out worldwide, including in America, Europe, Asia, Australia, and Africa. This research has been conducted in developing countries, such as India, Brazil, Indonesia, Latin America, South Africa, Malaysia, and others, and developed countries, such as the United States of America, the United Kingdom, China, Sweden, France, Japan, Canada, Germany, Switzerland, Portugal, Spain, the UAE, and others. The geographic distribution of the application can be seen in detail in Figure 6. This literature review shows that many Lean-Green research studies have been conducted in India (12.7%), including SMEs.

This literature review also considers published articles that have a high impact based on the number of citations. The article from Yang et al. [13], which had the highest citation, was followed by Florida [9], then Dües et al. [14], Mollenkopf et al. [25], Simpson and Power [29], Rothenberg et al. [30], Martínez-Jurado and Moyano-Fuentes [31], Garza-Reyes [15], and so on. For details, the 30 articles with the highest citations can be seen in Figure 7.

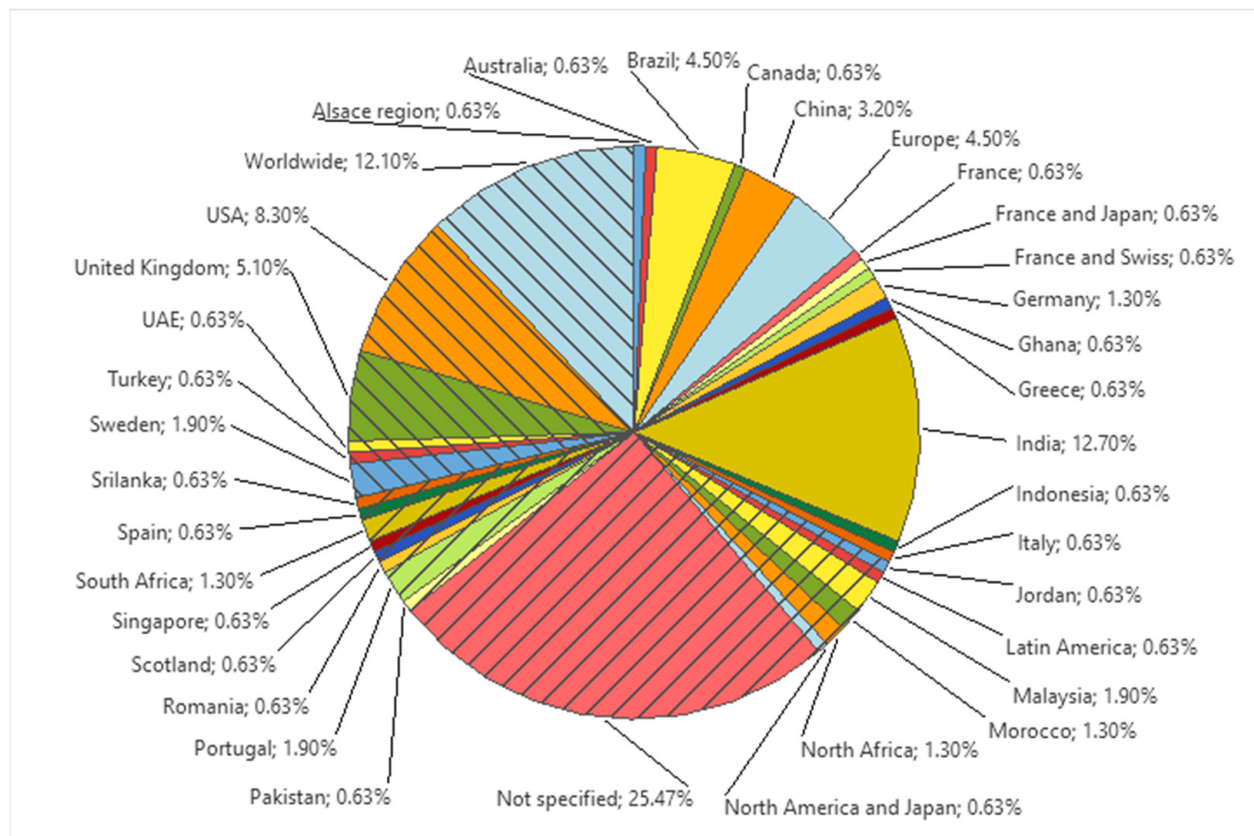


Figure 6. The geographic distribution of application.

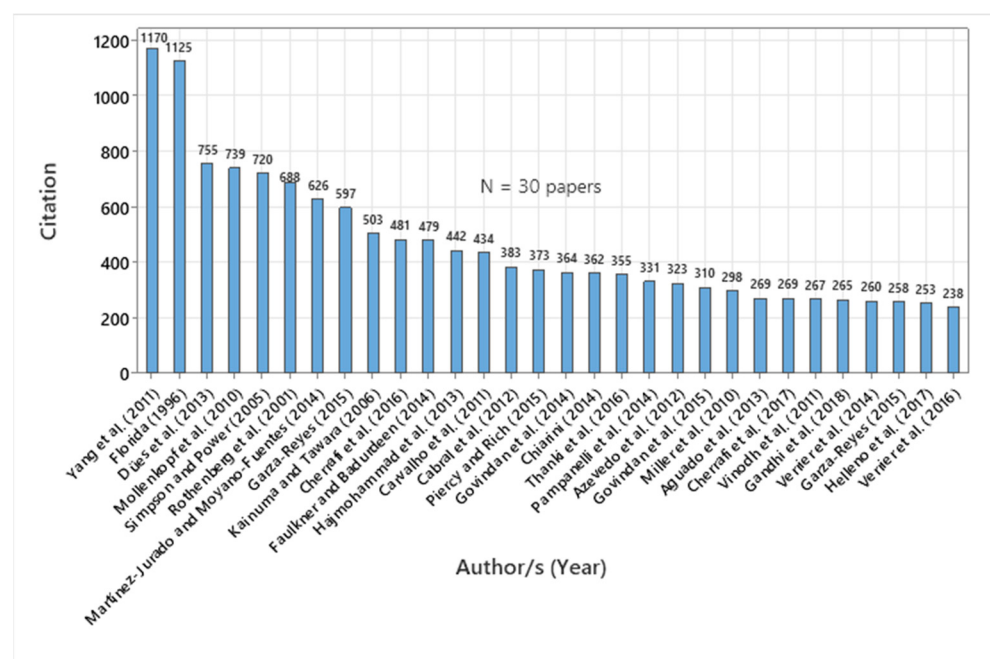


Figure 7. The thirty most cited papers [8,9,13–17,25,27,29–49].

3.2. Research Stream and Opportunities in Future Research

In order to find the distinct dimensions of research on lean and green topics, an in-depth evaluation was carried out on the linkages between lean, green, supply chain management, sustainability, and other management approaches, as illustrated in Figure 8.

All selected articles are reviewed to find areas of research that require further detailed development and to complete those areas of research. In line with Farias et al. [26], many research articles investigate the impact of lean-green practices on organizational sustainability performance, for example, operational performance, environmental performance, quality, productivity, financial performance, social performance, economic performance, and so on. However, as mentioned earlier in the introduction section, our review indicated that there is a lack of empirical research studies that comprehensively investigate the impact of lean and green practices on sustainable supply chain performance and involve all three aspects of the 3BL. In particular, it is also rare in the SME context.

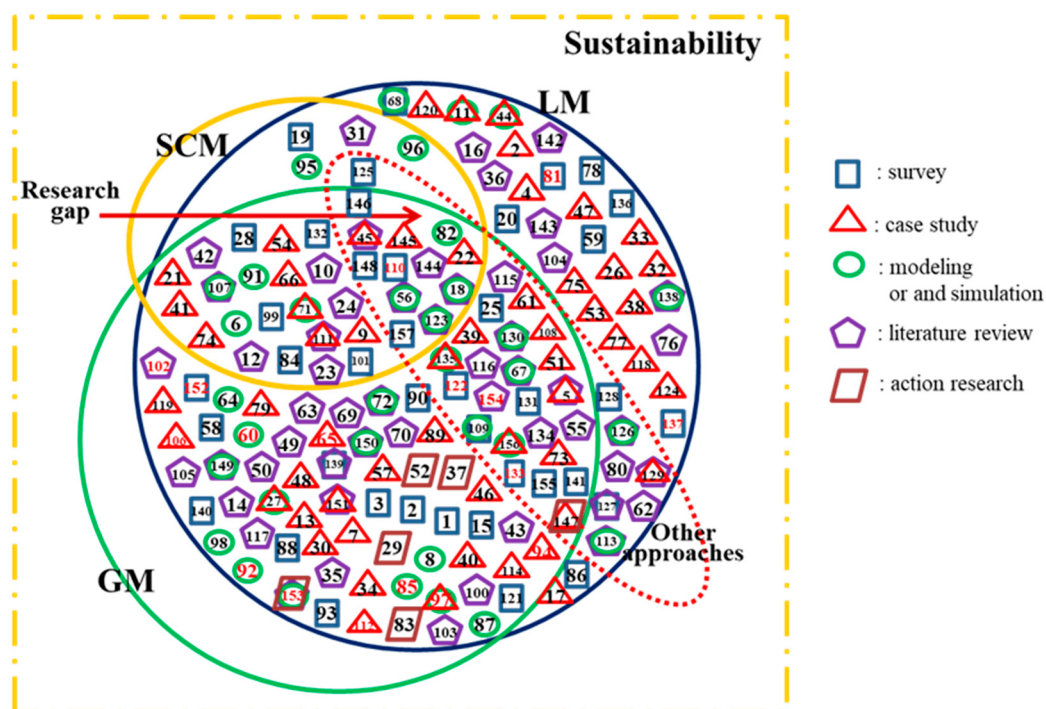


Figure 8. Links between lean, green, supply chain management, and sustainability in the literature review.

Figure 8 literature:

1. Florida [9]	41. Folinas et al. [50]	81. Sajan et al. [51]	121. Lartey et al. [52]
2. Maxwell et al. [53]	42. Duarte and Cruz-Machado [54]	82. Ruiz-Benitez et al. [55]	122. Dey et al. [56]
3. Rothenberg et al. [30]	43. Johansson and Sundin [57]	83. Barth and Melin [58]	123. Alqudah et al. [59]
4. Larson and Greenwood [60]	44. Wong and Wong [61]	84. Cherrafi et al. [62]	124. Tiwari et al. [63]
5. Simpson and Power [29]	45. Govindan et al. [42]	85. Gandhi et al. [49]	125. Nath and Agrawal [64]
6. Kainuma and Tawara [27]	46. Kurdve et al. [65]	86. Garza-Reyes et al. [66]	126. Mellado and Lou [67]
7. Vais et al. [68]	47. Piercy and Rich [43]	87. Gupta et al. [69]	127. Vallejo et al. [70]
8. Sawhney et al. [71]	48. Ng et al. [72]	88. Inman and Green [73]	128. R. et al. [74]
9. Mason et al. [75]	49. Garza-Reyes [15]	89. Leme Júnior et al. [76]	129. Parmar and Desai [77]
10. Mollenkopf et al. [25]	50. Qureshi et al. [78]	90. Ramos et al. [79]	130. Shokri and Li [80]
11. Miller et al. [32]	51. Wu et al. [81]	91. Thanki and Thakkar [82]	131. Udokporo et al. [83]
12. Carvalho et al. [84]	52. Domingo and Aguado [85]	92. Thanki and Thakkar [86]	132. Singh et al. [87]
13. Esmer et al. [88]	53. Ball [89]	93. Zhan et al. [90]	133. Ali et al. [91]
14. Clemens and Bakstran [92]	54. Wiese et al. [93]	94. Belhadi et al. [94]	134. Farrukh et al. [95]
15. Yang et al. [13]	55. Garza-Reyes [44]	95. Das [96]	135. Kaswan and Rathi [97]
16. Vinodh et al. [33]	56. Govindan et al. [45]	96. Zhu et al. [98]	136. Chen et al. [99]
17. Torielli et al. [100]	57. Verrier et al. [16]	97. Oliveira et al. [101]	137. Nawansir et al. [102]
18. Carvalho et al. [34]	58. Prasad et al. [103]	98. Leong et al. [104]	138. Kumar et al. [105]
19. Hong et al. [106]	59. Vinodh et al. [107]	99. Hussain et al. [108]	139. Tafazzoli et al. [109]
20. Bandehnezhad et al. [110]	60. Thanki et al. [46]	100. Farias et al. [26]	140. Agyabeng-Mensah et al. [111]
21. Azevedo et al. [35]	61. Sagnak and Kazancoglu [112]	101. Huo et al. [113]	141. Belhadi et al. [114]
22. Cabral et al. [36]	62. Cherrafi et al. [8]	102. Siegel et al. [6]	142. Solaimani and Sedighi [115]
23. Duarte and Cruz-Machado [116]	63. Hallam and Contreras [117]	103. Marco-Ferreira et al. [118]	143. Francis and Thomas [119]
24. Dües et al. [14]	64. Fercocq et al. [120]	104. Henao et al. [121]	144. Sharma et al. [122]
25. Hajmohammad et al. [37]	65. Thanki and Thakkar [123]	105. Bhattacharya et al. [124]	145. Essaber et al. [125]
26. Aguado et al. [38]	66. Campos and Vazquez-Brust [126]	106. Thanki and Thakkar [127]	146. Giovanni and Cariola [128]
27. Diaz-Elsayed et al. [129]	67. Kumara et al. [130]	107. Baliga et al. [131]	147. Tripathi et al. [132]
28. Wiengarten et al. [133]	68. Ugarte et al. [134]	108. Sony and Naik [135]	148. Raut et al. [136]
29. Pampanelli et al. [17]	69. Abreu et al. [137]	109. Kaswan and Rathi [138]	149. Teixeira et al. [139]
30. Galeazzo et al. [140]	70. Caldera et al. [141]	110. Dey et al. [142]	150. Cherrafi et al. [143]
31. Martínez-Jurado and Moyano-Fuentes [31]	71. Carvalho et al. [144]	111. Duarte and Machado [145]	151. Kurdve and Bellgran [146]

32. Chiarini [39]	72. Cherrafi et al. [47]	112. Choudhary et al. [1]	152. Thekkootte [24]
33. Faulkner and Badurdeen [40]	73. Cherrafi et al. [147]	113. Sindhvani et al. [148]	153. Siegel et al. [2]
34. Verrier et al. [41]	74. Duarte and Cruz-Machado [149]	114. Pandithawatta et al. [150]	154. Queiroz et al. [151]
35. Dhingra et al. [152]	75. Helleno et al. [48]	115. Gaikwad and Sunnapwar [153]	155. Jum'a et al. [154]
36. Ioppolo et al. [155]	76. Martínez-León and Calvo-Amodio [156]	116. Kaswan and Rathi [157]	156. Lim et al. [158]
37. Kurdve et al. [159]	77. Pinto and Mendes [160]	117. Abualfaraa et al. [161]	157. Waqas et al. [162]
38. Wu [163]	78. Raj et al. [164]	118. Hartini et al. [165]	
39. Banawi and Bilec [166]	79. Strzelczak [167]	119. Kumar and Rodrigues [168]	
40. Besseris and Kremmydas [169]	80. Chugani et al. [170]	120. Leite et al. [171]	

Some researchers revealed that the social dimension was included late in the discussion of sustainability requirements, causing a scarcity of theoretical and empirical studies on social sustainability. Our review shows increasing interest in social sustainability [2,172,173], which is about 41.4% of the 157 peer-reviewed journal papers. In fact, nowadays, the incorporation of the term “sustainability” in SCM is becoming one of the research trends. In highlighting this particular aspect of sustainable supply chain management (SSCM), this study is in line with Piplani et al. [174], who raised a number of questions that need to be addressed in this domain. For example, how should supply chains trade off economic and non-economic objectives when making managerial decisions? How do we extend the concept of lean principles beyond a pure operations perspective? How should supply chain members collaboratively deal with pressure from governments and other interest groups concerned with environmental and social issues?

A number of articles discuss and investigate how lean management affects environmental performance, or, in other words, as an enabler of increased environmental impacts. Several studies have found the opposite, where the application of environmentally friendly practices supports operational performance. It highlights the close relationship between the two practices and how the relationship between the two systems can support one another. To reduce or eliminate the challenges and weaknesses that arise when integrating these two practices, a number of selected articles discuss the relationship of lean and green practices with other model approaches, such as six sigma, agile, resilient, supply management, social management, process innovation, big data analytics, and others. For example, the Six Sigma approach is expected to reduce process variations that can lead to waste or inefficiency. An agile approach is expected to respond quickly to various customer needs. The resilient approach is expected to be capable of resistance, recovery, and so on.

The research streams are determined by detailing each article that focuses on the discussion of SMEs, as shown in Table 2. For each paper, we try to identify the enablers, main criteria, research findings, and limitations that support their research stream. Based on our review of 17 lean-green research papers in SMEs, the research streams can be divided into three categories: (1) influencing organizational performance (11 papers), (2) integrated lean-green implementation framework (5 papers), and (3) lean-green applications (1 paper). Lean-green studies in SMEs mostly use the survey method (29.4%), followed by case studies (23.5%), modeling and simulation (17.6%), etc.

Table 2. Enablers, findings, limitations, criteria, and research streams.

Author/s (Year)	Method/s	Enablers	Findings and Limitations	Criteria	Research Streams
Verrier et al. [41]	Case study: analyzed the practices of 21 Alsatian industrial companies.	ISO 14001 certification, green initiative and green performance plotting, corporate environmental program, lean-green matrix.	Findings: The study developed a Lean-Green management framework for SMEs that includes lean indicators, green intentions indicators, and green performance indicators. Limitations: Performance indicators need to be refined, and this is also a challenge in itself to convince many companies, especially SMEs, to adopt this Lean and Green methodology.	Green performance	
Thanki et al. [46]	Modelling and simulation: The AHP method was applied.	Lean: 5S, kaizen, SMED, visual control, cellular manufacturing, VSM, TPM, Kanban; Green: EMS, DFE, LCA, ISO 14001, 3R, EEC and IR, GSCP, OUNR.	Findings: The study developed an integrated framework for lean green systems to guide SMEs towards sustainable growth. Limitations: The study did not determine the interdependence between selected performance criteria and enablers, and it is necessary to conduct empirical investigative studies using SEM.	Operational and environmental performances	Influence on organizational performance
Sajan et al. [51]	A survey of 252 Indian manufacturing SMEs was undertaken. SEM was then used to examine the hypothesized relationships.	Process-centered focus, waste reduction, kaizen, 5S, pull production, JIT, high level of people involvement and participation, information sharing.	Findings: The study discovered that lean practice is positively associated with diverse sustainability performances (such as economic, environmental, and social) and that environmental sustainability is correlated with both economic and social sustainability performances. Limitations: The survey was limited to particular Indian states and relied on data from a cross-sectional survey of single respondents.	Sustainable performance (economic, environmental, and social performances)	

Table 2. Cont.

Author/s (Year)	Method/s	Enablers	Findings and Limitations	Criteria	Research Streams
Belhadi et al. [94]	A real-life case study of lean adoption at a small manufacturing company.	Pre-implementation step tools: lean-green policy, lean-green objectives, multi-functional team, pareto analysis, product/process matrix, master plan; Implementation step tools: 5S/housekeeping, green VSM, JIT, kaizen, TPM, six sigma, kanban, inventory reduction, cellular manufacturing, visual control; Post-implementation step tools: green scoreboard, knowledge management, work standards.	Findings: The study showed that there is a strong correlation between improvements in operational metrics and improvements in green metrics. Lean practices, such as 5S/housekeeping, SMED, Kanban, cellular manufacturing, AM, and QC, demonstrate widely their benefits for green performance. Limitations: The study cannot be generalized because it was only conducted at a pump manufacturing company.	Operational and environmental performances	Influence on organizational performance
Thanki and Thakkar [127]	The study employed a comprehensive approach by considering multiple case studies and DEAs in 8 Indian manufacturing SMEs.	Quality and environmental management certifications (such as ISO 9001, ISO 18001 [175], ISO 14001, ISO/TS 16949 [176]), organizational factors, lean-green tools and techniques: 5S/housekeeping, kaizen, TPM, visual control, SMED, GSCP, DFE, OUNR, 3R.	Findings: The study provided insight into lean-green performance improvement approaches in the SME context. Limitations: Because of the relatively small number of respondents and the nature of the organization analyzed, the study cannot be generalized.	Operational and environmental performances	
Dey et al. [142]	The survey data were gathered from 119 British SMEs and used a structural equation modeling approach. This study also had undertaken 12 case studies to validate the findings from the quantitative analysis.	Lean practices: Waste reduction, TQM, TPM, SPC, capacity utilisation, inventory management, SRM, CRM; Process innovation: Eco-design, GSCM, organizational green strategy; Sustainable practices: Economic (number of employees, infrastructure), environmental (waste management practices, energy consumption, and emission control), social (CSR practices).	Findings: The study demonstrated that although LP, sustainability practices, and PI help contribute to SME supply chain sustainability performance through efficiency and responsiveness, respectively, the mediation effect of LP is greater than that of PI. In addition, SMEs adopt LP when they focus on economic aspects and apply PI when they are under pressure from customers and/or policymakers. Limitations: The sample size of the dataset used in the current analysis is relatively small. Another limitation of the study is the borderline fit of the tested SEM model.	Sustainable performance (economic, environmental, and social performances)	

Table 2. Cont.

Author/s (Year)	Method/s	Enablers	Findings and Limitations	Criteria	Research Streams
Choudhary et al. [1]	This study was conducted using a single, detailed case study approach through a systematic methodology in a U.K.-based packaging manufacturing SME.	Process mapping, a novel green-integrated value stream mapping (GIVSM): current state and future state, root cause analysis (RCA), continuous improvement or Kaizen, visual management, SOPs, quality control, and supplier selection.	Findings: The study derived a novel green-integrated VSM to visualize the synergistic effect of lean-green on enhancing both operational efficiency and environmental performance. The research also suggests that it is necessary to reinvest both carbon and cost savings into sustainable procurement Limitations: The research only used a single case study.	Operational and environmental performances	
Dey et al. [56]	The SEM approach was used to analyze data gathered from 119 manufacturing SMEs in the Midlands, UK.	Lean manufacturing practices: waste reduction along the value stream, productivity enhancement programs (TQM, TPM, SPC, inventory control/management, capacity utilization), stakeholder management practices (SRM, CRM, management commitment, employee involvement); Sustainably-oriented innovation: eco-design (product design for reduced resource use, product design for reuse, recycling, and recovery, product design for emission reduction), green SCM (including green procurement, green manufacturing, and green marketing), organizational strategy (EMS ISO 14000) [177]; CSR practices: environmental management practices (energy management, resource management, waste management), social management practices (workforce wellbeing, wellbeing of concerned stakeholders, the implementation of CSR projects).	Findings: The study claimed that lean manufacturing practices and Sustainably-oriented innovation contribute to the achievement of both sustainability and economic performance. SOI mediates lean manufacturing practices to attain sustainability performance. In addition, CSR practices help enhance sustainability performance. The study also provides a conceptual framework for measuring sustainability performance with four major constructs, which consist of LMP, CSR, SOI, and sustainability performance. Limitations: The study focused on the LMP and SOI of manufacturing SMEs in the Midlands, UK. In addition, only CSR practices were considered mediators. Data had been collected from a small number of SMEs (119) in the UK. The constructs/latent variables and proxies/indicators are also limited.	Sustainable performance (economic, environmental, and social performances)	

Table 2. Cont.

Author/s (Year)	Method/s	Enablers	Findings and Limitations	Criteria	Research Streams
Ali et al. [91]	The data were gathered from 39 SMEs in Pakistan. SMEs from several industries, including manufacturing, automotive, service, and retail, were targeted. PLS factor analysis was used to perform the analysis. To examine the hypothesis's relationship, the Spearman correlation approach was applied.	Lean: productivity improvement, waste reduction or elimination, resource efficiency, TQM, JIT, inventory management, ISO 9001, etc.; Six Sigma: organizational, financial, human, and technological resources (the lens of RBV theory); Environmental sustainability practices: energy consumption reduction, raw material consumption reduction, life cycle assessment.	Findings: The study examines empirically the effect of lean, Six Sigma, and environmental sustainability on the performance of Pakistan SMEs. The results showed that the three management styles used had a positive impact on SMEs' environmental performance. Additionally, there was no significant association found between the three practices and SMEs' business and operational performance. Limitations: The study should be confirmed in the context of large enterprises. This was a cross-sectional study that investigated the association at a particular point in time. To cope with SMEs' inefficient and wasteful behaviors, which have a negative influence on overall business performance, SMEs need to refocus and reorganize their strategies. To attain this goal, it is assumed that lean, Six Sigma, and environmental sustainability approaches will be used.	Operational, business, and environmental performances	
Nawanir et al. [102]	The study used the SEM approach to analyze data collected from a total of 159 Malaysian manufacturing SMEs.	Lean: cellular layouts, flexible resources, pull system/kanban, quality at the source, quick setups, small lot production, supplier networks, TPM, uniform production level.	Findings: The results prove that the holistic implementation of LM practices influences positively to all 3BL dimensions, and SMEs should adopt the LM concept holistically. Limitations: The research is cross-sectional in nature and has the limitation of providing a clear picture of how LM affects each dimension of sustainability performance.	Sustainable performance (economic, environmental, and social performances)	

Table 2. Cont.

Author/s (Year)	Method/s	Enablers	Findings and Limitations	Criteria	Research Streams
Thekkooote [24]	The study used SEM with 210 participants in South African Manufacturing SMEs.	Lean manufacturing practices: (1) 5S, (2) Kaizen, (3) SMED, (4) Visual control, (5) VSM, (6) Cellular layout, (7) TPM, (8) Kanban, (9) Employee training, (10) Teamwork, (11) Continuous flow, (12) Lot size reduction, (13) Standard work, (14) Poka-Yoke; Green manufacturing practices: (1) EMS, (2) LCA, (3) DFE, (4) 3R, (5) GSCP, (6) OUNR, (7) ISO 14001, (8) Use of environmentally friendly raw materials; Sustainable manufacturing practices: (1) Reduced manufacturing costs, (2) Increased profit, (3) Reduced waste treatment costs, (4) Working conditions improved, (5) Labor relations improved, (6) Increased product responsibility, (7) Reduced production emissions per unit, (8) Decreased energy consumption in terms of noise, heat, and radiation, and (9) Reduced solid and liquid waste.	Findings: The study results demonstrate that LMP directly affects sustainability and also confirm that GMP has a significant mediating role. Limitations: The research focuses on manufacturing SMEs in South Africa, which may not have direct application to large-scale enterprises or other industrial sectors.	Sustainable performance (economic, environmental, and social performances)	
Gandhi et al. [49]	Modeling and simulation using MCDM methods such as TOPSIS and SAW with 9 experts.	Internal drivers: employee training, top management commitment, multi-skill worker, less machine breakdown, work standardization, technology upgradation, employee empowerment, organization culture; Economy and market drivers: cost savings, competitive advantage; Policy drivers: current legislation, future legislation, incentives; Society drivers: green brand image, public pressure.	Findings: The study revealed that top management commitment, technology up-gradation, current legislation, green brand image, and future legislation are the five most important drivers for the implementation of integrated lean and green practices in Indian manufacturing SMEs. Limitations: The study was still limited and requires further empirical investigation.	Drivers for Lean-Green implementation	Integrated implementation framework

Table 2. Cont.

Author/s (Year)	Method/s	Enablers	Findings and Limitations	Criteria	Research Streams
Thanki and Thakkar [86]	ISM and IRP modeling techniques were used in the analysis. The MICMAC analysis was also carried out.	(1) Effective leadership and management, (2) energy consumption reductions and waste minimization, (3) focus on customer, (4) worker involvement and training, (5) Communication of goals and objectives in relation to improvement initiatives (6) financial capabilities, skills, and expertise, (7) top management commitment, (8) changed mindsets and business culture establishment, (9) worker motivation and rewarding system (10) Initiatives for green waste disposal (11) make organizational strategies and policies clear, (12) capabilities of the organization (13) worker empowerment, (14) technology innovation, (15) government support (lean competition program and ISO or HACCP certification reimbursement program), (16) green standards adoption, (17) green manufacturing planning.	Findings: The study revealed “government support” as the most important factor in the effective adoption of lean-green in Indian SMEs, and it is placed at the bottom of the ISM hierarchy. Meanwhile, “green disposal initiatives” are identified at the top level of the ISM hierarchy. Limitations: The results cannot be generalized because the data are limited, and similar research is needed for other industrial sectors.	Drivers for Lean-Green implementation	Integrated implementation framework
Siegel et al. [6]	The study was conducted through a systematic review.	Cultural transformation, sustainable VSM, eco-design, ISO 14001, community engagement, LCA, local sourcing, reverse logistics, 5S, TPM, VSM, TQM, visual control, pull system, JIT, supplier network development, employee involvement or engagement, total preventive maintenance, TPM, cellular manufacturing, OEE, training, waste reduction, SMED, standardization, quick changeover, 5 why.	Findings: The study demonstrated a number of challenges to implementing Green-Lean practices in SMEs. The study also revealed that the most common challenge to implementing these practices is a lack of metrics and measurements. Limitations: The study did not describe the proposed model in detail, and there is a need for studies that have a greater focus on the SME context.	Drivers and Barriers for Lean-Green and Sustainability implementation	

Table 2. Cont.

Author/s (Year)	Method/s	Enablers	Findings and Limitations	Criteria	Research Streams
Siegel et al. [2]	The research methodology consists of 4 stages: (1) literature review, (2) interviews, (3) validity and refinement, and (4) framework.	Success factors: (1) management, (2) organizational goals and strategy, (3) Audits and reviews, (4) vision and guidance of the implementation framework; Challenges: (1) worker motivation and responsibilities, (2) measurements.	Findings: The research uncovers considerable implementation issues and also underlines the success factors for implementing Green-Lean and Sustainability in the SME context. Limitations: The sample size of the interviews was relatively small, and their study was geographically focused on Germany.	Drivers and Barriers for Lean-Green and Sustainability implementation	
Queiroz et al. [151]	The study used a SLR through top modeling approach.	Digital transformation, digital information through a radio frequency identification (RFID) chip, ICT, cloud computing technology, E-VSM, JIT, ERP, TPM, or OEE	Findings: The results showed that the visualization and integration of the process data collaborated with the performance measurement system, helping to make more appropriate decisions. Tools such as JIT, ERP, VSM, TPM, and E-VSM could be better supported by digitalization. Limitations: Not all papers can be read with the adopted algorithm.	Driver for Lean-Green implementation	
Oliveira et al. [101]	Case study, modeling, and simulation using two MCDM tools: AHP and Fuzzy-TOPSIS.	Continuous improvement, cross-project knowledge transfer, definition of value and value stream, ecodesign tools and green dynamic capabilities, knowledge and learning, life cycle assessment, process standardization, rapid prototyping simulation and testing, responsibility-based planning control, set-based engineering, simultaneous engineering, specialist career paths, workload leveling, strong project manager.	Findings: The study revealed 16 lean and green enablers for product development and also proposed a model that evaluates these practices regardless of organizational level. Each enabler was evaluated considering the SMEs context in Brazil. Limitations: The study cannot be generalized because only three companies were assessed, and it is necessary to conduct a survey with a wider scope.	Evaluation tool for new product development	Lean-Green application

Our review of selected articles on lean-green studies in SMEs suggests the distinct enablers of frameworks and guidance for implementing these practices, such as techniques and tools [6,24,46,51,56,91,94,178], metrics/measurements [2,41], top management commitment and leadership [49,86], organizational culture [6,49,86], organizational capabilities [86,91], government policies/legislations [49,86], public pressure [49], employee training [6,49,86,101], technology/infrastructure [49,86,91,142,151], other approaches such as innovation [56,142], six sigma [91], knowledge management [94,101], digital transformation [151], and so on. Critical lean practice tools and techniques in SMEs were found significant in the literature review, such as Kaizen [46,51,56,94,101,127,179], 5S or housekeeping [6,46,51,94,127], inventory reduction [6,51,56,91,94], waste reduction [6,51,86,91,142], visual control/poka-yoke [6,46,94,127], total productive maintenance (TPM) [6,46,56,94,127], employee involvement [6,51,56,86], work standardization [6,94,101], single-minute exchange die (SMED) [6,46,127], and value stream mapping (VSM) [6,41,101]. Critical green manufacturing tools and techniques in SMEs were found significant in the literature review, such as ISO14001 [6,41,46,56,86,127,179], reduce-reuse-recycle (3Rs) [46,56,86,91,127], life cycle assessment (LCA) [6,46,91,101], environmental emission control (EEC) [46,56,86,91,101], green supply chain practice (GSCP) [41,46,56,127], eco-design [41,56,101], and environmental management system (EMS) [46,56,86]. Nevertheless, most previous studies are limited to a particular country or industry, which cannot be generalized due to relatively small sample sizes, the nature of the organization studied, or data from a cross-sectional survey of single respondents.

Although the synthesis of lean and green practices enhances sustainability performance, various researchers highlight the challenges that businesses encounter when integrating and executing these two practices, especially for SMEs. Siegel [2] underlined that the current framework is more useful for large organizations, but it has not considered the characteristics of SMEs. Lack of financial and human resources is a challenge in implementing lean-green and sustainability. Hence, their study focused on developing a simplified and common framework for SMEs. Implementation of these two practices and sustainability improvement initiatives for smaller organizations is considered challenging. There is still a lack of research in this field. However, the existence of SMEs cannot be underestimated considering that they are numerous and do not stand alone as a single entity. Even though throughout the world, the role of SMEs is considered quite vital because SMEs and large organizations are often connected to complex supply chains or business networks [2,179,180]. Thus, the competitiveness of SMEs affects their ability to compete, survive, and contribute to a country's economic and social development.

Based on the resource-based view, the limited human resources of SMEs cause them to have less time to engage in additional tasks. Each SME employee is assigned a key role due to the lack of human resource reserves. Therefore, in general, SME management may perceive training as a waste of time. Additionally, Dues et al. [14] argued that the tendency to resist change as well as a lack of understanding and responsibility for environmental sustainability hampered its implementation. Similarly, SMEs' lack of financial resources limits them from investing heavily in human resource development, infrastructure, clean technology, or even digitalization. Albliwi et al. [181] revealed that labor constraints in SMEs are a critical failure factor for lean implementation. Thus, the transformation of organizational culture is one of the challenges for SMEs related to the implementation of improvement strategies.

Several researchers reveal that effective management and leadership present one of the main challenges [2,86,182]. Top management commitment and leadership can increase the success of continuous improvement programs because, on the one hand, SMEs often emphasize short-term goals with quick and uncomplicated achievements [183]. Meanwhile, on the other hand, employee resistance is another big challenge for SMEs. The involvement of employees and top management plays an important role in the implementation of this project.

Thanki and Thakkar [86] argue that the government's role is very important here. Gandhi et al. [49] also revealed that government policy is one of the most important drivers in the implementation of integrated green lean practices in Indian SMEs. Government policies and programs affect the sustainability performance and competitiveness of SMEs [184]. Banjo and Doren [185] suggest government intervention to encourage SMEs to be sustainable should go beyond financial assistance.

Singh et al. [186] investigated the strategies and policies of SMEs in China and India. The study found that SMEs regard lean adoption as more important for increasing productivity and organizational culture, as well as expanding their local supplier networks. According to Kot [28], there is no doubt that businesses in the SME sector need effective supply chain management in order to compete successfully on the global market. Uncertainties in supply and demand can be caused by parties in the supply chain having conflicting objectives and not working together. In order to direct the long-term operations of businesses, there is a need for effective and sustainable supply chain management, which is best defined as the integration of suppliers, manufacturers, distributors, and customers to emphasize their competitive advantages such as increased profitability, lowest costs, high quality of products, better customer service, and lower risk of negative environmental and social impacts.

Santos et al. [187] argued that SMEs can overcome their challenges related to resource constraints and market power only through collaboration. To promote collaboration and co-development of new products, information must be shared with all supply chain participants. According to Silvia et al. [188], SMEs play an important role in transmitting sustainability requirements by communicating and disseminating sustainable development practices effectively throughout their supply chain. Cader and Leatherman [189] suggest that effective and open communication with all stakeholders is necessary for sustainable development for SMEs and is one of the main aspects of collaborative synergy.

Thus, we integrate all of these views and discussions to suggest the following future research directions: (1) What practices or enablers can contribute to better lean and green integration for SMEs? (2) What factors or other constructs can moderate the impact of lean and green practices on the sustainability performance of SMEs supply chains? (3) Does top management commitment and leadership (TMCL) provide any moderating effect on the association between lean and green practices for SMEs? (4) Does organizational culture transformation (OCT) provide any moderating effect on the association between lean and green practices for SMEs? (5) Do lean and green practices have a significant impact on the sustainability performance of SMEs supply chains? (6) Does green practice provide any mediating effect between lean practice and the sustainability performance of SMEs supply chains? (7) What practices or enablers could contribute to the better supply chain performance of SMEs in terms of economic, environmental, and social criteria? (8) Does policy initiatives (PI) provide any moderating effect on the association between integrated lean-green practices and the sustainability performance of SMEs supply chains? (9) Does collaborative synergy (CS) provide any moderating effect on the association between integrated lean-green practices and the sustainability performance of SMEs supply chains? (10) What are the most critical performance criteria for lean-green integration in the supply chains of SMEs?

4. Conclusions

This systematic literature review is intended to find gaps in the lean-green research area that require development in future studies, especially for SMEs. This article aims to answer two research questions that are mentioned in the introduction section. The bibliometric analysis carried out made it possible to observe research trends on Lean and Green traced from 1996 to 2022. All selected articles were subjected to descriptive analysis, such as the distribution of articles published per year, the cumulative frequency of the number of articles published based on the research topic, the research method per year, the variety industrial sector, the geographic area of the research study, and the number of

citations. The results show that most of the research on Lean and Green uses the case study method, followed by a literature review. In its development, research based on surveys and modeling is also increasing, as well as action research or a combination of these methods. Meanwhile, lean-green studies in SMEs mostly use the survey method, followed by case studies, modeling, simulation, etc.

Our review also indicated that there is a lack of empirical research that comprehensively investigates the impact of lean and green practices on sustainable supply chain performance and involves all three aspects of the 3BL, namely economic, environmental, and social aspects. In particular, empirical research focusing on lean and green practices in manufacturing SMEs is also limited. While it is understandable that lean and green practices are mostly sensible for large companies, it is also important to bring these practices to SMEs, as they are the dominant players in various industry sectors. SMEs are part of larger supply chains and contribute substantially to the economy, and thus perhaps there is a need for a workable model that attracts them to lean and green practices, by, for example, involving the government and industry associations. Our review suggests such a robust and workable model is not currently available, a subject that requires development in future studies.

Based on our in-depth review, the research streams on lean-green studies in SMEs can be divided into three categories: influencing organizational performance, integrated lean-green implementation framework, and lean-green application. Our review of selected articles on lean-green studies in SMEs suggests the distinct enablers or challenges of frameworks and guidance for implementing these practices, such as tools and techniques, metrics/measurements, top management commitment and leadership, organizational culture, organizational capabilities, government policies/legislations, public pressure, employee training, technology/infrastructure, and other approaches such as innovation, six sigma, knowledge management, digital transformation, and so on. This article also discusses and reviews a number of challenges for SMEs in adopting lean-green, and we propose a number of research questions for future research directions.

A limitation of this review is the use of keywords, or “terms”, to select articles. This is a common limitation in SLR and is due to the subjectivity of the researcher. Thus, a new systematic literature review can be carried out by expanding the scope of the review by adopting a different article screening procedure. Unlike many studies on Lean and Green practices, we include the context of supply chain and sustainability in SME organizations performance to be further investigated.

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