

Lean manufacturing and sustainability pillars. A systematic literature review

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Abstract

Purpose – Organisations are no longer able to avoid the new and critical stakeholder awareness of the impacts they generate in the surrounding context. In this perspective, it is crucial to adopt an innovative business model that can optimise the entire corporate system, generating a positive long-term impact in terms of sustainability and value creation for all stakeholders. All this is explained by an integrated approach, Lean-Sustainability (LS), which represents a new management paradigm, based on the joint consideration of Lean practices and all pillars of sustainable development. Therefore, this study aims to analyse the current state of the art on the relationship between Lean and Sustainability, identifying possible gaps and opportunities for future research.

Design/methodology/approach – A Systematic Literature Review (SLR) is conducted to examine and classify 188 scientific documents on the issue of Lean and Sustainability practices published in the Scopus database from 2012 to 2024.

Findings – The results confirm the existence of a positive relationship between the adoption of a Lean approach and the achievement of sustainability goals, thus enabling organisations to improve their environmental, economic and social performance. However, it is emphasised that more empirical investigations on the subject are needed, which still appear to be lacking, especially with reference to the social pillar.

Originality/value – Besides enriching the literature on the subject, the study encourages companies to act in an integrated Lean-sustainability perspective, as it meets new stakeholder needs and increases competitiveness in the long term.

Keywords Sustainability, Systematic literature review, Lean production, Lean manufacturing, Lean and sustainability

Paper type Literature review

1. Introduction and theoretical framework

In a highly globalised context, characterised by a close interdependence of industrial, economic and financial systems and an inalienable ubiquity and mobility of people, the emergence of an unexpected condition, such as the COVID-19 pandemic, has necessarily disturbed the daily lives of people and companies, distorting priorities and revolutionising business models. Despite of having seriously altered the balance of the affected economies, the pandemic crisis has contributed to the development of new trends and the rapid rise in phenomena already underway (Almeida *et al.*, 2020; Pinzaru *et al.*, 2020; Trabucco and De Giovanni, 2021; Su *et al.*, 2022), such as digitalisation and sustainable development. The



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widely shared definition of sustainable development is the one formulated in the Brundtland Report, carried out in 1987 by the World Commission on Environment and Development (WCED). According to this report, sustainable development can be defined as “development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs” (WCED, 1987, p. 43). Even though this definition has undergone a profound evolution over time (Linnenluecke and Griffiths, 2010; Haugh and Talwar, 2010; Yin and Jamali, 2016; Hajian and Kashani, 2021), scholars agree that the concept of sustainability translates into the adoption of a three-dimensional approach to corporate governance, based on the integration of economic, social and environmental perspectives (Hourneaux *et al.*, 2018; Lozano, 2020; Loviscek, 2020; Spallini *et al.*, 2021). For organisations, sustainable development means improving social and human well-being and reducing their environmental impact, while ensuring the achievement of corporate objectives (Schaltegger *et al.*, 2022).

In this perspective, businesses are facing a huge challenge, which requires the definition of policies and strategies strongly oriented to achieve sustainable objectives, crucial for success and competitiveness in the market, not only today, but also in the future (Lopez-Torres *et al.*, 2022; Urbancová and Vrabcová, 2023). To this end, it is necessary to adopt an innovative business model that is able to optimise the entire corporate apparatus, producing a positive long-term impact in terms of sustainability and value creation for all the actors involved (Bocken and Geradts, 2020; Parida *et al.*, 2019; Shakeel *et al.*, 2020; Acciarini *et al.*, 2022). All this is explained in the context of an integrated approach Lean – Sustainability that represents a new management paradigm (Yu *et al.*, 2020; Teixeira *et al.*, 2021; Jum’a *et al.*, 2022; Wadood *et al.*, 2022), based on the joint consideration of economic, environmental and social sustainability, with the final aim to make the corporate system “agile, adaptive, and aligned in balancing the people and the planet with profits” (Kleindorfer *et al.*, 2005).

Although apparently distant, the themes of Lean Manufacturing and Sustainable Development are closely related and mutually complementary. Indeed, Lean Manufacturing, also known as Lean Production (Varela *et al.*, 2019) or Lean Thinking (Amaro *et al.*, 2019), is a set of techniques and strategies aimed at reducing waste by identifying and eliminating activities that do not add value to the final product or consumers (Verrier *et al.*, 2014; Rodrigues *et al.*, 2019; Santos *et al.*, 2019). Specifically, Lean Production identifies seven different kinds of waste, namely “overproduction, waiting, transport, defects, inappropriate processing, unnecessary inventory and unnecessary motion” (Azevedo *et al.*, 2019). However, in more recent developments of Lean thinking, an eighth waste has been identified, named the non-utilisation of human potential, which concerns the lack of employee involvement and recognition of workers’ skills (Nwanya and Oko, 2019; Patel *et al.*, 2022; Tanasic *et al.*, 2022). This waste refers to the failure to leverage employees’ full potential, which can lead to disengagement, lower productivity and decreased innovation. Addressing this issue is crucial for the social pillar of sustainability, as it emphasises the importance of human capital development, employee well-being, and continuous learning within organisations. Furthermore, two additional types of inefficiencies have been defined, that is, *muri* and *mura*. The former refers to the excessive workload on workers and equipment, while the latter pertains to the variability of production processes (Pieńkowski, 2014).

Through the implementation of different methodologies and tools, Lean Manufacturing thus allows for a decrease in waste and inefficiencies with consequent benefits not only in operational terms (Rodrigues *et al.*, 2019), but also in environmental and social dimensions (Dieste *et al.*, 2019; Dey *et al.*, 2020; Teixeira *et al.*, 2021; Jum’a *et al.*, 2022). According to Solaimani and Sedighi (2020), Lean tools generate a positive impact on all components of sustainability, reducing production costs (economic effect), waste of resources (environmental

effect) and activities dangerous to workers (social effects). In this sense, the adoption of an integrated Lean-Sustainability approach could support businesses in addressing the high costs associated with the availability of material and financial resources (Verrier *et al.*, 2014) and the growing attention to social and environmental issues (Fercoq *et al.*, 2016), thus acquiring an important and lasting competitive advantage.

Over time, many scholars have focused their attention on the existing correlation between Lean and sustainability (De Carvalho *et al.*, 2017; Tasdemir and Gazo, 2018; Dieste *et al.*, 2020; Dey *et al.*, 2020; Teixeira *et al.*, 2021; Jum'a *et al.*, 2022), trying to demonstrate that this combination allows companies to increase their performance in terms of operational efficiency and sustainable practices. In particular, the emphasis was placed on the obvious relationship between the Lean approach and the environmental component of sustainability (Dieste *et al.*, 2019; Francis and Thomas, 2020; Teixeira *et al.*, 2022; Jum'a *et al.*, 2023), starting from the same basic assumption, namely the reduction of waste. In fact, the green concept that aims to eliminate environmental waste combined with Lean concept seems to be a potential approach to improve environmental performance of organisations (Abreu *et al.*, 2017; Leong *et al.*, 2019; Chiarini *et al.*, 2023). For this reason, although the Lean techniques have always been analysed to achieve progress in terms of processes, activities, and business economy, in more recent years, efforts have been made to exploit their potential also in the environmental field (Tripathi *et al.*, 2021; de Oliveira Rezende *et al.*, 2022). In 2007, the USA Environmental Protection Agency (US EPA) investigated the possible integration between Lean practices and environmental protection activities, analysing the experiences of some American companies such as 3M, General Motors, and Lockheed Martin. In particular, the study pointed out the natural adaptability of Lean management tools to the analysis of environmental waste, demonstrating that there are real and direct environmental benefits resulting from the simple and direct application of these approaches. The application of Lean techniques, focused on the elimination of waste and non-value activities, together with the use of environmental parameters, focused on the identification and elimination of environmental waste, allows at the same time to increase production efficiency, and reduce environmental impact (Inman and Green, 2018; Garza-Reyes *et al.*, 2018; Dieste *et al.*, 2020; Silva *et al.*, 2020; Teixeira *et al.*, 2022). Similarly, Cherrafi *et al.* (2018) identified a positive correlation between Lean methodology and environmental protection activities, stating that Lean practices, such as reducing setup time, and green practices, such as Life Cycle Assessments (LCA) and eco-design, contribute to improving the environmental performance. In the same way, Udokporo *et al.* (2020) confirmed the influence of Lean tools in reducing waste in environmental terms and decreasing expenses besides lead-times through the development of a structural equation modelling based on data gathered from 96 fast-moving consumer goods organisations. It's evident, therefore, that the integration between Lean and green approaches to the management of the company can bring a superior enhancement of the organisation's performance (Fercoq *et al.*, 2016; Dieste *et al.*, 2019; Singh *et al.*, 2021a; Kovilage, 2021; Teixeira *et al.*, 2022), ensuring simultaneously competitiveness in the market and respect for the environment. At the same time, Lean positive effects on economic performance, as well as on operational performance, were already demonstrated several times (Henao *et al.*, 2019), namely in terms of cost savings and quality improvement (Santos *et al.*, 2019; Sá *et al.*, 2020; Murmura *et al.*, 2021). The adoption of Lean strategies, focused on the efficient use of resources and the maximisation of the value flow created, allows for the sustainment of lower costs and the increase in the quality of the products offered.

Although the correlation between the Lean philosophy and the economic and environmental pillars of sustainability has been widely discussed and validated in the

empirical and academic fields, many scholars agree that it is necessary to explore the impact on the social dimension (Tasdemir and Gazo, 2018; Caiado *et al.*, 2019; Dey *et al.*, 2020; Chavez *et al.*, 2022; Jum'a *et al.*, 2022; Teixeira *et al.*, 2022). According to Teixeira *et al.* (2021), most studies on the effects of the combination Lean and Sustainability only reported positive effects for the economic and environmental pillars of sustainability (Fernández Carrera *et al.*, 2021; Ciannella and Santos, 2022; Chavez *et al.*, 2022). Similarly, Choudhary *et al.* (2019) stated that there are not many empirical studies that analyse the Lean approach regarding its gains in terms of sustainability (as a whole), especially within the scope of the manufacturing sector.

Hence, given the need to acquire more knowledge to understand the relationship between Lean and sustainability, this study aims to identify the main trends in this field of study, while outlining possible future research directions. Specifically, it seeks to address the following research question:

RQ1. What is the current state of the art regarding the integration of Lean Production (or Manufacturing) and the three pillars of sustainability?

To this end, a Systematic Literature Review (SLR) is conducted, which led to the identification of 188 documents relevant to the topic explored.

This research work thus contributes to enhancing the existing literature by summarising the main findings on this subject and identifying possible gaps to be filled in the next studies. Furthermore, it offers insights for enterprises on the need to implement tools capable of combining Lean methodologies with the three dimensions of sustainability, responding to the increasing attention on social welfare and environmental preservation.

The paper is organised into the following sections. Firstly (Section 2), the applied research methodology and the research criteria for gathering all analysed information are presented. Secondly, the results of the systematic literature review are described (Section 3). Thirdly (Section 4), the discussion of the findings obtained, the main conclusions and contributions, the future research opportunities, as well as the limitations of the study are illustrated.

2. Research methodology

To identify, classify and summarise the current state of knowledge regarding the relationship between Lean manufacturing and sustainability, alongside defining future research agendas on the topic, a Systematic Literature Review (SLR) is developed. This methodology provides insight into current and future research trends (Tranfield *et al.*, 2003; Jones, 2004), while ensuring the replicability, reliability, accuracy, and transparency of the conducted literature review (Fink, 2019; Watson and Webster, 2020).

The first step in conducting a systematic literature review concerns the selection of sources, which should be of high quality and reliability. Therefore, it has been decided to use the Scopus database, which is characterised by its quality standards, wide range of publications covered, ease in downloading data and completeness of information available (Harzing and Alakangas, 2016; Herrera-Franco *et al.*, 2020). Next, it is necessary to define the search criteria. The correct choice of keywords becomes crucial to compose the sample and ensure that the search is complete and robust (De Carvalho *et al.*, 2017); these are carefully chosen based on their prevalence and significance in existing literature. To this end, the keywords identified are (“Lean manufacturing” OR “Lean production”) AND “sustainability”; they have been searched in the title, abstract and keywords of each type of document present in the chosen online database and consistent with the topic investigated.

By including these keywords within the Scopus database, the research ensures that no relevant study has been overlooked, thus enhancing the robustness of the sample.

Thirdly, the time period to be considered for the study has to be established. To perform an as comprehensive as possible analysis of Lean and sustainability publications, the period selected is from 2012 to 2024. The timeframe of 2012 to 2024 is chosen for several reasons. Firstly, this period marks a significant phase in the evolution of sustainability practices within industries, with increased global emphasis on environmental, economic, and social sustainability. The starting year, 2012, is selected as it could be considered a starting recovery year that follows the global financial crisis of 2008–2009, a period that witnessed a paradigm shift in business practices towards more sustainable models as companies sought resilience and long-term viability. Additionally, the decision to include publications up to 2024 allows for the most current trends and practices to be analysed, providing a contemporary perspective on the integration of Lean and sustainability. This approach ensures that the review is both current and reflective of the latest developments in the field.

These three steps led to a sample of 652 publications.

With the aim of refining and delimiting the analysis to the most relevant and pertinent publications for the subject under investigation, additional selection criteria are applied. The study includes articles, conference papers, book chapters, books that have reached the final stage of publication, excluding those in press. Furthermore, it is decided to limit the selection exclusively to documents in English, as this is the most widely used language in scientific publications (Cisneros *et al.*, 2018). Consistent with the objective of the study, three specific research categories were considered:

- (1) Business, Management and Accounting;
- (2) Social Science; and
- (3) Economics, Econometrics and Finance.

As a final step in the filtering process, all abstracts are carefully read to assess their relevance to the field investigated. At the end of this screening process, a final sample of 188 publications is obtained.

The selected documents are examined through an in-depth content analysis, for which Microsoft Excel spreadsheets were used. In particular, the elements explored concern the year of publication, type of document, journal, average citations per year and country of origin. A classification by area of application and research stream focus is also carried out; finally, synergies between Lean and the three dimensions of sustainability are identified.

3. Results

3.1 *Distribution of publications over time*

The scientific contributions obtained during the period considered (2012–2024) show an increase, especially in the last few years (Figure 1). Out of 188 papers, 154 were published in the period 2018–2024, denoting the growing interest of researchers in the relationship between Lean and sustainability. These data also show that the research topic is still recent and suggest that this trend will continue to grow over time as more publications are added to the literature on the topic. The explanation for this increase could be the greater insistence with which practitioners and scholars are asked to find business solutions that are both efficient and sustainable. 2021 and 2022 are the years with the highest number of publications, with 28 in both cases. These are followed by 2023 and 2024, each with 23 and 18 documents.

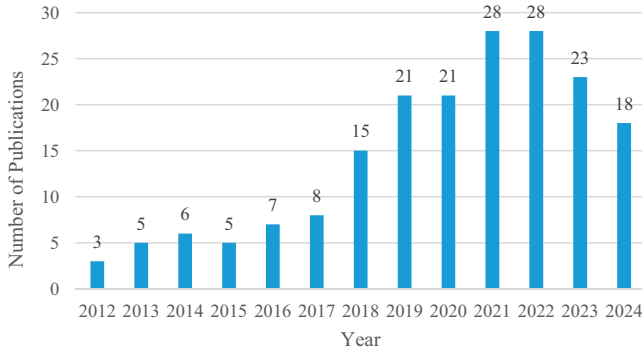


Figure 1. Distribution of publications over years from 2012 to 2024
Source: Authors' own work

3.2 Document type, citation and journal distribution

As illustrated in [Figure 2](#), the majority of publications in the field are articles, which account for 79.3% of the total considered, underlining once again the interest of the scientific community in the potential related to the combination of Lean and sustainability dimensions. Although conference proceedings take less time to be published, they make up only 13.3%, while book chapters and books are just under 8.0%. In terms of citations ([Figure 3](#)), 2019 is the year with the highest average number of citations (151.8). Despite 2021 and 2022 being the years with the most publications, they rank fourth and fifth in terms of average annual citations, each with values of 95.2 and 89.8.

Considering only articles, the *Journal of Cleaner Production and Sustainability* are the journals with the highest number of publications on Lean and sustainability, 34 and 30, respectively (see [Table 1](#)). The difference is, therefore, considerable compared to the other journals, where the number of published articles ranges between 7 and 2. It should also be pointed out that many of the identified journals have only one publication. In total, 80 journals were identified, thus demonstrating that the Lean-sustainability relationship investigated is particularly complex and is suitable for multiple areas of interest and

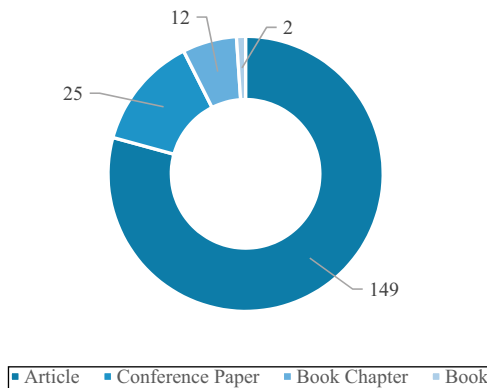


Figure 2. Document type
Source: Authors' own work

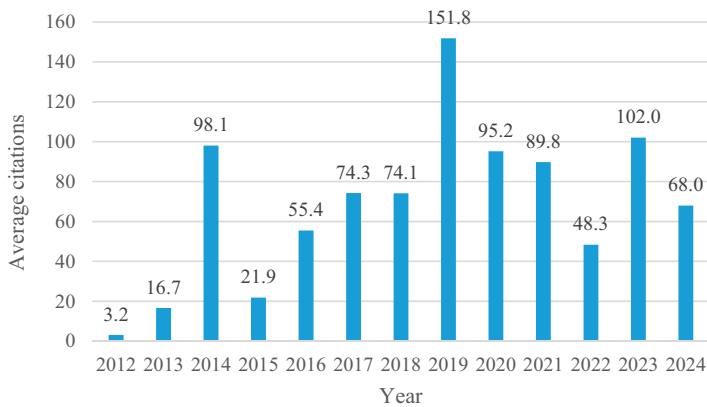


Figure 3. Distribution of publications per average citations per year
Source: Authors' own work

application (i.e. [Abualfaraa et al., 2023](#); [de Souza Lima et al., 2023](#); [Eskandari et al., 2022](#); [Goyal et al., 2022](#); [Maware and Parsley, 2023](#); [Martins et al., 2023](#)).

3.3 Geographical distribution

As illustrated in [Figure 4](#), the scientific contribution to the relationship between Lean and sustainability varies significantly from one country to another. Nevertheless, it was possible to identify the top 10 countries that generated the most research work on the topic. Based on the author affiliation available in the Scopus database, India is the most active country on the subject with a total number of 35 publications, followed by Brazil (16), Spain (14), the USA (12), the UK (10) and Portugal (10). These results can be attributed to several factors, including the industrial and policy environments in these nations. For instance, India's prominence in Lean and sustainability research is supported by its large and diverse manufacturing sector, which faces increasing pressure to adopt sustainable practices due to both domestic and international regulatory demands. Moreover, India's academic institutions and research bodies have increasingly focused on sustainability, driven by national policies that encourage green growth and resource efficiency.

In the UK and the USA, the strong collaboration between academia and industry plays a crucial role in advancing Lean and sustainability research. These countries benefit from well-established networks that facilitate the transfer of knowledge and best practices between researchers and practitioners. Additionally, government policies and funding mechanisms in these nations often prioritise sustainability research, further contributing to the high output of scholarly work in this area.

3.4 Application area and research stream focus

The publications are also distributed according to the area of application and the type of interaction between Lean and sustainable dimensions. It is important to stress that some empirical studies made a generic reference to belonging to the manufacturing sector, without specifying the precise industry segment. Therefore, these research works are combined into a single category, namely "other manufacturing." Denoting that the Lean-sustainability relationship is still in the development phase, it can be seen how the predominance of publications belongs to the theoretical area, which accounts for 41% of the total considered

Table 1. Publication distribution per journal

Journal	Publications	
	n	%
<i>Journal of Cleaner Production Sustainability (Switzerland)</i>	34	18.1
<i>Proceedings of the International Conference on Industrial Engineering and Operations Management</i>	30	16.0
<i>Journal of Manufacturing Technology Management</i>	7	3.7
<i>Production Planning and Control</i>	7	3.7
<i>International Journal of Production Economics</i>	5	2.7
<i>International Journal of Lean Six Sigma</i>	4	2.1
<i>International Journal of Production Research</i>	4	2.1
<i>Advances in Transdisciplinary Engineering</i>	4	2.1
<i>Lean Engineering for Global Development</i>	4	2.1
<i>Journal of Green Building</i>	3	1.6
<i>Proceedings of the Summer School Francesco Turco</i>	3	1.6
<i>Process Integration and Optimization for Sustainability</i>	2	1.1
<i>International Journal of Productivity and Performance Management</i>	2	1.1
<i>Technological Forecasting and Social Change</i>	2	1.1
<i>Journal of Advanced Manufacturing Technology</i>	2	1.1
<i>International Journal of Quality and Service Sciences</i>	2	1.1
<i>Journal of Construction Engineering and Management</i>	2	1.1
<i>Environmental Impact Assessment Review</i>	2	1.1
<i>IEEE International Conference on Industrial Engineering and Engineering Management</i>	2	1.1
<i>IEEE Transactions on Engineering Management</i>	2	1.1
<i>International Journal of Productivity and Quality Management</i>	2	1.1
<i>TQM Journal</i>	2	1.1
<i>Circular Economy Implementation for Sustainability in the Built Environment</i>	2	1.1
<i>International Journal of Mathematical, Engineering and Management Sciences</i>	1	0.5
<i>Social Responsibility Journal</i>	1	0.5
<i>Benchmarking</i>	1	0.5
<i>Clean Technologies and Environmental Policy</i>	1	0.5
<i>Increasing Supply Chain Performance in Digital Society</i>	1	0.5
<i>2022 IEEE 14th International Conference of Logistics and Supply Chain Management, LOGISTIQUA 2022</i>	1	0.5
<i>International Journal of Public Sector Performance Management</i>	1	0.5
<i>International Journal of Enterprise Network Management</i>	1	0.5
<i>2022 International Conference on Interdisciplinary Research in Technology and Management, IRTM 2022 – Proceedings</i>	1	0.5
<i>International Journal of Systems Science: Operations and Logistics</i>	1	0.5
<i>Journal of Open Innovation: Technology, Market, and Complexity</i>	1	0.5
<i>Strategic Direction</i>	1	0.5
<i>Design Methodology for Future Products: Data Driven, Agile and Flexible</i>	1	0.5
<i>Corporate Governance (Bingley)</i>	1	0.5
<i>Gestao e Producao</i>	1	0.5
<i>International Journal of Supply Chain Management</i>	1	0.5
<i>International Journal of Business Excellence</i>	1	0.5
<i>International Journal of Social Ecology and Sustainable Development</i>	1	0.5
<i>International Journal of Quality and Reliability Management</i>	1	0.5
<i>Managing Technology for Inclusive and Sustainable Growth – 28th International Conference for the International Association of Management of Technology, IAMOT 2019</i>	1	0.5
<i>International Journal of Services and Operations Management</i>	1	0.5
<i>Quality – Access to Success</i>	1	0.5
<i>Kybernetes</i>	1	0.5

(continued)

Table 1. Continued

Journal	Publications	
	n	%
<i>World Sustainability Series</i>	1	0.5
<i>Proceedings of the 32nd International Business Information Management Association Conference, IBIMA 2018 - Vision 2020: Sustainable Economic Development and Application of Innovation Management from Regional Expansion to Global Growth</i>	1	0.5
<i>International Journal of Business Innovation and Research</i>	1	0.5
<i>Supply Chain Forum</i>	1	0.5
<i>Novosibirsk State Pedagogical University Bulletin</i>	1	0.5
<i>International Journal of Fashion Design, Technology and Education</i>	1	0.5
<i>Journal of Business Ethics</i>	1	0.5
<i>PICMET 2016 – Portland International Conference on Management of Engineering and Technology: Technology Management For Social Innovation, Proceedings</i>	1	0.5
<i>Journal of Management Development</i>	1	0.5
<i>Journal of Purchasing and Supply Management</i>	1	0.5
<i>Human Factors and Ergonomics In Manufacturing</i>	1	0.5
<i>Innovation, Technology and Knowledge Management</i>	1	0.5
<i>Journal of Japan Industrial Management Association</i>	1	0.5
<i>Safety Science</i>	1	0.5
<i>The Green Factory: Creating Lean and Sustainable Manufacturing</i>	1	0.5
<i>International Journal of Industrial Engineering and Management</i>	1	0.5
<i>Sustainability: Utilizing Lean Six Sigma Techniques</i>	1	0.5
<i>International Journal of Value Chain Management</i>	1	0.5
<i>International Conference on Quality Engineering and Management</i>	1	0.5
<i>Engineering, Construction and Architectural Management</i>	1	0.5
<i>Springer Proceedings in Business and Economics</i>	1	0.5
<i>Proceedings of the 11th International Conference on Production Research – Americas: Icpur Americas 2022</i>	1	0.5
<i>HBRC Journal</i>	1	0.5
<i>Proceedings of the LACCEI international multi-conference for engineering, education and technology</i>	1	0.5
<i>Total Quality Management and Business Excellence</i>	1	0.5
<i>Quality Innovation Prosperity</i>	1	0.5
<i>International Journal of Innovation and Sustainable Development</i>	1	0.5
<i>Lecture Notes in Production Engineering</i>	1	0.5
<i>Journal of Business and Industrial Marketing</i>	1	0.5
<i>Asia-Pacific Journal of Business Administration</i>	1	0.5
<i>Data Analytics and Business Intelligence: Computational Frameworks, Practices, and Applications</i>	1	0.5
<i>EMJ – Engineering Management Journal</i>	1	0.5
<i>Journal of Decision Systems</i>	1	0.5
Total	188	100.0

Source(s): Authors' own work

(Table 2). This is followed by the “other manufacturing” category, which accounts for 29.3%, confirming that the integration of Lean and sustainability is an effective solution to meet today’s pressing challenges and to respond to the growing stakeholder demand for sustainable solutions. The remaining publications are spread across a variety of sectors, with construction (4.8%) and automotive (3.7%) predominating. This fragmentation demonstrates the polyhedral nature and versatility of the integrated Lean-sustainability approach, which can be applied in different areas. As can be seen from Table 2, moreover, most studies (both

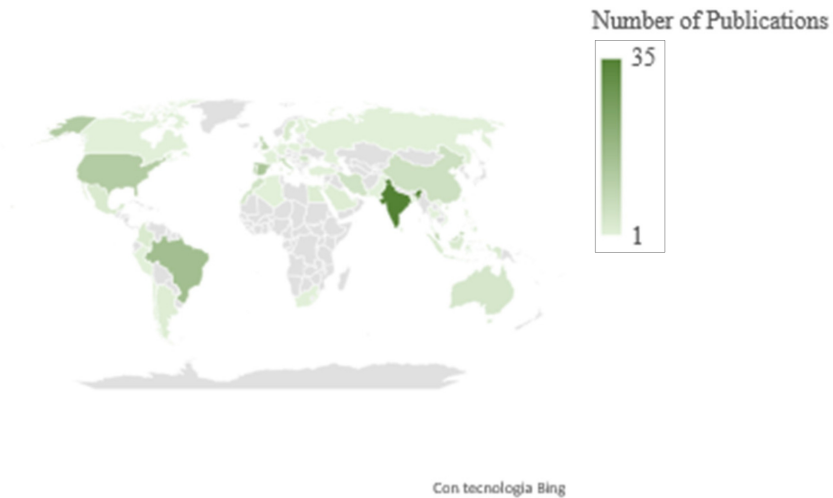


Figure 4. Geographical distribution of publications
Source: Authors' own work

theoretical and empirical) appear to pay more attention to the combination of Lean and one or two sustainability dimensions, predominantly the environmental one or its conjunction with the economic component. For example, the manufacturing sector has mostly focused on the Lean interaction with the environment and the environment and economy, which together account for 58.1% of the total publications in the sector. Similar considerations can be made for construction, agrifood, energy, iron and steel, healthcare and packaging. Adopting a holistic approach to the topic mainly involves publications of a theoretical nature (38.8%), while little interest is paid to the social dimension. Excluding studies that consider Lean and sustainability (as a whole), only 6.9% of the publications investigated the relationship between Lean and the social pillar, either singly or jointly with one of the other two dimensions of sustainability.

The concentration of publications in industries like manufacturing and construction is not surprising, given the significant environmental and economic impact these sectors have. Manufacturing has long been a focus of Lean practices due to its potential for efficiency gains and waste reduction, which directly align with sustainability goals. The construction industry, similarly, has seen growing interest in Lean methodologies to improve project efficiency, reduce material waste, and enhance sustainability outcomes in a sector traditionally associated with high resource consumption and waste generation.

On the other hand, sectors such as healthcare, education, and apparel, though represented, face unique challenges and barriers that may explain their lower representation in Lean and sustainability research. For instance, the healthcare sector deals with complex regulatory environments and a strong emphasis on patient safety, which can complicate the integration of Lean practices with sustainability initiatives. Similarly, the apparel industry, while increasingly focused on sustainability due to consumer demand, faces challenges related to supply chain transparency and the adoption of sustainable materials and practices, which can limit the application of Lean methodologies. A more nuanced analysis of these sectors can reveal future research opportunities addressing these barriers.

Table 2. Application area distribution and research stream focus of publications (number of publications; percentages)

Application area	Total sample		Lean + sustainability		Lean + environment		Lean + economic		Lean + social		Lean + environment and economic		Lean + environment and social		Lean + economic and social	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Theoretical	77	41.0	26	38.8	28	53.8	6	37.5	4	36.4	13	32.5	0	0.0	0	0.0
Agri-food	6	3.2	0	0.0	0	0.0	2	12.5	0	0.0	4	10.0	0	0.0	0	0.0
Apparel/Textile	5	2.7	2	3.0	2	3.8	0	0.0	1	9.1	0	0.0	0	0.0	0	0.0
Automotive	7	3.7	3	4.5	0	0.0	2	12.5	0	0.0	1	2.5	0	0.0	1	50.0
Bottled drinking water	1	0.6	1	1.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Chemical	1	0.6	1	1.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Construction	9	4.8	2	3.0	5	9.6	1	6.3	0	0.0	1	2.5	0	0.0	0	0.0
Cookware manufacturing	1	0.6	1	1.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Cork	1	0.6	1	1.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Education	3	1.9	1	1.9	0	0.0	0	0.0	0	0.0	1	3.1	0	0.0	1	50.0
Electronics	2	1.3	0	0.0	1	2.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Energy	2	1.3	0	0.0	1	2.2	0	0.0	0	0.0	1	3.1	0	0.0	0	0.0
e-Waste recovery plant	1	0.6	1	1.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Foundry	1	0.6	0	0.0	0	0.0	0	0.0	0	0.0	1	3.1	0	0.0	0	0.0
Furniture	2	1.3	1	1.9	0	0.0	0	0.0	0	0.0	1	3.1	0	0.0	0	0.0
Healthcare	1	0.6	0	0.0	1	2.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Iron and steel	1	0.6	0	0.0	0	0.0	0	0.0	0	0.0	1	3.1	0	0.0	0	0.0
Mechanical	1	0.6	1	1.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Metal welding	1	0.6	0	0.0	0	0.0	0	0.0	1	10.0	0	0.0	0	0.0	0	0.0
Metalworking	1	0.5	1	1.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Oil and gas	1	0.5	1	1.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Other manufacturing	55	29.3	19	28.4	12	23.1	5	31.3	5	45.5	14	35.0	0	0.0	0	0.0
Mining machinery and automobile industries	1	0.6	0	0.0	0	0.0	0	0.0	0	0.0	1	3.1	0	0.0	0	0.0
Packaging	2	1.3	0	0.0	1	2.2	0	0.0	0	0.0	1	3.1	0	0.0	0	0.0
Pharmaceutical	1	0.6	1	1.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Plastic/petrochemical	2	1.3	2	3.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Silicon carbide manufacturing	1	0.6	1	1.9	0	2.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Waste management	1	0.6	0	0.0	1	2.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	188	100.0	67	100.0	52	100.0	16	100.0	11	100.0	40	100.0	0	0.0	2	100.0

Source(s): Authors' own work

3.5 Publications from the perspective of lean and sustainability pillars

In general, publications seem to address the combination of Lean and sustainability more holistically (35.6%), focusing equally on all three dimensions (Figure 5). In comparative terms, however, it emerges that 65.4% of the studies addressed only one (42.0%) or two (22.3%) pillars of sustainability. Specifically, the dimension most investigated individually is the environmental one (27.7%), likely due to its close relationship with the Lean principles of waste reduction and resource efficiency (Dieste *et al.*, 2019; Lobo Mesquita *et al.*, 2022). Numerous studies demonstrated that the adoption of Lean contributes significantly to reducing environmental impacts such as energy consumption, material waste and emissions (Ugarte *et al.*, 2016; Ball and Lunt, 2020; Francis and Thomas, 2020; Farrukh *et al.*, 2022; Prasad *et al.*, 2022). Nevertheless, its integration with broader and more comprehensive environmental strategies remains an ongoing research topic. Caldera *et al.* (2019) noted that the environmental benefits of Lean are not fully realised without the inclusion of additional green practices. In particular, their study found that Lean implementation does not directly address environmental issues, including energy consumption and emissions, which require targeted green practices. Similarly, Cherrafi *et al.* (2017) emphasised the importance of combining the Lean approach with Green and Six Sigma methodologies to achieve superior sustainability performance. Such integration provides a more comprehensive solution by embedding efficiency and environmental objectives. Consistent with this perspective, recent studies have highlighted the synergistic potential of integrating Lean and Green practices. Abualfaraa *et al.* (2023) propose a theoretical framework aimed at combining the two approaches within manufacturing SMEs, demonstrating that while Lean is widely used for operational improvement, environmental results emerge with greater intensity only when adoption is supported by environmental awareness and green strategies. The framework developed shows that, when implemented simultaneously, the two approaches are mutually reinforcing, allowing economic, environmental and social objectives to be addressed in a systemic manner. However, the authors also point out the complexity of integration, due to obstacles such as resistance to change, financial constraints and lack of environmental expertise. In a study conducted in China, Chen *et al.* (2020) confirmed that Lean Manufacturing promotes virtuous environmental practices when supported by specific enabling factors. Among these, stakeholder pressure and employee involvement emerge as key determinants for translating Lean principles into tangible environmental benefits. The

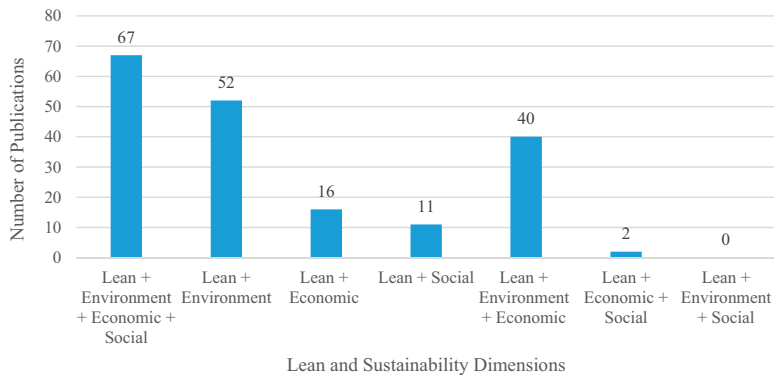


Figure 5. Distribution of publications based on lean and sustainability pillars

Source: Authors' own work

effectiveness of Lean environmental practices is also enhanced by the adoption of environmental management systems such as ISO 14001 and organisational culture, which must be consistently aligned to maximise ecological performance. [Iranmanesh et al. \(2019\)](#) also pointed out the crucial role of organisational culture in amplifying the effects of Lean practices on environmental sustainability. Their research work demonstrates that specific Lean practices – particularly those related to production processes, product design, and supplier relationships – can lead to significant improvements in environmental performance when supported by a widespread and embedded Lean culture. This suggests that effectively translating Lean principles into tangible environmental outcomes requires combining the technical implementation of tools with a shared orientation towards continuous improvement and environmental responsibility.

Furthermore, the joint analysis of economic and environmental sustainability represents a noteworthy area of interest (21.3%), reflecting a natural alignment with the Lean focus on cost efficiency and resource optimisation ([Pearce et al., 2018](#); [Mishra et al., 2020](#); [Afum et al., 2021](#); [Sadiq et al., 2021](#); [Teixeira et al., 2021](#)). Several studies have explored this relationship. For instance, [Agyabeng-Mensah et al. \(2020\)](#) found that Lean management led to a relative competitive quality advantage and higher environmental performance. On the other hand, [Singh et al. \(2021b\)](#) highlighted the importance of environmental Lean Six Sigma enablers in Indian micro, small and medium-sized enterprises, showing that integrating environmental practices can reduce costs and environmental impacts. However, both studies recognise the challenge of balancing short-term economic gains with long-term environmental benefits, particularly in smaller enterprises where resource constraints may limit the implementation of green practices on a large scale. These findings suggest the need for strategic integration of environmental goals into Lean initiatives, enabling both economic and environmental sustainability to be effectively pursued as part of a holistic improvement process.

[Choudhary et al. \(2019\)](#), for example, introduced Green Integrated Value Stream Mapping (GIVSM), a tool to simultaneously analyse economic waste and environmental impacts along the value stream. Application of the method has shown promising results in terms of reducing material consumption, lead times and emissions, generating combined benefits on both economic and environmental dimensions. However, the authors emphasise that the effectiveness of GIVSM depends on a broader strategic commitment towards environmental sustainability, emphasising the risk of its instrumental use aimed solely at cost reduction objectives. [Qureshi et al. \(2022\)](#) advanced the discussion by proposing a conceptual framework for Lean-Green integration explicitly oriented towards the joint maximisation of economic and environmental performance. The model identifies different enablers and barriers at the organisational, operational and external levels, highlighting how alignment between internal efficiency efforts and external institutional pressures (regulations, market demand) is essential to achieve results in both pillars. Furthermore, the simultaneous creation of economic and environmental value requires a strong ability to adapt to sectoral and territorial specificities, rather than the application of standardised solutions. Expanding on this perspective, [Tripathi et al. \(2022\)](#) analysed the relationship between Lean principles and Smart Manufacturing technologies in resource-constrained contexts. Their study indicates that digital tools, such as real-time monitoring and process automation, can enhance the environmental responsiveness and operational efficiency of Lean systems. However, the effectiveness of such integration is conditioned by the technological and managerial maturity of the organisation, which may limit its broader adoption among small and medium-sized enterprises.

Conversely, the social component is less explored, both in isolation (5.9%) and in conjunction with other dimensions (1.1%). This is consistent with the findings of previous

studies, which have underlined the centrality of environmental and economic considerations in Lean and sustainability research (Henao *et al.*, 2019; Chavez *et al.*, 2022; Chiarini *et al.*, 2023). However, the social pillar is gaining increasing attention in recent Lean research. Emerging contributions stress the need for structured assessments and supportive work environments as critical factors to embed social sustainability within the Lean approach (Díaz-Reza *et al.*, 2024; Piwowar-Sulej and Iqbal, 2024). Hamja *et al.* (2022) pointed out that Lean contributes positively to social performance by enhancing occupational health, safety, and worker involvement. Despite these insights, challenges in ensuring long-term sustainability remain, with outcomes varying depending on factors such as training, worker engagement, and top management support. Ciannella and Santos (2022) also identified a positive relationship between Lean and social sustainability, with practices such as 5S and Kaizen significantly improving workplace ergonomics and reducing job stress. Nonetheless, the study highlights a gap in fully integrating this pillar into the Lean framework. Manzaneres-Cañizares *et al.* (2022) criticised the limitations of conventional Lean applications in addressing social sustainability, especially in high-risk operational contexts. They propose an evaluation framework that incorporates ergonomic and psychosocial indicators into the 5S methodology, stating that social conditions should be systematically assessed and explicitly integrated into Lean process design. As argued by García-Alcaraz *et al.* (2019), the effectiveness of Lean practices is enhanced by the creation of work environments that foster human contribution and favour collaborative process management. In this regard, the social dimension assumes a pivotal role for broader organisational improvement, thereby expanding the transformative scope of Lean initiatives. To achieve holistic sustainability, aligning Lean initiatives with employee well-being is essential, ensuring that social aspects are included in the implementation process. Future research should develop a more comprehensive framework to implement Lean strategies that encompass all three dimensions of sustainability.

3.6 Impact categories between lean and sustainability pillars

As illustrated in Figure 6, the analysis of the reviewed literature has identified 27 specific impact categories of Lean implementation on the three pillars of sustainability. These findings provide a comprehensive view of how Lean methodologies contribute to environmental improvements, economic performance, and social well-being. To address the need for a deeper investigation, this section critically examines key studies that offer concrete evidence of Lean contributions across all three dimensions of sustainability, considering impact categories for each dimension.

Several studies highlight how Lean practices can significantly reduce resource consumption, minimise waste and pollution, and enhance energy efficiency. For instance, Salvador *et al.* (2021) demonstrated that integrating Lean with Life Cycle Assessment (LCA) enabled a Brazilian brush manufacturer to achieve environmental impact reductions ranging from 5% to 15% across nine impact categories, including ecosystem toxicity and global warming. Similarly, de Oliveira Rezende *et al.* (2022) found that a Lean-green hybrid approach helped a construction company identify the most sustainable process alternative, leading to an 8% reduction in global warming potential.

A broader-scale study by de Souza Lima *et al.* (2023) further confirmed the versatility of Lean strategies in achieving environmental benefits. A Lean initiative in a higher education institute resulted in a reduction of 444,754 printed paper sheets, translating to 1.38 million litres of water saved, 43.82 kg of CO₂ emissions avoided, and 67 trees preserved. Moreover, Singh and Rathi (2024) found that the implementation of an Environmental Lean Six Sigma

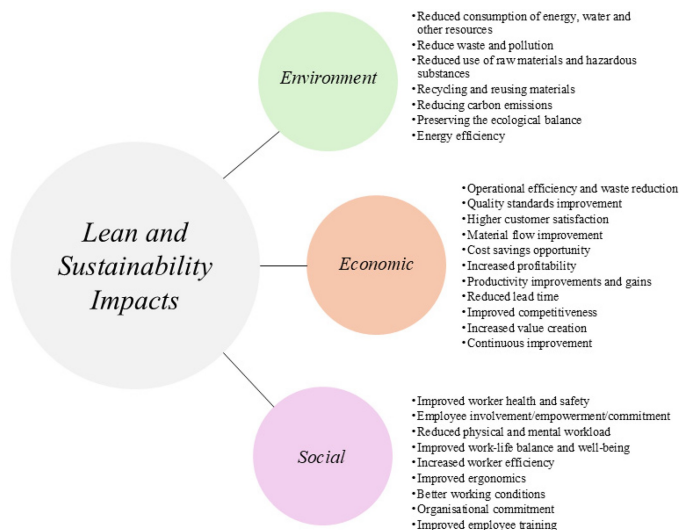


Figure 6. Lean and sustainability pillars: impact categories
Source: Authors' own work

framework in an Indian medical equipment manufacturing company led to a 44.5% improvement in indoor air quality and a 95.5% reduction in carbon monoxide emissions.

From an economic perspective, Lean practices enhance operational efficiency, productivity, and cost savings, fostering competitiveness and profitability. In the food industry, [Garcia-Garcia et al. \(2022\)](#) observed that Lean implementation led to a 30% reduction in changeover times, an increase in overall equipment effectiveness above 70%, and a 10% decrease in labour costs. Similar benefits were reported in the automotive sector: [Mishra et al. \(2020\)](#) found that a Lean-driven reduction in cycle time by 30% resulted in substantial cost savings and optimised resource utilisation. Consistently, [Gonçales Filho et al. \(2020\)](#) demonstrated how Lean production in a furniture manufacturing setting contributed to a 44.79% increase in operating income, confirming its role in driving financial sustainability.

Concerning social sustainability, Lean initiatives are widely acknowledged for their positive effect on workforce well-being, employee engagement and organisational commitment. The papers included in this review demonstrate that using Lean tools can contribute to safer working environments, greater job satisfaction and improved team collaboration. In this regard, [Randhawa and Ahuja \(2018\)](#) found that the adoption of Lean tools significantly improved job satisfaction and health conditions among workers in an automotive company in India. The rate of absenteeism decreased from 14.9% to 6.42%, and there was a significant increase in employee suggestions. Furthermore, the frequency and severity of work accidents exhibited a marked decline, with both rates close to zero.

4. Discussion

The purpose of this study is to provide an overview of the existing literature on the Lean and sustainability relationship, thus identifying possible gaps and future research directions. To this end, a systematic literature analysis is conducted, allowing for the evaluation and classification of the selected studies in terms of publication year, document type, journal,

average annual citations, and country of origin. Specifically, the results of the analysis performed indicate that interest in the Lean-sustainability combination is quite recent, with 2021 and 2022 being the years with the largest number of publications and 2019 the year with the highest average annual citations. The scientific production is primarily composed of articles, mainly published in the *Journal of Cleaner Production and Sustainability*, which are renowned for the field of research investigated. Although the relationship of Lean manufacturing with sustainability is explored in different parts of the world, India, Brazil and Spain are the countries with the most publications on this topic. The study also categorised the reviewed publications according to the area of application and research stream focus. To date, most of the existing literature on the topic is characterised by predominantly theoretical studies, confirming that the integrated Lean-sustainability approach is rather recent (Tasdemir and Gazo, 2018; Dey *et al.*, 2020; Jum'a *et al.*, 2022). It is followed by the manufacturing, automotive and construction sectors, which are particularly affected by societal pressures to transition towards more efficient and sustainable business models (Ferreira *et al.*, 2021; He and Ortiz, 2021; Bashir *et al.*, 2022). In addition, it is predominantly theoretical studies that focus on the combination of Lean and sustainability in a holistic manner, by considering all three sustainable pillars together.

In contrast, the research conducted in the different areas examined appears to focus mainly on the interaction between Lean and only one or two of the dimensions of sustainability, namely the environment and the environment and economy. While several studies revealed that Lean significantly contributes to reducing environmental impacts, such as energy consumption and waste generation, without targeted integration of ecological practices, the environmental benefits of Lean could remain partial and not fully realised. Empirical evidence from real-world applications confirms the effectiveness of this integrated approach. The Lean and Environment Toolkit, developed by the USA Environmental Protection Agency (US EPA, 2007a, 2007b), highlights successful implementations in companies such as 3M, General Motors, and Lockheed Martin. These cases demonstrate how Lean tools, when combined with environmental performance metrics, can lead to substantial reductions in waste, energy use, and emissions, thereby achieving operational and ecological benefits.

The current trend in Lean-sustainability research, particularly the increased focus on integrating environmental and economic pillars, further reflects a broader shift in business practices towards sustainability over the past decade. Compared to previous years or decades, where Lean was primarily viewed through the lens of operational efficiency, there is now a growing recognition of its potential to drive sustainable development. This evolution mirrors the increasing importance of sustainability in global business practices, driven by factors such as climate change, resource scarcity, and heightened consumer awareness. As a result, Lean methodologies have become more closely aligned with sustainability objectives. However, it has also underscored the complexity of balancing pressing economic needs with long-term environmental concerns (Agyabeng-Mensah *et al.*, 2020; Singh *et al.*, 2021b). In this context, including environmental objectives in the early stage of Lean planning is imperative. The development of more coherent and sustainable strategies would enable organisations to reduce conflicts that may arise between short-term economic priorities and long-term environmental sustainability.

Less investigated, on the other hand, is the relationship between Lean practices and social performance. This is in line with the findings of several authors, who agree that the social pillar requires more attention from both academics and practitioners (De Carvalho *et al.*, 2017; Caiado *et al.*, 2019; Teixeira *et al.*, 2021; Jum'a *et al.*, 2022; Ciannella and Santos, 2022). Despite recent studies that have begun to explore the social implications of Lean, the integration of social aspects into the Lean approach remains a critical gap in research. One

aspect still largely unexplored in this context is the impact of the eighth waste, that is, the underutilised human talent. These results confirm the need to conduct more empirical investigations on Lean and sustainability (Choudhary *et al.*, 2019; Teixeira *et al.*, 2021; Chavez *et al.*, 2022; Jum'a *et al.*, 2022), especially regarding the social dimension. To address this gap, there is a growing need for a comprehensive framework that considers the impacts of Lean on all three pillars of sustainability in an integrated and holistic manner. This requires a shift from a purely operational focus to one that integrates sustainability goals at the core of Lean practices, enabling businesses to address the complexity of balancing these dimensions without compromising any single aspect. In this regard, some practical tools have been developed to facilitate the integration between Lean practices and sustainability principles. One example is the Sustainable Value Stream Mapping (Sus-VSM), which expands the traditional Lean Value Stream Mapping by incorporating environmental and social performance indicators. This allows organisations to optimise resource flows and reduce environmental impacts while improving social conditions such as workplace safety and employee satisfaction (Hartini *et al.*, 2021; Rathi *et al.*, 2022).

Understanding the mechanisms by which organisations can leverage employee capabilities while maintaining Lean efficiency could provide valuable insights into achieving a more balanced approach to sustainability. Indeed, as the last aspect investigated in the study reveals, there are many synergies between Lean and sustainability, including the social pillar (Fernández Carrera *et al.*, 2021; Ciannella and Santos, 2022). Specifically, the main interactions found between Lean, and the environment concern the reduction of waste and consumption of energy, water and other resources used during the production process. Reduced costs, improved quality standards and increased customer satisfaction, on the other hand, are the main economic benefits of adopting Lean strategies.

From a social perspective, greater health and safety in the workplace can be achieved through better organisation and cleanliness of spaces, in addition to greater involvement and well-being of workers, who are considered fundamental by Lean thinking for the success of the business organisation. Lean practices such as Kaizen, Just-in-Time, and 5S could play a crucial role in improving workplace conditions by fostering employee participation, reducing physical strain, and creating a safer and more ergonomic work environment (Chavez *et al.*, 2022; Díaz-Reza *et al.*, 2024).

5. Conclusions

In the light of the above, it is possible to argue that the adoption of Lean techniques and methodologies can positively influence the achievement of sustainability goals (Tasdemir and Gazo, 2018; Yu *et al.*, 2020; Teixeira *et al.*, 2021; Jum'a *et al.*, 2022), through several tools that enable organisations to significantly improve their environmental, social and economic performance. These include 5S, Sustainable Value Stream Mapping (Sus-VSM) and Green Lean Six Sigma (GLSS) (Hartini *et al.*, 2021; Teixeira *et al.*, 2021; Manzanares-Cañizares *et al.*, 2022; Rathi *et al.*, 2022; Díaz-Reza *et al.*, 2024).

However, given the lack of empirical evidence, future studies should focus on the application of the integrated Lean-sustainability approach across economic sectors, paying attention to assessing the effects on environmental, economic, and social performance as a whole. In addition, it might also be interesting to understand what barriers have so far prevented the implementation of Lean and sustainability in an integrated perspective, to support possible future applications.

The paper has both theoretical and practical contributions. It contributes to the academic literature by identifying the main issues discussed regarding Lean manufacturing and sustainability identifying key gaps and research opportunities. In particular, it highlights the

imbalance in existing research, where the environmental and economic dimensions of sustainability have been extensively studied, while the social pillar remains underexplored. To further enhance the social dimension, companies should implement Lean strategies that prioritise worker involvement in continuous improvement processes, encourage leadership development at all levels, and provide training programs aimed at upskilling employees in Lean methodologies. A bottom-up approach, where employees actively contribute to process improvements, can foster a culture of engagement, leading to higher job satisfaction and organisational commitment. In this regard, Lean-based workforce empowerment strategies, such as Kaizen events, can be instrumental in ensuring active employee participation in decision-making and innovation. Additionally, workplace safety can be significantly improved through Lean tools like 5S and visual management, which help create organised, ergonomic, and hazard-free environments. Finally, the adoption of performance indicators that assess social impact, such as employee satisfaction, retention rates, and workplace well-being metrics, can provide companies with valuable insights to continuously refine their Lean practices in alignment with social sustainability goals.

To support the practical implementation of the Lean-Sustainability paradigm, structured frameworks and digital tools are emerging as key enablers. Among these, Green Lean Six Sigma (GLSS) stands out as an integrated approach that combines continuous improvement, waste reduction, and sustainability metrics. GLSS has already shown positive results in various industries, promoting environmental stewardship, cost efficiency, and improved workforce conditions (Teixeira *et al.*, 2021; Farrukh *et al.*, 2023).

Moreover, the advent of digital technologies has opened new frontiers for applying Lean and Sustainability principles. Digital twin platforms, which means virtual clones of physical processes, are increasingly used to simulate and optimise production systems using real-time Lean and Green Key Performance Indicators (KPIs). These tools can support decision-making by predicting the environmental and social impact of process improvements before implementation, offering a high-potential direction for future research and industrial applications (Pater and Stadnicka, 2021).

Such technological advancements not only enhance the operationalisation of Lean-sustainability principles in real-world contexts but also open new avenues for academic inquiry. Building on this, the research provides a roadmap for future studies by identifying the following key directions:

- Exploring the social pillar of sustainability, since more empirical studies are needed to assess how Lean can improve workforce engagement, health and safety conditions, and job satisfaction.
- Investigating the eighth waste (underutilised talent) in the Lean-sustainability context, examining how organisations can leverage employee skills and knowledge to enhance sustainability outcomes.
- Developing integrative models and frameworks, considering the need for conceptual and empirical models that link Lean strategies with long-term sustainability benefits, particularly regarding trade-offs and synergies among the three pillars.
- While manufacturing has been the main focus, further research, such as cross-industry studies or sectoral analyses, should explore how Lean and sustainability integration functions in other sectors, such as healthcare, education, and services.
- The development of performance indicators and assessment tools that consider economic, environmental, and social factors is crucial for both academic and practical advancements, to measure the effectiveness of Lean and sustainability practices.

The findings of this study also have significant practical implications for a range of stakeholders, including policymakers, industry leaders, and academics.

For businesses, the findings suggest that developing structured performance measurement systems that account for sustainability dimensions can enhance decision-making and long-term value creation. Companies that align their Lean strategies with sustainability goals can gain a competitive advantage by improving resource efficiency, reducing waste, and enhancing brand reputation.

For policymakers, the research highlights the need for supportive regulations and incentives that encourage the adoption of integrated Lean-sustainability practices across various sectors. Policies that promote resource efficiency, waste reduction, and the adoption of cLean technologies can further drive the integration of these practices.

For industry leaders, the study underscores the competitive advantages that can be gained through the implementation of Lean-sustainability initiatives. Companies that successfully integrate these practices can expect not only operational improvements but also enhanced reputation and compliance with increasingly stringent environmental and social standards. The findings suggest that industry leaders should prioritise the development of strategies that align Lean practices with broader sustainability goals to stay ahead in a rapidly evolving business environment.

Finally, this research is not without limitations. The first concerns the use of a single database, namely Scopus. Therefore, the inclusion of other databases could expand the identified literature and results. Secondly, the use of a specific query might have led to the exclusion of further scientific contributions in the field. Different terms could generate alternative results. Thirdly, despite the systematic procedure of the literature review performed, the process of refining the studies, the inclusion and exclusion criteria and the categorisation of the identified scientific contributions are not completely immune to subjectivity. Fourthly, only documents in English were selected, potentially excluding important contributions in other languages. Future studies could involve more databases, use different keyword combinations for the identification of scientific contributions on the topic, and include documents written in other languages.

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