



A Systematic Literature Review of Sustainable Manufacturing: Green Manufacturing Practices in Asia

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ABSTRACT

Sustainable manufacturing is a popular topic due to its importance. Green manufacturing practices have been widely applied in Asia. This study aims to provide a comprehensive overview of the current knowledge of sustainable manufacturing practices in Asia, mainly green manufacturing practices. Based on the systematic literature review using VOS Viewer software to analyze the content of the published articles, the literature on sustainable manufacturing practices can be classified into three main categories: Sustainable manufacturing, Sustainability practices, and Environmental management. Most of the literature related to Green sustainable science technology, Environmental Science, Engineering, Manufacturing, Engineering, Environmental, and Environmental Studies accounted for 18.84%, 17.39%, 10.41%, 10.41%, and 8.70% of the total 50 documents included in the review, respectively.

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1. INTRODUCTION

Sustainable manufacturing has become a crucial topic recently as stakeholders seek to balance economic growth with environmental protection (MUHARDI et al., 2020; Ngu et al., 2020). It involves developing and implementing practices that minimize the environmental impact of production processes while maximizing efficiency. As concerns over climate change and resource depletion continue to grow, sustainable manufacturing has become a

pressing issue for researchers, policymakers, and industry practitioners alike (Abbass et al., 2022; Hussain et al., 2019).

This systematic literature review focuses on the green manufacturing practices adopted in Asia, pivotal in the global manufacturing landscape. Asia, in recent years, has become a powerhouse for manufacturing, playing a crucial role in global supply (Beyond Factory Asia: Fuelling Growth in a Changing World, 2013). This is due to multiple vital reasons: their

strategic location, abundant labor force, expanding consumer markets, and infrastructure development. In 2018, Asia was reported to make up 90.62% of the total value added in global manufacturing. In contrast, Africa contributes only 2.04%, and Latin America 7.34% to the sector (Kruse et al., 2023). The continents like North America, Europe, and Australia were not considered as the focus of the paper is towards developing countries, and there needed to be more readily available data. However, this still indicates that Asia makes up a significant portion of the continents with developing economies.

Thus, some of the world's largest manufacturing industries lie in Asia, with significant environmental footprints. This study will aid in understanding Asia's part in the global supply chain Asia and addressing environmental concerns associated with its large manufacturing industries. Therefore, adopting sustainable manufacturing practices in Asia is critical to achieving global sustainability objectives (Ike et al., 2019).

The body of research shows an increasing focus on green manufacturing since 2015 (Bendig et al., 2023). Nevertheless, these studies have specific constraints, including no region-specific information in their coverage. Existing studies conducted literature reviews utilizing keyword screening without regional filtering, as seen in publications by (Bastas, 2021; Bendig et al., 2023 Despeisse et al., 2022; Pathak & Singh, 2020; Pereira, 2019)

In recognition of a gap in current research, a systematic literature review focused on sustainable manufacturing in Asia is proposed. By conducting this research, the most popular sustainable manufacturing topic that has been done in Asia can be defined by category using VOS Viewer.

This review aims to provide a comprehensive overview of the current knowledge on sustainable manufacturing

practices in Asia, mainly green manufacturing practices. Green manufacturing practices refer to strategies and techniques that minimize the environmental impact of production processes (Abualfaraa et al., 2020). Through this review, we aim to identify the key challenges and opportunities for implementing sustainable manufacturing practices in Asia and highlight the most effective strategies for their adoption. The review is roughly structured as follows: First, an overview of the critical concepts and definitions of sustainable and green manufacturing are provided. Subsequently, a systematic analysis of the literature on sustainable manufacturing practices in Asia is presented, examining current trends and future directions in this area. Finally, the conclusion presents recommendations for policymakers, industry practitioners, and researchers on promoting sustainable manufacturing practices in Asia.

2. RESEARCH METHODOLOGY

This research followed the steps shown in **Figure 1**. The initiation of data collection began in 2007 and was chosen due to its substantial temporal span for conducting research review until 2023. The articles were gathered from respected international publishers, including Elsevier, Taylor & Francis Group, MDPI Sustainability, Emerald, ProQuest, Korea Science, Springer, Growing Science, Sage Journals, Wiley, and IEEE, which serve as primary sources, as the majority of highly cited sustainable manufacturing journals are featured within these databases. The materials compiled from previous studies include objectives, methodology, and findings. Furthermore, this paper adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework for conducting a comprehensive review of the available literature. This depicted on **Figure 2**.

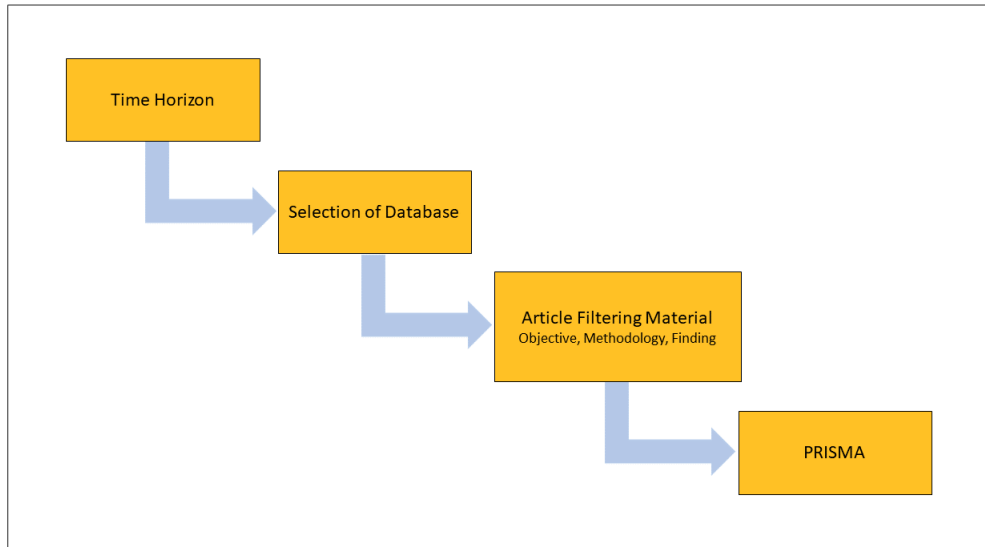


Figure 1. Research Framework

Consistent with the PRISMA guidelines, a scoping procedure was utilized to identify the most pertinent articles on sustainability indicators and assessment. The employment of this technique facilitated the systematic identification of essential components and the categorization of relevant search terms (Shu et al., 2019)

A comprehensive literature search is conducted using a strict measure due to the broad practice nature of manufacturing. This literature search is performed using relevant databases and relevant keywords such as “sustainability manufacturing practices,” “sustainable manufacturing,” “green manufacturing,” “material reuse,” and “industry 4.0.”

The keyword “sustainable manufacturing” was used most in each database

search to find the relevant literature. To ensure that the latest sustainability practices were emphasized. Initially, 2,700 documents were identified, including research articles, conference papers, etc. The scope of the literature search was subsequently narrowed down to research articles and review papers. To keep the topic relevant, 1,000 recently added papers are selected. Further selection is done by filtering papers that have relevance to “green manufacturing,” “lean Six Sigma,” and “industry 4.0.”, resulting in the selection of 103 documents, as illustrated in **Figure 2**. The next step involved selecting articles from major industrial countries in Asia, which resulted in 50 documents from Google Scholar. Subsequently, the data was exported to an Excel sheet to continue the systematic review.

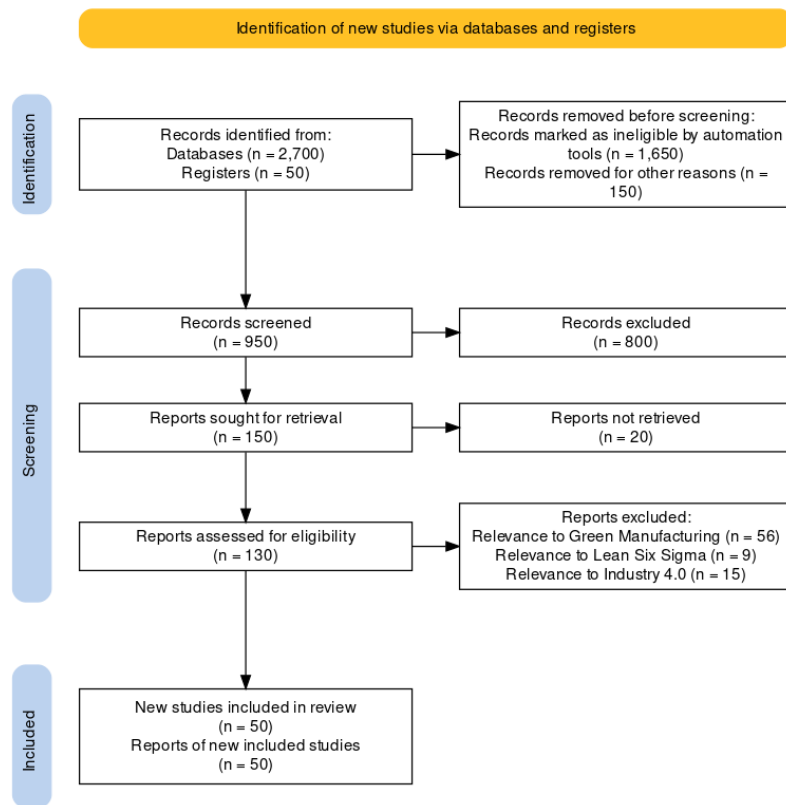


Figure 2 PRISMA Research Method

3. RESULTS AND DISCUSSION

Figure 3 demonstrates the evolution of publication trends regarding sustainable manufacturing practices in Asia in the past five years, focusing on green practices. Figure 3 depicts those Asian countries, such as India, Indonesia, Malaysia, and China, that are growing interested in implementing eco-friendly business practices in their manufacturing industries. The surge of publications in 2020 indicates a heightened awareness and consideration of sustainable manufacturing practices.

However, the number of publications slightly decreased in the following years, with only four papers published each year in 2021 and 2022. The year 2023 exhibits a renewed interest in sustainable manufacturing practices, with eight papers published that year. This study suggests a growing interest in creating sustainable and eco-friendly industries in Asia, which can positively impact the environment and contribute to global efforts to combat climate change.

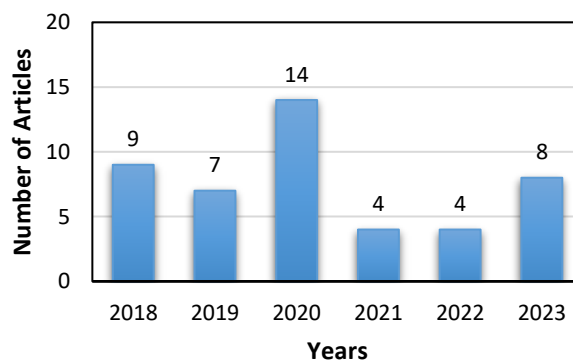


Figure 3. Distribution of published papers

Table 1. Distribution of published records according to research discipline (2007–2023).

Categories Title	Frequency	Percentage (%)
Green & sustainable science & technology	13	18.84
Environmental Science	12	17.39
Engineering, Manufacturing	7	10.14
Engineering, Environmental	7	10.14
Environmental Studies	6	8.70
Operations Research & Management Science	4	5.80
Management	3	4.35
Business	3	4.35
Engineering, Chemical	2	2.90
Thermodynamic	1	1.45
Social Sciences	1	1.45
Social science, Interdisciplinary	1	1.45
Materials Science, Multidisciplinary	1	1.45
Information science & library science	1	1.45
Engineering, Mechanical	1	1.45
Energy & Fuels	1	1.45
Economics	1	1.45
Computer Science, Interdisciplinary Applications	1	1.45
Computer science	1	1.45
Agronomy	1	1.45
Agricultural Engineering	1	1.45

Using the Web of Science database to identify the subject categories of the articles shown in **Table 1**. The table indicates that most of the literature was about Green and sustainable science technology, Environmental Science, Engineering, Manufacturing, Engineering, Environmental, and Environmental Studies. These categories comprise 18.84%, 17.39%, 10.41%,

10.41%, and 8.70% of the total documents included in the review, respectively. However, ten articles were not available on the Web of Science.

The citation report for the top 10 articles selected from the past 15 years, from 2007 to 2023, will be shown in **Table 2**. They are here to find the mean of citations per year to determine which article has been the most cited. The article with the most citations is “Smart Manufacturing” from the International Journal of Production Research, Volume (56). It was cited a total of 553 times from 2018. This is followed by “Green Manufacturing: An Evaluation of Environmentally Sustainable Manufacturing Practices and Their Impact on Competitive Outcomes” from IEEE Transactions on Engineering Management, Volume 54 (Rusinko, 2007), cited 522 times from 2007.

The third most cited article is “The Impact of Sustainable Manufacturing Practices on Sustainability Performance: Empirical Evidence from Malaysia” from the International Journal of Operations & Production Management, Vol.37 (2017). This article was cited a total of 398 times in 2017. The fourth most cited article is from Technological Forecasting and Social Change, Volume time 160 (2020). The article is “Corporate Social Responsibility and Environmental Performance: The Mediating Role of Environmental Strategy and Green Innovation” with 359 citations from 2020. The fifth most cited is “Sustainable Manufacturing in Industry 4.0: An Emerging Research Agenda,” published by the International Journal of Production Research, Vol.58.(2020), cited 263 times from 2020.

Table 2. Most-cited articles

Author	Title	Amount Citation
(Kusiak, 2018)	Smart Manufacturing	553
(Rusinko, 2007)	Green Manufacturing: An Evaluation of Environmentally Sustainable Manufacturing Practices and Their Impact on Competitive Outcomes	522
(Abdul-Rashid, Sa-kundarini, et al., 2017)	The impact of sustainable manufacturing practices on sustainability performance: Empirical evidence from Malaysia (International Journal of Operations & Production Management, 2017, Vol.37 (2), p.182-204)	398
(Kraus et al., 2020)	Corporate social responsibility and environmental performance: The mediating role of environmental strategy and green innovation	359
(Machado et al., 2020)	Sustainable Manufacturing in Industry 4.0: An Emerging Research Agenda (International Journal of Production Research, 2020, Vol.58 (5), p.1462-1484)	263
(Cai et al., 2019)	Promoting sustainability of the manufacturing industry through the lean energy-saving and emission-reduction strategy	194
(Rehman et al., 2021)	Analyzing the relationship between green innovation and environmental performance in large manufacturing firms	172
(Yildiz Çankaya & Sezen, 2019)	Effects of green supply chain management practices on sustainability performance	166
(Rashid et al., 2013)	Resource Conservative Manufacturing: An Essential Change in Business and Technology Paradigm for Sustainable Manufacturing (Journal of Cleaner Production, 2013, Vol.57, p.166-177)	165
(Yong et al., 2019)	Pathways towards sustainability in manufacturing organizations: Empirical evidence on the role of green human resource management	159

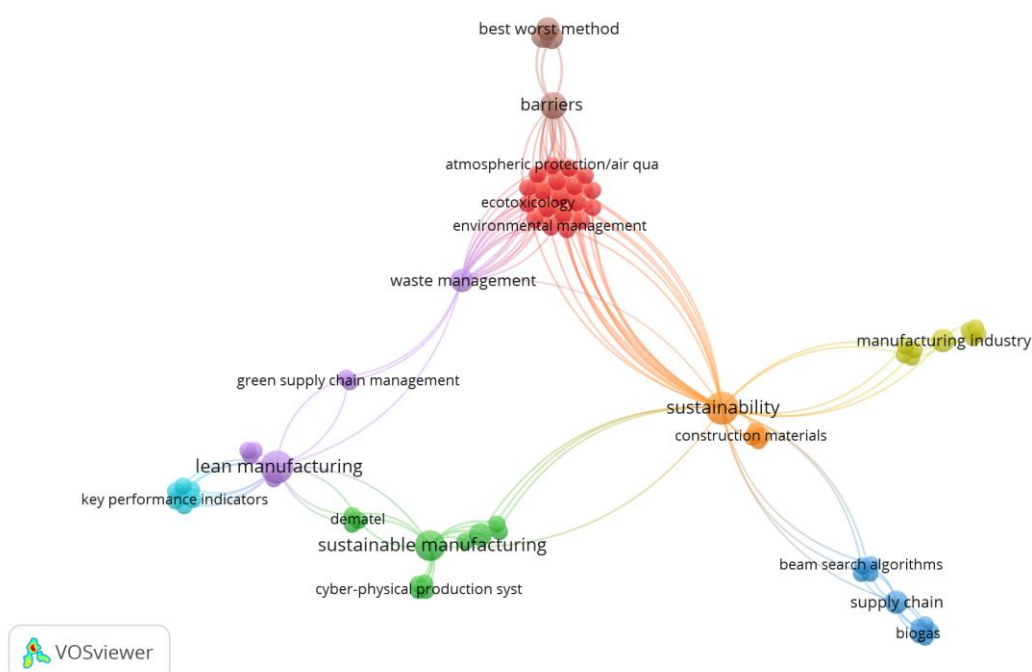


Figure 4. Bibliometric analysis using Vos Viewer

4. CLASSIFICATIONS OF LITERATURE ON SUSTAINABLE MANUFACTURING PRACTICES

Figure 4 was utilized to investigate the classifications of research; the studies were subjected to content analysis, which involved using VOS Viewer software to analyze the content of the published articles. This software enabled the creation of data networks based on the text, which clustered linked concepts together. Through this process, the researchers were able to identify the key themes and concepts present in the studies, thereby facilitating a better understanding of the research. Recent research has demonstrated that author keywords and those added during the publication indexation process in databases are equally effective for bibliometric analysis to examine the structures of research fields (Lis et al., 2020). The co-occurrence analysis of keywords in the research field related to sustainable manufacturing practices in Asian countries was conducted using two categories of keywords: author keywords and keywords added during publication indexation. The research dataset comprised 52 records; the most frequent 127 keywords repeated in the papers were carefully selected and refined. The content analysis results are presented in **Figure 4**, which shows several clusters, with the central cluster representing themes related to sustainability, sustainable manufacturing, manufacturing industry, waste management, and green supply chain, all related to green manufacturing practices. All the clusters are converted into subsections, which are sustainable manufacturing: green processes, sustainability practices, and waste management.

4.1. Sustainable Manufacturing: Green Processes

The literature on sustainable manufacturing practices includes several studies

that examine the impact of these practices on environmental and competitive outcomes. For instance, Abdul-Rashid et. al. (2017) found that corporate social responsibility and environmental performance are positively related, with environmental strategy and green innovation mediating this relationship. Similarly, Wahab Leo (2022) showed that green supply chain management practices positively affect sustainability performance. Meanwhile, Yong et. al (2019) investigated the impact of sustainable manufacturing practices on sustainability performance in Malaysia, finding positive relationships between the two.

Green manufacturing processes have become increasingly important in recent years due to the urgent need to reduce environmental impact and meet sustainability goals. As stated by Kusiak (2018), innovative manufacturing practices can be leveraged to optimize energy usage and reduce waste in the production process. Rusinko (2013) evaluated the impact of sustainable manufacturing practices on competitive outcomes and found that environmentally sustainable practices can increase a company's competitiveness. Empirical evidence from Malaysia supports this finding, showing that sustainable manufacturing practices positively impact sustainability performance (Abdul-Rashid, Sakundarini et al., 2017; Malik Mustafa, 2021)

The role of corporate social responsibility (CSR) in promoting environmental performance has also been explored. (Kraus et al., 2020) found that environmental strategy and green innovation mediate the relationship between CSR and environmental performance. Similarly, (Machado et al., 2020) identify sustainable manufacturing as an emerging research agenda in Industry 4.0, highlighting the importance of incorporating green practices into new

technological advances (Ciliberto et al., 2021).

Lean manufacturing practices effectively promote sustainability in the manufacturing industry (M. Imran & Jingzu, 2022). (Cai et al., 2019) propose a lean energy-saving and emission-reduction strategy to promote sustainability, while Rehman et. al. (2021) analyze the relationship between green innovation and environmental performance in large manufacturing firms. Green supply chain management practices have also been shown to affect sustainability performance positively (Çankaya & Sezen, 2016). Resource conservation is also an important aspect of sustainable manufacturing. Abdul-Rashid et. al. (2017) proposes resource-conservative manufacturing as an essential change in the business and technology paradigm for sustainable manufacturing. Green human resource management has been shown to play a role in promoting sustainability in manufacturing organizations (Yong et al., 2019).

Additive manufacturing, a key component of Industry 4.0, has been evaluated regarding its impact on sustainability. Guo et al. (2022) provide an overview of the energy demand and environmental impact of additive manufacturing (Sarkis & Zhu, 2017) and discuss the importance of taking the road less travelled towards environmental sustainability in production. Integrating lean and green practices has also been proposed as an effective way to promote sustainability. Fercoq et. al. (2016) propose lean/green integration focused on waste reduction techniques, while Albufaraa et. al. (2020) discusses the link between lean-green manufacturing practices and sustainability. Similarly, the potential for sustainable manufacturing within Industry 4.0 has been explored, highlighting the opportunities for sustainability within this technological framework (Carvalho et

al., 2018);(Sartal et al., 2014); (Sharma et al., 2021).

Modeling the barriers to implementing green manufacturing practices has been identified as an essential area of research. Karuppiyah et. al. (2020) proposes an integrated approach to modeling these barriers in SMEs. At the same time Qureshi et. al. (2020) identify lean culture as a moderator in the impact of lean manufacturing practices on firms' sustainable performance. Finally, sustainability assessment using lean manufacturing tools effectively promotes sustainability in the manufacturing industry (Hartini et al., 2020).

Overall, the literature supports the importance of incorporating green practices into manufacturing processes to promote sustainability and reduce environmental impact. Lean practices, green supply chain management, and resource conservation can all contribute to sustainable manufacturing, while advances in Industry 4.0 provide new opportunities for sustainable production. However, barriers to implementing green practices must be addressed, and further research is needed to fully understand the relationship between green practices and sustainability in different manufacturing contexts and industries. Identifying and overcoming these barriers is essential to promote sustainable manufacturing and reduce environmental impact effectively. Furthermore, more research is needed to explore the potential of emerging technologies, such as Industry 4.0, for promoting sustainable manufacturing practices.

4.2. Sustainability practices

Some may misconstrue Sustainability practices with green processes. However, they are related terms but defined differently. Sustainability is about meeting the needs of the present without compromising the ability of future generations to meet their own needs (Chen et al., 2020).

Green processes are methods of production or operation that reduce negative environmental impacts.

Sustainability practices have gained significant attention in the manufacturing industry due to the negative impacts of industrial processes on the environment and society (Sarkis, 2021). This literature review aims to analyze the most relevant articles on sustainability practices in manufacturing. The ten articles reviewed cover various topics related to sustainable manufacturing practices and their impact on organizational outcomes. The relationship between green manufacturing practices and their impact on competitive outcomes is explored by Jabbour (Rusinko, 2007). The authors found that green manufacturing practices can improve environmental performance and business competitiveness.

The relationship between sustainable manufacturing practices and sustainability performance in the Malaysian manufacturing sector. The study found that sustainable manufacturing practices positively affect sustainability performance (Abdul-Rashid et al., 2017). The relationship between corporate social responsibility, environmental performance, and the mediating role of environmental strategy and green innovation. The study found that environmental strategy and green innovation significantly mediate the relationship between CSR and environmental performance (Kraus et al., 2020)—the emerging research agenda on sustainable manufacturing in Industry 4.0. The authors identify the main research themes, gaps, and opportunities in sustainable manufacturing in Industry 4.0 (Machado et al., 2020). A new paradigm for sustainable manufacturing called Resource Conservative Manufacturing (RCM) is proposed by Bahrami et al. (2017). RCM is a comprehensive framework for achieving sustainable manufacturing by conserving resources and

reducing waste (Cherrafi et al., 2018). The role of green human resource management (GHRM) in promoting sustainable manufacturing is investigated by (Yong et al., 2019). The study found that GHRM is crucial in fostering sustainable manufacturing practices.

The impact of green supply chain management practices on sustainability performance is explored by (Rehman et al., 2021). The study found that green supply chain management practices positively impact sustainability performance. The integration of lean and green principles to reduce waste in manufacturing processes is examined by Sharma et al. (2021). The study found that integrating lean and green principles can improve environmental performance and reduce waste. An overview of what is known and unknown about sustainable manufacturing in Industry 4.0 is provided by O'Brien and Hurley (2019). The authors identify gaps in knowledge and opportunities for future research. The systematic review and bibliometric analysis of sustainable manufacturing practices in the ASEAN region is presented by Qureshi et al. (2020). The study identified six sustainable manufacturing practices categories: energy and resource efficiency, waste reduction, and sustainable supply chain management. This literature review examines sustainable manufacturing practices and their impact on sustainability performance. Studies have shown that sustainable manufacturing practices positively affect firms' environmental performance. For instance, Abdul-Rashid, Sakundarini, Raja Ghazilla, and Thursday (2017) found that Malaysian firms that adopted sustainable manufacturing practices had better sustainability performance than those that did not. Similarly, Sascha Krausa, Shafique Ur Rehmanb, and F. Javier Sendra García (2018) discovered that environmental strategy and green innovation mediated

the relationship between corporate social responsibility and environmental performance. Moreover, Machado, Winroth, and Ribeiro da Silva (2020) asserted that sustainable manufacturing in Industry 4.0 was an emerging research agenda that could lead to more sustainable practices.

Several studies have shown that lean manufacturing techniques can promote sustainability in manufacturing industries. For example, Wei Cai, Kee-hung Lai, Conghu Liu, Fangfang Wei, Minda Ma, Shun Jia, Zhigang Jiang, and Li Ly (2018) argued that lean energy-saving and emission-reduction strategies could help to promote the sustainability of the manufacturing industry. Fercoq, Lamouri, and Carbone (2016) also highlighted the importance of integrating lean and green techniques to reduce waste and promote sustainability.

Green supply chain management practices can also improve sustainability performance in manufacturing firms (Çankaya & Sezen, 2015). Furthermore, green human resource management can be crucial in promoting sustainability in manufacturing organizations (Yong et al., 2018). Additionally, additive manufacturing can be sustainable if energy demand and environmental impact are considered (Peng et al., 2019). Several studies have evaluated the barriers to implementing sustainable manufacturing practices. For instance, Javed Malek and Tushar N. Desai (2019) prioritized the barriers to sustainable manufacturing using the Best Worst Method. Karuppihraj et al. (2020) integrated the barriers to implementing green manufacturing practices in SMEs. Moreover, (R. Imran et al., 2022) found that lean culture moderated the relationship between lean manufacturing practices and firms' sustainable performance.

Finally, Sartal, Bellas, Mejias, and Garcia-Collado (2020) highlighted the concept

of sustainable manufacturing, its evolution, and opportunities within Industry 4.0. They suggested that combining sustainable manufacturing practices and Industry 4.0 could lead to more sustainable manufacturing processes.

Overall, this review highlights the positive impact of sustainable manufacturing practices on sustainability performance in manufacturing firms. It also emphasizes the importance of integrating lean and green techniques, green supply chain management practices, green human resource management, and additive manufacturing to promote sustainability. Additionally, the review identifies barriers to implementing sustainable manufacturing practices and highlights opportunities for sustainable manufacturing within Industry 4.0.

4.3. Environmental Management

Environmental management and regulation are critical components of sustainable development, and their implementation plays a vital role in ensuring the protection of natural resources and the prevention of pollution. Managing environmental issues involves several processes, including planning, assessment, implementation, and direction of tools that enforce compliance with environmental laws and policies. One widely promoted global environmental management practice is integrated environmental management, which is an approach that considers environmental, social, and economic factors in decision-making processes (Zaman et al., 2022). However, despite its importance, the integration of environmental management practices into firms' ethics is still limited, particularly concerning water, land resources, and ecology issues (Gawusu et al., 2022).

Developing comprehensive strategies that incorporate best practices for environmental management and sustainability is essential to address these challenges. One

promising solution for solid waste management is incorporating municipal and construction solid waste in geopolymer composites. This approach presents a sustainable and cost-effective solution for solid waste management while also contributing to producing sustainable construction materials. To achieve this, appropriate treatment and processing of the waste material are necessary to ensure that the resulting products meet quality and safety standards (Tang et al., 2020). Another promising approach to reducing carbon emissions in manufacturing is using an evaluation method based on the state space model of the carbon footprint (Li & Wang, 2022). This method considers the entire manufacturing process and effectively reduces energy consumption and waste emissions.

The successful implementation of this approach requires the involvement of experts in the field and a comprehensive understanding of the manufacturing process (Cai et al., 2019). Ten supermarket products' packaging waste and CO₂ reduction potential in Taiwan were evaluated under different reuse strategies, including Reduce, Return, and Refill. The results demonstrated that adopting these strategies could significantly reduce packaging waste and CO₂ emissions (Lin et al., 2023). In Indonesia, implementing waste segregation, on-site recycling and reuse, equipment modification, and improving house-keeping have proven effective in reducing waste in manufacturing firms. However, several barriers must be overcome to ensure effective waste minimization, including the need for expertise, employee awareness, reliable information and data, and efficient government cooperation and policies (Masudin et al., 2018).

In addition, several challenges of sustainability barriers are found in the gaps between knowledge and opportunities,

green manufacturing implementation, and limited integration between sustainable practices and firms' ethics in Asia, especially regarding water, land resources, and ecology. This evaluation pointed out several obstacles to sustainability implementation, including knowledge and expertise requirements, employee awareness, trustworthy information and reliable data, and effective government cooperation policies. Those must be overcome to improve sustainability implementation, especially green manufacturing in Asia.

Some future research recommendations include analyzing the potential of emerging technologies in Asia's green manufacturing practices amidst the founding of this research and providing more comprehensive analysis to overcome other barriers mentioned in this research, conducting a longitudinal study using this study that involved past 15 years literature review as the baseline to figure out the long-term impact analysis of green manufacturing practices of firms that adopted such practices or whether any diminishing returns over time occurred, and perform deeper analysis on green manufacturing practices and outcomes between Asian countries and factors contributing to the variation, including how different countries' policy approaches in Asia affects integration between sustainable practices and firms' ethics to overcome this paper limitation.

5. CONCLUSION

This paper conducts a systematic review of sustainable manufacturing, focused on green manufacturing practices in Asia, using the PRISMA framework and relevant keywords. Although there was a decline in interest found in 2021 and 2022, there was a significant increase in publications related to this topic in 2023. Published records from the past 15 years

found green sustainable science and technology as the majority of literature topics in Asia, with 18.84% of total relevant documents. The conversion of bibliometric analysis narrows the analysis to three subsections that impact sustainable and green manufacturing in Asia: green processes, sustainability practices, and waste management. The results highlighted several promising green manufacturing techniques, including lean manufacturing, resource conservative manufacturing (RCM), green human resource management

(GHRM), geopolymer composites usage for solid waste management, waste segregation, onsite recycling and reuse, equipment modification, housekeeping improvement, and state space modeling usage for carbon footprint evaluation. This paper also emphasized the opportunities of incorporating green practices into new technological advances in Industry 4.0, such as emerging technologies in additive manufacturing as Industry 4.0's key component to consider energy demand and environmental impact.

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