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SUSTAINABLE PRACTICES IN MANUFACTURING: A REVIEW

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Abstract

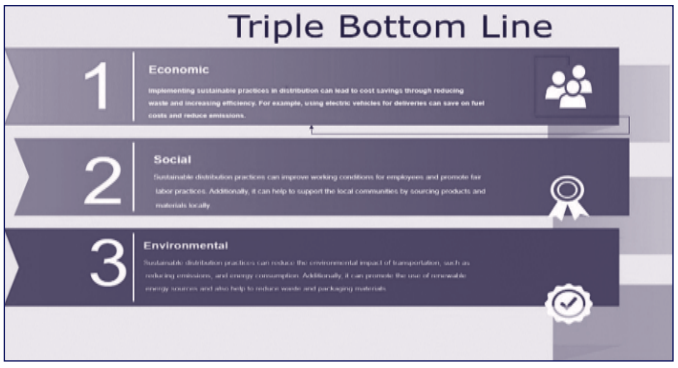
Sustainable manufacturing, which considers economic, environmental, and social factors, is a crucial area for the industry to remain competitive. To better understand sustainable practices in manufacturing, extensive research is necessary. In this article main focus of study on the recent research carrying out in last year's where it has been observed that due to covid-19 in last 2 years it was a bad impact on manufacturing industry in terms of production and implementation part of sustainable practices also. The study found that manufacturers are focused on reducing their carbon footprint, implementing recycling and reuse programs, and adopting sustainable sourcing and supply chain management practices. The study identified drivers and barriers to the implementation of sustainable practices and proposed a conceptual framework for adoption of sustainable practices in manufacturing. However, the study had limitations as it only used articles from the Google Scholar database for analysis. Overall, the manufacturing industry must find more environment friendly alternatives to lessen the harmful effects of production on the environment.

Keywords: Sustainability, sustainable practices, manufacturing, N Vivo-12.

INTRODUCTION

Sustainable practices in manufacturing involve adopting environmentally-friendly and socially responsible methods to reduce environmental impact and achieve cost savings.[1] ,[2].This is becoming increasingly important due to consumer and government emphasis on sustainability.[3],[4]. Achieving sustainable manufacturing can be done through process optimization, product design, supply chain management, and renewable energy sources. [4],[5]. Ultimately, implementing sustainable practices in manufacturing is essential for a more sustainable future and can provide economic and social benefits to companies and society. In the context of business, managing the "triple bottom line" (TBL) [6],[7],[8] which includes pursuing economic, social, and environmental goals, is a typical definition of sustainability. The fact is that modern companies of all sizes, whether they are headquartered in developed or underdeveloped countries, cannot afford to disregard the need to integrate sustainable practises into their everyday operations. The conventional company model, which places all of its attention solely on making a profit, is no longer reliable in light of the present changes in the economic and social landscape [9].

Fig. 1. Triple Bottom Line Concept

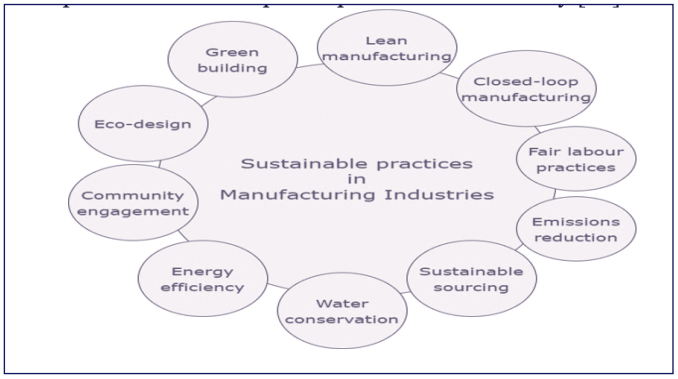


Sustainability has become increasingly important for the success of businesses, with social and environmental sustainability gaining more attention from organisations for their institutional legitimacy. However, adoption of sustainable business models has been uneven at municipal, national, and sectoral levels. Sustainable practices in manufacturing involve using environmentally-friendly and socially responsible methods such as renewable energy sources, reducing waste and emissions, and fair labour practices. Examples include process optimization, product design, supply chain management, and recycling programs. Meeting present consumer needs without compromising the ability of future generations to meet their own needs is the essence of sustainability[10]. Some examples of sustainable manufacturing practices include:

- Lean manufacturing: This approach emphasizes minimizing waste and maximizing efficiency in the production process. [11].
- Closed-loop manufacturing: This method involves reusing or recycling materials and resources during the production process. [12].
- Green building: Using sustainable building practices in the design and construction of manufacturing facilities can help to minimize the environmental impact of the facility. [13].
- Eco-design: This is the process of designing products with sustainability in mind, taking into account the entire life cycle of a product, from the sourcing of raw materials to the disposal of the product at end-of-life [14].
- Energy efficiency: Implementing energy-efficient technologies and practices in the production process can help to reduce energy consumption and costs. [15],[16],[17].
- Water conservation: Implementing water conservation measures in manufacturing can help to reduce water consumption and costs [18],[19].

- Sustainable sourcing: Sourcing raw materials from sustainable and responsible suppliers can help to reduce the environmental impact of production [20],[21].
- Emissions reduction: Implementing measures to reduce emissions from production can help to minimize the environmental impact of manufacturing [22],[23].
- Fair labour practices: Implementing ethical and fair labour practices in the production process can help to promote human rights and social responsibility [24].
- Community engagement: Engaging with the local community and stakeholders can help to build positive relationships and promote sustainability [25].

Fig. 2. Best sustainable practices in manufacturing industries



Sustainable manufacturing practices are environmentally-friendly and socially responsible methods used in the production of goods. They can reduce environmental impact, increase efficiency, promote fair labor practices, conserve natural resources, address safety issues, and improve a company's sustainability performance. [15],[26],[27]. Sustainable manufacturing is an effective solution to mitigate the negative impact of production on the environment and conserve natural resources. By focusing on product lifecycles, integrated environmental policies, and management systems, manufacturing organizations can adopt sustainable manufacturing practices that also address concerns about community, product, and employee safety. Overall, sustainable manufacturing offers a promising path towards achieving a more sustainable future for our planet.

The key role of sustainable practices in manufacturing industries

Today's manufacturing sectors use up more natural resources each year, making the systems unsustainable over the long run. One of the major users of energy and raw materials is the industrial sector. Additionally, they produce and discharge massive amounts of trash and pollutants that are bad for the environment. As a result, it is obvious that manufacturing must play a significant role in the transition to a society that is more sustainable [28],[29]. By recycling trash, switching to non-renewable products, or deploying new clean technologies, manufacturing enterprises may lessen their environmental impact.

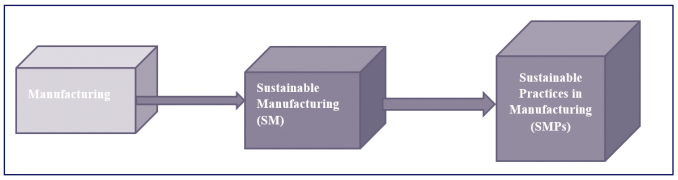
Manufacturing is characterised as "all industrial activity from the customer to the plant and back to the customer, thus embracing all the many services that are related to the manufacturing chain." Environmental issues are linked to every manufacturing process, from raw materials through to finished goods (disposal of packaging and old goods). These factors account for the observed trend toward more environmentally friendly production [16],[5]. As previously said, sustainability is defined as actions taken to raise living standards while preserving ecosystems and resources for future generations. Current academic literature describes sustainability as a multifaceted notion with various dimensions, including economic, social, and environmental performance. The economic and social spheres are significantly impacted by the industrial sector.

New organisational and economic methods are required in light of the past's ecologically harmful industrialisation. In reaction to this, sustainable development was created. Sustainable development [30],[31],[32],[33] may be defined as a process of change in which resource consumption, institutional development, technological advancement, and orientation of investments are all in line with both current and future demands. In an effort to strike a balance between economic development, social development, and environmental protection, society, governments, and businesses embrace this. Regarding sustainable development, the industrial sector occupies a special place. The manufacturing industry is viewed as a major cause of many social and environmental issues, but it is also one of the key forces behind economic growth, thus it has the power to effect change.

This is one of the factors contributing to the growing importance of the topic of sustainable manufacturing. Sustainable manufacturing[34],[35] is the use of resources wisely to produce goods and services that are able to protect the environment while achieving social and economic goals. New technology, organisational and regulatory measures, and consistent social behaviour can all help with this. In order to decrease waste and the amount of inputs required, today's methods to sustainable manufacturing mostly concentrate on efficiency and effective use of resources and energy. Efficiency in using resources and energy will be a key factor in determining a manufacturer's longterm performance. For as long as possible, corporations could find it appealing to adhere to the lowest environmental norms. It would be far wiser for businesses to prioritise sustainability now so they have more time to experiment with new products, processes, and organisational structures. They can build competencies that are difficult to duplicate and earn a competitive edge. A competitive advantage may be gained by investing in more sustainable practises, and doing so is connected to long-term cost savings.

Sustainable practises (SP) [35],[2],[36] technologies that use less energy-intensive or polluting materials or minimise pollution to lessen the negative effects of goods and services on the environment. The transition to cleaner manufacturing is mostly facilitated by SP, which also serve as a practical tool for enterprises to pursue other sustainable goals such as sustainable development. Additionally, SP can support the creation of a beneficial relationship between social and economic requirements and environmental restrictions.

Fig. 3. Hierarchy process in manufacturing industry



Sustainable Practices in manufacturing also considers the company's profits in addition to environmental concerns. The manufacturing sector benefits from more effective and efficient, fiercely competitive, and lucrative sustainable and green manufacturing (GM) [37]. Sustainable manufacturing encompasses the entire production process, including logistics and supply chain, and differs from Green Manufacturing (GM). Sustainable practices improve product quality, reduce costs, and address environmental issues, while also placing a strong emphasis on social responsibility, such as worker and community safety. It can also provide a more fulfilling workplace and sustainable business models, unlike GM, which only addresses environmental concerns. [34],[38]. Incorporating sustainable manufacturing techniques, such as using non-hazardous materials, reducing energy and material usage, and designing reusable and recyclable products, can give manufacturing companies a competitive edge. Employee involvement is also important. Examples of sustainability practices used by large firms include eco-design, renewable energy use, waste minimization, and product life cycle management. Sustainable manufacturing strategies allow businesses to produce goods with zero or very low environmental and social impact by focusing on the production sectors. To support the creation of sustainable goods and procedures, appropriate sustainable practices or strategies must be developed.

LITERATURE REVIEW

Sustainable manufacturing practices in the Indian context can include a wide range of strategies and techniques to reduce the environmental impact of manufacturing while also promoting social and economic development. Some specific examples of sustainable manufacturing practices that have been implemented or proposed in India include:

- Energy efficiency: Indian manufacturers have begun implementing energy-efficient technologies such as LED lighting, variable frequency drives, and efficient motors to reduce their energy consumption [38]. Additionally, many manufacturers in India have started using renewable energy sources such as solar and wind power to offset their energy usage.
- Water conservation: Many Indian manufacturers have implemented water conservation measures such as rainwater harvesting, recycling of wastewater, and use of water-efficient technologies to reduce their water usage [39].
- Waste management: Many Indian manufacturers have implemented waste management practices such as recycling, composting, and incineration to reduce their waste output[40].
- Green buildings: Indian manufacturers have begun incorporating green building design principles, such as natural lighting, energy-efficient HVAC systems, and renewable energy systems, into their facilities to reduce their environmental impact [41].
- Cleaner production: Indian manufacturers have started adopting cleaner production techniques such as process optimization, substitution of hazardous materials, and production process redesign to reduce their environmental impact [31].
- Sustainable sourcing: Many Indian manufacturers have started implementing sustainable sourcing practices such as using materials from sustainable and responsibly managed sources to minimize their environmental impact and promote social and economic development [31], [41].
- Corporate social responsibility: Indian manufacturers are increasingly implementing corporate social responsibility (CSR) initiatives to promote sustainable development, such as community development programs, fair labor practices, and environmental initiatives [9].

Overall, these are some examples of sustainable manufacturing practices that are being implemented or proposed in the Indian context. The adoption of these practices varies across different sectors and companies depending on their individual circumstances.

Table 1. Literature review table

References	Title	Keywords	Source Title	Focus Industry	Methodology Or Techniques used	Outcomes	Country
[1]	Exploring themes of sustainable practices in manufacturing industry: Using thematic networks approach	Green HRM practices; environmental management system; sustainable performance; thematic networks approach	Sustainability	Manufacturing Industry	Qualitative methodology following an interpretivist approach	Discusses important implications for managers and organizations	Malaysia
[2]	Evaluating critical factors to implement sustainable oriented innovation practices: An analysis of micro, small, and medium manufacturing enterprises	Sustainable oriented innovation practices; Analytical Hierarchy Process (AHP); Collaboration capability	Journal of Cleaner Production	Micro, Small and Medium Enterprises (MSMEs)	Analytical Hierarchy Process (AHP)	This paper highlights essential Critical Factors (CFs) to implement SOI practices.	India

[7]	Sustainable procurement practices in the supplier selection process: an exploratory study in the context of Brazilian manufacturing companies	Sustainable procurement , manufacturing companies , ISO20400	Corporate Governance: The International Journal of Business in Society	Manufacturing Industry	CRITIC (Criteria Importance Through Inter criteria Correlation)	A negative issue to be highlighted is that almost 20% of analysed companies did not even considered in their supplier selection process.	Brazil
[42]	Sustainable manufacturing practices, competitive capabilities, and sustainable performance: Moderating role of environmental regulations	Sustainable manufacturing practices; competitive capabilities; sustainable performance; environmental regulations; SMEs	Sustainability	SMEs	Partial Least Squares Structural Equation Modelling (PLS-SEM)	Gaining competitive capabilities have a positive mediating impact on the relationship between SMPs and SMEs' sustainable performance	China
[43]	Sustainable Manufacturing Practices and Sustainability Performance: A Conceptual Framework for Manufacturing SMEs	sustainable manufacturing practices, sustainability performance, firm capabilities, manufacturing SMEs, Covid-19	Business Management and Strategy	SMEs	Explanatory quantitative study	This article does not just inform firms and authorities on the importance of SMPs for superior performance but also guides firms towards understanding and improving their current SMPs	Malaysia
[44]	Sustainable Manufacturing Practices of Small and Medium Furniture Enterprises in New Zealand	sustainable manufacturing practices, sustainability performance, firm capabilities,	Journal of Asia Entrepreneurship and Sustainability	Small and Medium Furniture Enterprises (SMFEs)	semi-structured interview method	It was discovered that regarding the impact of sustainable manufacturing practices on companies, most current managers did not have a strong desire for such practices.	New Zealand
[45]	Sustainable Operations Management Practices and Competitive Advantage of Manufacturing Firms in Kenya	Sustainable operations management practices, competitive advantage.	ESJ Social sciences	Manufacturing Industry	Slovin's formula	The findings of the paper are relevant to the advancement of environmental policy and practices	Kenya
[46]	Social Sustainable Supply Chain Practices Evidence From the Indian Manufacturing Sector: An Empirical Study	ANOVA and Correlation, Factor Analysis, Manufacturing, Social Sustainability, Supply Chain, Sustainability	International Journal of Social Ecology and Sustainable Development (IJSESD)	Manufacturing Industry	Questionnaire based study	Sustainable supply chain covering social perspectives as well-chosen Indian manufacturing companies to investigate social perspectives.	India
[47]	Uptake of Sustainable Manufacturing Practices By Food Manufacturing Firms: A Systematic Review	Environmental management standards, Food manufacturing firms, Food security, Vote count	International Journal of Advanced Science and Technology	Food industry	Review	This paper systematically reviews the heterogeneity of firm conditions and owner characteristics	
[48]	Pressure or premium: what works best where? Antecedents and outcomes of sustainable manufacturing practices	sustainable manufacturing; green manufacturing; stakeholder pressure; customer willingness to pay; cost performance; quality performance	International Journal of Production Research	Multinational enterprises (MNEs)	International Manufacturing Strategy Survey (IMSS) and partial least squares structural equation modelling (PLS-SEM)	Relationship between sustainability efforts and operational performance is mediated through sustainability performance.	India, China and OECD

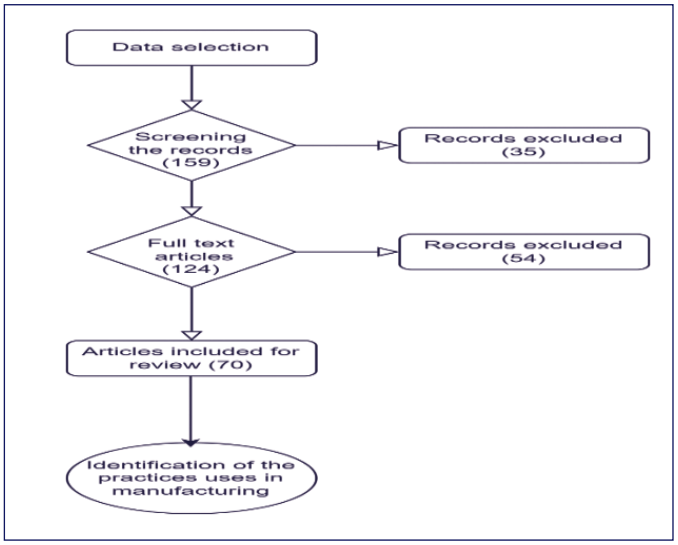
[49]	The role of environmental awareness and green technological usage to foster sustainable green practices in Bangladeshi manufacturing SMEs	environment sustainable practices, environment friendly materials, small and medium enterprise, green technology, awareness, Bangladesh	International Journal of Advanced Science and Technology	Manufacturing Industry	Structured questionnaire	SME manufacturer to foster the environmental sustainable practices	Bangladesh
[50]	Sustainable Practices and Business Performance: Evidence from Sri Lankan Manufacturing Firms	Sustainable Practices, Business Performance, Environmental Practices, Human Resource Management Practices, Corporate Governance	European Journal of Business management	Manufacturing Industry	Survey methodology	This paper is a novelty for Sri Lankan manufacturing industry and for policymakers as it provides new insights to the manufacturing industry on sustainable practices (SP) and the business performance (BP).	Shrilanka
[51]	Green manufacturing practices and sustainable performance among Ghanaian manufacturing SMEs: the explanatory link of green supply chain integration	Green manufacturing practices, Green supply chain integration, Economic performance, Environmental performance, Social performance	Management of Environmental Quality: An International Journal	Manufacturing Industry	Explanatory research & Structured questionnaire	The results indicate that GMPs have a significant positive effect on sustainable performance.	Ghana
[52]	Do green human resource management practices contribute to sustainable performance in manufacturing industry?	Green human resource practices; green selection; green training; green rewards; sustainable performance; triple bottom line; TBL.	International Journal of Environment and Sustainable Development	Manufacturing Industry	Quantitative research and SEM	This study adhered directions for future research with inherent limitations. The findings from this study will be useful for Malaysian ISO-14001 certified firms and elsewhere with a similar economy	Malaysia
[53]	Sustainable manufacturing practices in a textile company: A case study	sustainable manufacturing practices, sustainability, case study, environment, textile	International Journal of Supply Chain Management (IJSCM)	Textile Industry	Case study	The findings of this study also have a noticeable implication, especially for the textile company and other practitioners, to evaluate their current manufacturing practices.	Malaysia
[54]	Supplier selection for the adoption of green innovation in sustainable supply chain management practices: A case of the Chinese textile manufacturing industry	supplier selection; green innovation; sustainable supply chain management; manufacturing industry; MCDM; FAHP; FTOPSIS	MDPI	Textile Industry	Case study , MCDM ,FAHP , FTOPSIS	These findings will help managers, practitioners, and policymakers implement green innovation criteria in sustainable manufacturing supply chains	China
[55]	Sustainable procurement practices and performance of procurement in food and beverages manufacturing firms in Kenya	Sustainable Procurement Practices, Procurement Performance, Manufacturing firms, Nairobi County, Reverse Logistics, Green Specification, Green Inventory Management and Green Tendering	Global scientific journal	Food and beverage industry	descriptive cross-sectional survey	The study recommends that a further study should incorporate service industry in order to compare and bring out a global view.	Kenya
[56]	Moderating effect of firm age and size on the relationship between sustainable operations management practices and competitive advantage of manufacturing firms in Kenya	Sustainable operations management practices, firm age, firm size, competitive advantage, manufacturing firms	DBA Africa Management Review	Manufacturing Industry	Slovin's formula	Understanding of reciprocal causal mechanism linking SOMPs and competitive advantage and circumstances shaping that link.	Kenya

[57]	The Role of Manufacturing Organizations in the Adoption of Sustainable Supply Chain Management Practices and Performance	Sustainability, Adoption and Supply Chain-Management	Journal of Advances in Social Science and Humanities	Manufacturing Industry	Survey , Factor analysis	The study have significant impact on the manufacturers in Nigeria for understand the potential positive effects sustainable supply chain practices could have on different dimensions of performance and be more proactive in the adoption of such practices.	Nigeria
[58]	Influence of Sustainable Management Practices, Strategic Orientation and Organizational Culture on Sustainability Performance in Manufacturing Firms	business administration, sustainability performance, multiple regression analysis, manufacturing firms, Philippines	IOER International Multidisciplinary Research Journal	Manufacturing Industry	survey questionnaire	The best predictor that significantly contributed to the variations of sustainability performance.	Philippines

REVIEW METHODOLOGY

Any research must include a literature review. Provided an organised evaluation of the literature through an iterative cycle of developing appropriate search terms, looking for pertinent literature, and conducting the analysis at the end. The authors of this paper used a similar review process. The methodology employed combines social network, content analysis, and bibliometric tools. Through Google Scholar databases, cutting-edge research was carried out for this study. To understand how the level of interest in the topic has changed after the application of sustainable practices or methods implemented in various manufacturing organizations, in the previous years. A thorough literature review was used as the research methodology for this investigation. The study's primary stages were as follows:

Fig. 5. Research process adopted for selection of literature.



KEYWORDS SELECTION

Use NVivo12's keyword query function to search for and analyse the keywords in available data, and identify patterns and themes within the research. Review the list of keywords and prioritize the most relevant and specific terms for your research. Consider the context of research, and include any specific industry or geographic terms that might be relevant. For example, "sustainable practices in automotive manufacturing" or "sustainable practices in European manufacturing. "Sustainable, manufacturing , sustainability, Green manufacturing, Eco-friendly manufacturing, Carbon footprint reduction, Energy efficiency , Renewable energy sources, Water conservation, Recycling and waste reduction, Sustainable materials, Lean manufacturing, Life cycle assessment, Corporate social responsibility, Industrial ecology, Clean production, Climate change mitigation most common keywords find in the context of our topic.

Figure. 6. Word Cloud Nvivo 12 Output. Source: Current study.

Table 2. NVivo 12 Output Word Frequency.

Word	Count	Weighted (%) Percentage	Similar Words
Sustainable	5904	0.80	Keeping, maintain, sustain, sustainability, sustainable
Manufacturing	4888	0.67	Production , Generation , Making
Practices	4500	0.61	Commitment, good, practices, use
Performance	4424	0.60	Operations, performance, sustainable performance
Management	4308	0.59	Administration , management
Environmental	4089	0.56	Environmental, ecological, conservational
Sustainability	3327	0.45	Unattainability , suitability stability , substantiality, sustaining
Research	3000	0.41	Analysis , exploration , research
Green	2590	0.35	Green

After conducting literature review from the data source it has been found that there many good journals which are publishing the work relevant to this topic after study here it is suggesting 25 top journals in the field of "sustainable practice in manufacturing". Few of them is used in this study.

1. Journal of Cleaner Production
2. International Journal of Sustainable Manufacturing
3. Journal of Sustainable Manufacturing
4. Journal of Manufacturing Technology Management
5. Journal of Sustainable Development
6. Journal of Sustainable Energy Systems
7. Journal of Sustainable Engineering
8. Journal of Sustainable Materials Science and Engineering
9. Journal of Sustainable Industrial Design and Engineering
10. Journal of Sustainable Manufacturing and Advanced Recycling
11. Journal of Sustainable Industrial Engineering,
12. Journal of Sustainable Manufacturing and Production Systems
13. Journal of Sustainable Manufacturing Technologies,
14. Journal of Sustainable Manufacturing and Environmental Management
15. Journal of Sustainable Manufacturing and Operations Management,
16. Journal of Sustainable Manufacturing and Supply Chain
17. Journal of Sustainable Manufacturing and Lean Six Sigma,
18. Journal of Sustainable Manufacturing and Green Technology
19. Journal of Sustainable Manufacturing and Industrial Ecology,
20. Journal of Sustainable Manufacturing and Sustainability Science
21. Journal of Sustainable Manufacturing and Design,
22. Journal of Sustainable Manufacturing and Quality Management
23. Journal of Sustainable Manufacturing and Technology Innovation,
24. Journal of Sustainable Manufacturing and Materials Management
25. Journal of Sustainable Manufacturing and Corporate Social Responsibility.

The sustainable practices being adopted by different sectors in India in the form of a list. Here are some examples of sustainable practices being implemented in various industries in India:

Automotive Industry:
- Adoption of electric and hybrid vehicle technologies [59]
- Implementation of energy-efficient manufacturing processes [22]
- Use of lightweight materials to reduce vehicle weight and improve fuel efficiency [22]
- Implementation of lean manufacturing principles to reduce waste [60]
- Use of sustainable and renewable energy sources [61]

Textile Industry:
- Use of organic cotton, bamboo, and other sustainable fibers [62]
- Implementation of water-efficient dyeing and finishing processes [63]
- Use of recycled materials in production [64]
- Adoption of digital printing technologies to reduce water and energy usage[26], [65]
- Implementation of closed-loop systems to minimize waste [54]

Construction Industry:
- Use of sustainable materials such as bamboo, rammed earth, and fly ash bricks [24]
- Use of green building design principles to minimize energy and water usage [13]
- Use of renewable energy sources such as solar power [53]
- Implementation of waste management and recycling processes [16]
- Use of sustainable sourcing and procurement practices [37]

Food Processing Industry:
- Implementation of energy-efficient technologies to reduce energy usage [25]
- Use of sustainable packaging materials[25]
- Adoption of water-efficient technologies [62]
- Use of sustainable agricultural practices[25]Implementation of waste management and recycling processes [13]

Information Technology Industry:
- Use of energy-efficient servers and data centers[64]
- Implementation of telecommuting and other remote work practices [10]
- Adoption of cloud computing to reduce energy usage[10]
- Use of sustainable materials in product manufacturing[26]
- Implementing circular economy principles[66]

Chemicals Industry:
- Use of renewable raw materials [18]
- Recycling of materials and waste reduction [18]
- Implementation of energy-efficient processes [67]
- Reduction of emissions and pollution [30]

These are just a few examples of sustainable practices being implemented in various industries in India. It is important to note that sustainable practices can vary depending on the size, location, and stage of development of a particular company or sector. Additionally, there are many challenges that can arise when trying to implement sustainable practices, such as lack of awareness, limited resources, and regulatory barriers. Table 2 shows some practices followed by manufacturing companies during 2000 to 2022.

Table 3. Sustainable practices

Time Period	Sustainable Practices
2000s-2010s	1.Energy efficiency and conservation [32] 2.Pollution prevention and control [68] 3.Resource conservation and recycling [69]
2011s-2020s	1. Life Cycle Assessment [70] 2.Lean Manufacturing [33] 3.Green Supply Chain Management [21] 4.Industrial Ecology [71] 5.Corporate Social Responsibility [72] 6.ISO 14001 Environmental Management Systems [50] 7.Energy management systems like ISO 50001 [73]
2021s-2022	1.Circular economy [30] 2.Advanced analytics for sustainability [74] 3.Decarbonisation [75] 4.Digitalization for sustainability [1] 5.Building Information Modelling (BIM) for sustainable building design [30]

RESEARCH GAPS

Research gaps exist in sustainable practices across various industries. In agriculture, research is needed on sustainable intensification and livestock production systems. In energy, more research is required on renewable energy integration, energy storage, and environmental and social impacts of renewables. In transportation, research is needed on the adoption of low-carbon options and necessary infrastructure. In building, research is required on retrofitting existing buildings and sustainable design. In waste management, research is needed on waste reduction, increasing recycling rates, and closed-loop systems for resource recovery.

Table 4 and Table 5 present a list of barriers and enablers identified as an outcome of review of research articles relating to topics.

Table 4. Barriers to implementation of sustainable practices in manufacturing.

Barriers	Description
Lack of knowledge and understanding	Many individuals and organizations may not fully understand the concept of sustainability or how to implement sustainable practices.
Financial constraints	Implementing sustainable practices can be costly, and may not be financially feasible for some individuals or organizations.
Resistance to change	Some individuals or organizations may be resistant to change and may not be willing to adopt new sustainable practices.
Limited resources and support	Limited resources and support may make it difficult for individuals or organizations to implement sustainable practices.
Lack of government regulations and incentives	Without government regulations and incentives, individuals and organizations may not feel compelled to adopt sustainable practices.

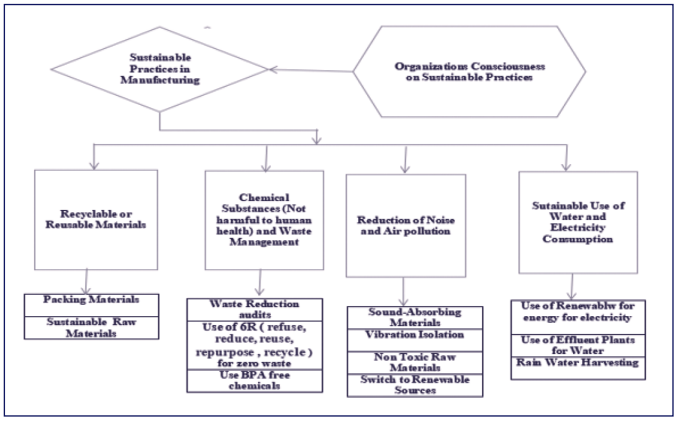
Table 5. Enablers to implementation of sustainable practices in manufacturing.Top of Form

Enablers	Description
Strong leadership	Clear and consistent support and direction from senior management to drive sustainable practices throughout the organization.
Employee engagement	Active involvement and commitment of employees in identifying and implementing sustainable practices.
Clear goals and targets	Establishing measurable goals and targets to track progress and ensure accountability.
Collaboration and partnerships	Building relationships with external stakeholders and partners to share knowledge, resources, and best practices.
Education and training	Providing education and training opportunities for employees to increase understanding and knowledge of sustainable practices.
Data and measurement	Collecting and analysing data to track performance and identify areas for improvement.
Innovation and experimentation	Encouraging experimentation and innovation to identify new and improved sustainable practices.
Financial incentives	Implementing financial incentives to encourage the adoption of sustainable practices.
Communication and transparency	Communicating progress and performance to internal and external stakeholders and being transparent about sustainable practices.

CONCEPTUAL FRAMEWORK

The conceptual framework for this study was developed with assistance from the already available literature on this subject, which has been discussed in the literature review. This study focuses on four sustainable manufacturing practices: waste management, sustainable manufacturing process, sustainable use of water and power, and sustainable material. Developing a framework for sustainable manufacturing practices involves identifying and addressing the environmental, social, and economic impacts of the manufacturing process. The framework should include strategies such as energy efficiency and renewable energy, resource efficiency and waste reduction, product design and lifecycle management, supply chain management and sustainable sourcing, community engagement and social responsibility, and compliance with environmental and labour laws and regulations. It's important to conduct an assessment of the current state of manufacturing operations, identify areas for improvement, develop a plan of action, implement the plan, track progress, communicate efforts, and continually improve. Organizational consciousness is critical in shaping an organization's understanding of its impact on the environment and society, and in guiding its actions to reduce that impact. Developing a framework for sustainable manufacturing can take time and requires collaboration with experts, employees, and stakeholders.

Fig. 3. Conceptual framework



This paper examines various sustainable production practices within the manufacturing industry, including waste management, energy and water conservation, use of renewable resources, and responsible material sourcing. Understanding and implementing these practices is crucial for organizations to reduce their environmental impact and create a more sustainable future.

CONCLUSION

Sustainable practices in manufacturing involve incorporating environmental, social, and economic considerations into the manufacturing process to minimize negative impacts and promote long-term viability. These practices can include implementing energy-efficient technologies, reducing waste and emissions, and incorporating sustainable materials into products. Adopting sustainable manufacturing practices can help companies reduce their environmental footprint, improve their reputation, and access new markets, while also potentially saving money on energy and raw materials costs. However, sustainable manufacturing is an ongoing process and requires continuous improvement, learning and adaptation to changing market needs and new technologies.

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