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Review Paper : Policy Research – Survey Paper

Sustainable Manufacturing Process And Its Effects: A Review

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Abstract: Sustainable practices and a manufacturing strategy inform strategic decisions. Deep learning improves manufacturing sustainability, notably predictive maintenance and quality control. Industry 4.0 supports sustainable production in various ways. Additive manufacturing reduces environmental impact by improving material efficiency. Mixed reality (MR)'s environmental sustainability promise needs further study. Sustainable manufacturing balances profit, social responsibility, and the environment. Sustainable, digital, and agile transformations are driven by Industry 4.0 and customer needs. Zero Defect and data-driven technologies enable sustainable production. Risk factors and mitigation techniques are identified, focusing on disruption risks and regulatory changes. Sustainability education should be in engineering courses. Studying stakeholder barriers reveals ways to reduce them. Lean Six Sigma and 6R principles reduce waste and promote sustainable production. Historical context shows sustainability's relevance. Industry 5.0 improves sustainable production using new technologies, teamwork, and ethics. Energy-intensive sectors adopt smart, sustainable production using edge-cloud techniques and cutting-edge technologies.

Keywords: Sustainability, Industry 4.0, Deep learning, Mixed reality, Lean Six Sigma, 6R Principles.

1. Introduction

In an increasingly populous world, sustainable manufacturing is essential to tackling pressing environmental problems like pollution, resource depletion, and climate change. In reaction to several environmental crises that occurred between 1960 and 1980, the idea of sustainability first surfaced in the 1970s and 1980s. Sustainability is the avoidance of needless changes to the atmosphere, soil, water, forests, and animal habitats, according to the Brundtland report from 1987. Green or eco-friendly manufacturing, commonly referred to as sustainable manufacturing, is a multifaceted process that aims to reduce environmental impact while maximizing benefits to the economy and society. It seeks to develop products that, over the course of their lives, have the fewest negative environmental effects possible. The ultimate objective is to meet present-day demand for goods without sacrificing the capacity of future generations to meet their own. Sustainable manufacturing takes an integrated approach, acknowledging the complex interplay between social, environmental, and economic factors. The goal is to minimize waste, pollution, and depletion of resources throughout the entire lifecycle of the product, from the extraction of raw materials to their disposal. Refillable resources are prioritized, and negative environmental effects and resource consumption are minimized. Regulations and policies promoting a thorough, sustainable manufacturing strategy frequently address environmental concerns. The main goals of sustainable manufacturing are non-polluting, safe, inexpensive, and resource- and energy efficient processes. It aims to lessen negative environmental effects, protect resources, enhance social welfare, and generate revenue. Governments, organizations, and legislators are pushing sustainable manufacturing practices, making organizational sustainability performance a primary concern for manufacturing companies.

A number of factors, such as leadership commitment, effective resource management, investment in research and development, employee empowerment, and waste management, are critical to the successful adoption of eco-friendly practices. Spending on research and development is essential for sustainable manufacturing, and adopting cutting-edge technologies is a must. Employee education fosters a creative and ethical workplace environment. Programs for recycling and waste management are crucial for reducing environmental effects. Eco-friendliness is further enhanced by sustainability incorporated into product design and lifecycle assessments from production to disposal. External factors that impact waste disposal,

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emissions limitations, and production processes are government laws and policies. Sustainable manufacturing is influenced by stakeholder pressures, market demand for eco-friendly products and services, and availability of sustainable raw materials and energy sources.

Businesses that use green practices and technologies gain a competitive advantage, which is influenced by incentives and funding availability. A company's ability to manufacture sustainably is impacted by the pricing, availability, and scarcity of natural resources. The sustainability landscape is further shaped by changes in consumer expectations, regulatory policies, and technological advancements in energy efficiency and waste reduction. Using sustainable manufacturing practices has long-term social and economic benefits in addition to environmental benefits. The landscape of sustainable manufacturing is changing as competitors in the industry adopt sustainable practices to remain competitive. Advances in sustainable technology facilitate the adoption of environmentally friendly practices by businesses, indicating a bright future with widespread environmental consciousness.

2. Literature Survey

2.1. Sustainable Manufacturing Strategies and Policies

Dharmendra Hariyani et al. (2022) list 12 variables, including rules, incentives, and technology, in their industrial growth sustainability research. They identify biases and propose empirical research in specific organizational contexts to support sustainable manufacturing, stressing policy paradigm shifts and performance evaluation. Anastasiia Moldavska et al. (2017) illustrate 1990–2016 research community SM terminology conflicts. Despite 11 subcategories having similar footing, the remaining 67 diverge due to inconsistent sustainability and organizational tool nomenclature. Principles and a systems approach help minimize sustainable manufacturing misunderstandings.

2.2. Technology Integration for Sustainability

Sustainability 4.0, introduced by M Javaid et al. (2022), uses IoT, AI, ML, and more to efficiently use manufacturing resources for environmental sustainability, social inclusion, and continuous commercial operations. Digitization quantifies processes and cuts waste. M. Caterino et al. (2022) review manufacturing sustainability literature (2000–2021) on Industry 4.0 and design. Research could cover underrepresented topics including human factors, resilience, adaptation, and agility. A Jamwal et al. (2022) study Deep Learning (DL) methods for environmentally friendly manufacturing and blame a lack of worker skills for poor AI adoption. DL models improve problem detection, predictive maintenance, and quality control and create a sustainable manufacturing framework. More research and testing are needed to benefit from Industry 4.0. In their 2020 study, C Enyoghasi et al. identify uses for Industry 4.0 and sustainable manufacturing technologies at various levels. For environmental sustainability in manufacturing, S Thiede et al. (2022) suggest researching energy, materials, and emissions and offering Mixed Reality (MR) design alternatives. J Leng et al. (2019) examine blockchain's merits and cons for sustainable manufacturing in line with the UN Sustainable Development Goals. It emphasizes mass deployment of blockchain in manufacturing and product lifecycle management for effect.

2.3. Environmental Impact and Life Cycle Assessment

The environmental impact of additive and subtractive manufacturing for sustainable production, S R Krishna et al. (2021) study PCB supports and bevel gears in aircraft. It uses life cycle assessment software to compare environmental consequences on human health, ecosystems, resource availability, and material and energy use. Due to its 75%–85% lower material utilization, additive manufacturing has a lower environmental impact.

2.4. Innovation and Performance in Sustainable Manufacturing

A Goyal et al. (2021) propose the Green Quality Circle for multinational industrial environmental issues. By tackling difficulties methodically, shop floor workers can improve production operations environmentally, especially in poor developing nations. B Pande et al. (2022) link SMPs to a company's MS conceptually. In a case study, SMPs fit into MS. This promotes green manufacturing. J Malak et al. (2021) use literature and Delphi analysis to examine sustainable manufacturing concerns and solutions across three levels. N Hami et al. (2015) examine whether innovation performance (IP) mediates the SMP-ES link. Internal SMP-ES gains are mediated by process innovation. Product and process innovations can offset external SMP, showing the need of innovation in sustainable profit methods. F Badurdeen et al. (2017) suggest a closed-loop system using creative and sustainable manufacturing. Profit, social and environmental responsibility, and societal prosperity must be balanced in modern and sustainable production. P Maliszewska J. et al. (2022) say sustainable development knowledge drives organizational success. Future research will use a manufacturing knowledge map to study SD manufacturing decision models. R Titmarsh et al. (2020) integrate Lean Six Sigma with the 6R ideas for sustainable production. This Industry 4.0 strategy reduces waste with machine learning and IoT sensors. Yip et al. (2021) use TBL to

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analyze sustainable manufacturing. Social network analysis (SNA) helps achieve efficient, sustainable manufacturing by overcoming stakeholder obstacles and improving network metrics.

2.5. Industry Transformations and Global Perspectives

Manufacturers must improve their environmental performance as they develop and make better products. L Litos et al. (2023) suggest using an eco-efficiency maturity model to guide innovation to close the eco-efficiency-effectiveness gap. Systematic improvement is their goal. Due to Industry 4.0 and rising customer demands, F Psarommatis et al. (2022) advocate major manufacturing sector reform. Their entire framework emphasizes agility, digital connection, sustainability, Zero Defect Manufacturing (ZDM), and data-driven technologies' important role in process and product quality.

Industry 5.0 may support sustainable manufacturing, said M Ghobakhloo et al. (2023). They emphasise 12 key functions, new technologies, collaboration, and ethics. Their strategic plan stresses Industry 5.0's global impact and advises stakeholders on function precedence for implementation.

S Ma et al. (2022) examine energy-intensive manufacturers' Industry 4.0 transition to intelligent and sustainable production. They advocate edge-cloud cooperation and smart manufacturing for data gathering, preprocessing, storage, and analysis. The report emphasizes the need for production data-based sustainability research.

M. Tanco et al. (2021) discuss Latin American SMEs' sustainable manufacturing issues. The study found weak rules, resource constraints, and social attitudes hamper SMEs' sustainability. Government, university, and organization cooperation on circular economy concepts is being promoted.

Durgupta et al. (2018) offer modular computer-aided process design for sustainable manufacturing education in engineering. The SMART CN project developed 21 sustainability-themed engineering modules to educate educators and students about sustainable manufacturing.

M Chand et al. (2020) examine supply, operational, disruption, transportation, financial, and demand risks in sustainable manufacturing. They use GTA and risk mitigation to quantify these risks' effects on sustainable manufacturing systems. Disruption, demand, money, and speedy regulation are prioritized. Sustainability emerged from 1970s and 1980s environmental disasters, according to A Awasthi et al. (2020). Sustainability is maintaining natural equilibrium and avoiding ecological and species crisis thresholds. The UN World defines sustainable development as social progress, economic growth, and environmental balance that meets current needs without compromising future generations.

3. Result and Discussion

Considering the industrial growth and expansion on multiple facets of sustainable manufacturing, the research collectively highlights the growing significance of sustainable manufacturing and emphasizes the need for a paradigm shift in the way industries operate to align with environmental and social responsibility. The crucial role that innovation plays in driving sustainable manufacturing—in both processes and products—emerges as a major theme. It's clear that businesses are realizing the financial gains from incorporating sustainable practices into their operations, and they're highlighting how innovation can improve profits while simultaneously advancing social and environmental objectives. To promote a shared understanding of sustainable manufacturing across various sectors, standardization and uniform terminology are emphasized as crucial elements.

To prevent misunderstandings and encourage its wider adoption, it is imperative to address the lack of agreement among researchers regarding definitions for sustainable manufacturing. Innovations in technology present opportunities to improve manufacturing sustainability, especially within the framework of Industry 4.0 and its possible progression into Industry 5.0. Modern technologies like blockchain, IoT, AI, ML, and mixed reality can be integrated to maximize efficiency, minimize waste, and enhance environmental performance. In sustainable manufacturing, the emphasis on risk assessment and mitigation is another important factor. Achieving sustainable practices while preserving economic viability requires identifying and managing a variety of risks, from operational and supply risks to changes in finance and regulations.

The study also addresses the difficulties small and medium-sized businesses (SMEs) have implementing sustainable manufacturing practices, highlighting the significance of cooperation between governmental, academic, and non-profit institutions in facilitating SMEs' shift to sustainable practices. Furthermore, the study emphasized the need for a balance between economic growth, environmental stewardship, and societal well-being by highlighting calls for an all-encompassing and multidisciplinary approach to sustainable manufacturing. These studies offer important insights and recommendations for future research and practice in the pursuit of a more sustainable and responsible manufacturing sector, which is helpful as organizations

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and policymakers navigate the complex landscape of sustainable manufacturing

4. Conclusion

The research evaluation shows that sustainable manufacturing is becoming more important in industry. Laws, incentives, and technology contribute to sustainable manufacturing, according to the research assessment. Innovation as a bridge between sustainable practices and economic sustainability, policymaking paradigm shift, and performance evaluation model are stressed. Sustainability 4.0, which integrates blockchain, AI, and IoT, is essential for environmental sustainability and resource efficiency. Sustainable manufacturing, the reviews emphasize human factors and resilience, neglected fields. The report recommends a manufacturing sustainability plan that includes technology, teamwork, and education and training. Governments, academia, and organizations must collaborate for a more inclusive and sustainable global economy. This review aims to improve manufacturing sustainability as Industry 5.0 advances.

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