

Sustainable Manufacturing Practices

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Sustainable manufacturing was defined as "the creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers and are economically sound".

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1. Introduction

Sustainability in manufacturing has gained wide recognition in recent years with more calls for manufacturers to ensure preserving the environment and social alleviation besides economic growth. Sustainable development is essential to cope with environmental problems (e.g., climate change and pollution) caused by the rapid pursuit of economic growth ^[1] and requires joint efforts from several parties, particularly governments and business organizations ^[2]. The sustainability concept emphasizes businesses' social and environmental contributions to society while maintaining financial profitability as well ^[3]. Aboelmaged ^[4] indicated that research on sustainability is divided into two main streams, green manufacturing and sustainable manufacturing, and argued for sustainability manufacturing.

We build on Garetti and Taisch's ^[5] definition of sustainable manufacturing as the firm's ability to maintain the intelligent use of natural resources to fulfill economic, social, and environmental aspects, which eventually leads to improving quality of life and preserving the environment. Recognizing the fact that 20% of global carbon dioxide emission is generated by the manufacturing of goods, sustainable manufacturing is advocated to increase sustainability awareness and provide a huge contribution to global GDP ^[6]. As an emergent field, sustainable manufacturing has gained increasing attention from academicians and policymakers during the last decade ^[4], which replaces traditional operating practices with innovative processes that consider economic, social, and environmental effects ^[7]. Prior research on sustainable manufacturing identified the four "Rs" strategies: reduce, remanufacture, recycle, and reuse as the fundamental cornerstones of environmentally conscious manufacturing ^[8] and determining good SMPs ^[9]. Garetti et al. ^[5] argued that sustainable manufacturing ensures that operational processes, starting from the product design phase to packaging and delivery to the consumer phase, consider the efficient consumption of natural resources and the interests of stakeholders.

Researchers highlighted the neglecting of some environmental concerns such as water contamination and waste recycling ^[10] and emerging types of pollution such as face masks produced by large-scale manufacturing ^[11]. China's economic growth since 1978 was accompanied with the huge consumption of natural resources and high environmental costs ^[12]. China's quick economic recovery from COVID-19 has provided a vast yet narrow opportunity to build a clean, safe, and fair economy ^[13]. In addressing climate change, Li et al. ^[14] argued that Chinese manufacturing has undertaken the responsibility of energy conservation and emission reduction.

Behjati ^[15] reported that 64% of air pollution is generated by manufacturing SMEs, and only 0.4 of these SMEs adhere to environmental protection. Global industrialization forces SMEs to adhere to environmental regulations and responsibilities to adopt sustainable manufacturing, which results in generating less waste ^[16]. Khan, Sisi, and Siquin ^[17] argued that governments can develop and implement relevant environmental regulations to decrease the negative impact of manufacturing organizations on the environment and normalize their economic behavior. Governments, nongovernmental organizations, and customers undertake an increasing role in forcing SMEs to adopt sustainability ^[18]. Zailani et al. ^[19] stated that due to social issues and global warming, regulatory agencies and stakeholders play a significant role in forcing manufacturing firms to adopt sustainability. Firms have increased their awareness of competitive advantages that can be gained from sustainable performance due to stakeholders' increasing demand for firms' social and environmental responsibility ^[20]. Many countries are striving to achieve the United Nations' 2030 sustainable development goals through developing and implementing relevant regulations ^[21]. Therefore, it is essential to ensure manufacturing SMEs'

involvement in adopting favorable environmental manufacturing practices in their process and business strategy and to adhere to relevant environmental laws and regulations.

2. Sustainable Manufacturing Practices, Competitive Capabilities, and Sustainable Performance

This entry builds on the firm's natural-resource-based view (NRBV) developed by Hart ^[22] as an extension to the resource-based view which emphasizes the influential role of organizational resources and capabilities in gaining and sustaining competitive advantages. NRBV argues that firms can gain competitive advantages when interacting with their natural environment through sustainable development ^[22]. For instance, decreasing wastes and preventing pollutants can lead to decreasing manufacturing costs and enhancing efficiency. Further, NRBV pays increasing attention to pressures maintained by stakeholders and calls for integrating such pressures with organizational processes and strategies to achieve sustainable development. Many researchers have employed the NRBV within the SMEs context. For example, Aragon-Correa et al. ^[23] reported that stakeholder management, strategic proactivity, and shared vision capabilities were positively related to Spanish SMEs' environmental leadership, adherence to environmental regulations, and pollution prevention, which enhanced their financial performance, while Woo et al. ^[24] highlighted that labor productivity can be enhanced through adopting environmental innovation in SMEs' business strategy.

Research on sustainability focused mainly on large enterprises with little attention paid to examining SMEs' sustainable performance ^{[25][26]}. The involvement of SMEs in advancing sustainable development goals determined by the United Nations is essential due to their fundamental impact on economic, social, and environmental perspectives ^[24]. The majority of studies undertaken to examine SMEs' sustainability focused on the influence of green, lean, innovation, and other enablers of sustainable performance or identifying the drivers and barriers of implementing sustainability ^[27]. Prieto-Sandoval et al. ^[28] highlighted the need for more research on the relationship between the circular economy implementation and SMEs sustainable development. While manufacturing SMEs contributes significantly to national GDP, they cause negative impacts on the environment due to avoiding environmentally sustainable practices in their strategies and processes ^[29].

Researchers highlighted the impact of adopting SMPs and of enhancing economic, social, and environmental performance. Afum et al. and Hong et al. indicated a positive relationship between sustainable practices and firms' sustainable performance ^{[30][31]}. Firms can promote and improve their image before stakeholders through adopting favorable environmental practices ^[32]. Organizational social performance is extended from its corporate social responsibility initiative and refers to the actual achievement in maintaining and improving the quality besides enhancing environmental protection ^[26]. According to Zailani et al. ^[33], firms' environmentally friendly practices such as packaging and waste reduction have a positive impact on their social performance through providing eco-products, motivating the involvement of nongovernmental organizations in organizational sustainable activities, and increasing public awareness toward sustainability.

Saqib and Zhang ^[34] indicated that sustainable practices of manufacturing, procurement, and distribution are significantly related to a firm's sustainability performance. Similarly, Abdul-Rashid et al. ^[35] found that a sustainable manufacturing process is positively related to sustainability performance in the Malaysian manufacturing sector. However, Habidin et al. ^[36] argued that only fewer SMPs serve as predictors of SMEs' environmental performance in the Malaysian automotive industry. Firms' environmental performance is positively affected by adopting manufacturing practices that aim to manage carbon dioxide emissions, wastes, and pollutants and reduce energy consumption. Operational outcomes gained from SMPs involve cost reduction, improving production flexibility, accelerating product delivery, and improving product quality ^{[37][38]}. Li et al. ^[14] underlined that Chinese intensive energy-based firm's social performance is positively related to recycling, while green product innovation positively influenced financial performance.

Sroufe ^[39] found that environmentally based design practices such as the high usage of recycled materials and those that are designed to reduce CO₂ emissions and disassembly significantly reduce costs and increase firms' market share. The extant literature established a positive relationship between favorable environmental practices during the manufacturing process (e.g., controlling emissions, waste reduction, effective management of disposals and pollutants, and decreasing energy consumption) and the firm's profitability ^{[40][41][42]}.

Sustainable practices used to reflect the solution of sustainability issues involve sustainable manufacturing, sustainable procurement, and sustainable distribution ^[43]. We focus on the adoption of sustainable manufacturing among Chinese SMEs and its impact on their sustainable performance. The major SMPs involve the implementation of the 3Rs, minimizing waste, reducing the generation of hazardous substances, and ensuring an efficient use of energy ^[44]. In a

similar vein, Chin et al. ^[45] depicted SMPs as the process of reducing, reusing, and recycling resources and collaborating to recover the components of a product, while minimizing resources consumption during the manufacturing process. Many researchers underlined that SMPs are vital for enhancing a company's sustainable performance ^{[46][47][48]}. In this vein, Yildiz et al. ^[43] argued that SMPs play an influential role in improving firms' sustainable performance.

Firms maintaining competitive capabilities such as innovation, quality, cost, flexibility, and efficiency can provide distinctive customer value and outperform their competitors. This study builds on four competitive dimensions in operations research: quality, flexibility, cost, and delivery ^[49]. Manufacturing companies who maintain such capabilities can achieve customer satisfaction through providing goods and services at a lower cost, with fast delivery, with qualified products, and by responding to changing customers and market needs. Former research undertaken by Porter and van der Linde ^[50] underlined that adopting green practices allows firms to reduce resource consumption, utilize byproducts efficiently, reduce downtime, maintain a safer workplace, reduce product and operation handling costs, provide qualified products, and increase scrap value. In this regard, Bhardwaj ^[51] argued that enhancements in managing processes and product manufacturing lead to increasing production flexibility and accelerating product delivery to consumers. Aboelmaged ^[4] indicated a positive relationship between SMPs and competitive capabilities (quality, cost, delivery, and flexibility).

SMPs minimize manufacturing costs, provide valuable products, and respond to social and environmental concerns ^[52]. In addition, SMPs improve operational processes to produce high-quality products that satisfy customers and increase a firm's market share ^[53]. Ramayah et al. ^[54] underlined that SMPs such as reducing solid waste enhance Malaysian SMEs' competitive performance. Sezen and Çankaya ^[55] found that firms' operational performance was positively related to green manufacturing applications through ensuring occupational safety, enhancing production efficiency, and minimizing manufacturing costs in the Turkish manufacturing sector. Agan et al. ^[56] argued that firms can boost their competitive advantages and increase their profit in the long run through the adoption of SMPs. Further, SMPs improve operational efficiency, which, in turn, enhances the firm's long-term profitability, reduce production cost ^[50], and improve the quality and delivery of products and enhance production flexibility ^[37].

Firms need to gain relevant competitive advantages to survive and maintain distinctive performance. This study predicts that undertaking SMPs enables manufacturing SMEs to gain competitive advantages and maintain superior sustainable performance. In his research on linking SMEs' business models and performance, Anwar ^[57] indicated that competitive advantages had a positive mediating influence. Wu and Pagell ^[58] indicated that adopting environmental practices allows SMEs to maintain operational efficiencies, which in turn, enhances their financial performance ^[59]. Firms undertaking sustainability practices can gain competitive advantages and enter new markets ^[60], maintain strong social relations with employees ^{[61][62]}, and increase their customer base and maintain a positive brand image ^[63].

Gadenne et al. ^[64] found that cost-saving intentions are the fundamental reasons behind SMEs' adoption of sustainable practices, while Sáez-Martínez et al. ^[65] found that the strategic intention of SMEs leads to undertaking environmental responsibility. SMEs have limited knowledge of sustainability practices due to some internal factors such as organizational culture and external factors including suppliers and customers ^[66]. Kozłowski et al. established that recycling practices allow firms to avoid reducing wastes and pollutants through minimizing the usage of new raw materials and energy consumption ^[67].

Eslami et al. ^[68] advocated that manufacturing firms need to adopt sustainable practices to meet emerging customers' needs for sustainable products and to adhere to environmental regulations. Manufacturing firms face several challenges to adopting sustainable manufacturing such as environmental regulations, resources depletion, and pressures from customers and nongovernmental organizations. Jawahir et al. ^[69] stressed the need for more research on sustainable manufacturing and found that it reduces unfavorable environmental impact through improving resource and energy efficiency, generating a minimum quality of waste, providing a safer work climate, and maintaining high-quality products at affordable costs. SMEs' performance is positively related to pursuing competitive strategy and maintaining competitive advantages ^{[70][71]}.

Environmental regulations have emerged in many countries to guide sustainability processes and policies and to shape firms' sustainable behaviors and actions. Many countries have developed different levels of environmental regulations to stimulate manufacturers' interest in adopting SMPs. Environmental regulations issued by the government present some restrictions on the manufacturing process to ensure resource utilization, clean production, and social responsibilities. Shankar et al. ^[72] and Mittal and Sangwan ^[73] underlined that imminent environmental legislations have resulted in clean production and efficient resource utilization in the manufacturing process in Indian and Malaysian manufacturing organizations. In his research on the drivers of sustainable manufacturing, Aboelmaged ^[4] reported that environmental regulations do not affect SMPs.

Research revealed that compliance with environmental regulations of using clean technologies, waste management, product and packaging recycling, carbon emissions, energy efficiency, and pollution prevention is a fundamental driver for SMEs' adoption of corporate environmental reporting practices ^{[64][74]}. Firms that emphasize improving their environmental performance through reducing undesirable outputs such as wastes, CO2 emissions, and pollutants during manufacturing processes enhance their economic performance ^[75].

Triguero et al. ^[76] stated that SMEs show promising compliance with environmental regulations, while Panwar et al. ^[77] argued that environmental regulations encourage SMEs' engagement in corporate environmental reporting practices along with the perceived cost reductions. Luo et al. ^[12] showed that regulations and incentives are essential for implementing green manufacturing in Chinese manufacturing SMEs. Testa et al. ^[78] argued that maximizing the value of resources enables firms to gain and sustain competitive advantages. In this regard, environmental regulations need to encourage the circulation of resources and limit the use of materials in the manufacturing process to maximize resources value and guide firms to explore innovative production modes.

The world has witnessed an increasing level of political and social awareness of the significance of developing environmental responsibility at the organizational level with only 20% of firms adhering to environmental regulations and showing a high degree of environmental responsibility ^[65]. In the Chinese context, the "Thirteenth Five-Year Plan" was declared to promote and implement sustainability ^[79]. Sustainable manufacturing ensures that products are fully recyclable, completely disassembled, and protect the environment ^[80].

Zhao et al. ^[81] showed that efficiency improvement and CO2 reduction are positively related to market-based regulations and government subsidies. Porter and Linde ^[50] argued that proper design and effective implementation of environmental regulation can mitigate carbon dioxide emission and stimulate more green innovation, which in turn offsets the regulatory costs and increases profitability. Xing et al. ^[82] found that environmental regulation can help improve financial performance via sustainability innovation and green dynamic capability.