

Green Manufacturing and Environmental Sustainability: A Conceptual Framework.

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Abstract

Increasing environmental degradation, climate change, and resource depletion have intensified the need for sustainable practices. Manufacturing activities significantly contribute to pollution, waste generation, and carbon emissions. As a result, various strategies are being put in place to compel firms to shift toward green manufacturing practices to reduce environmental impact and promote long-term sustainability. Green manufacturing being one of those strategies, has emerged as a means capable of enhancing environmental sustainability. The main objective of this study is to examine the influence of green manufacturing on environmental sustainability. The study provides a conceptual review of green manufacturing and environmental, the study will offer insights that can guide managerial decisions and policy development. This study is underpinned by Natural Resource-Based view theory, stating that firms gain sustainable competitive advantage by developing capabilities that reduce environmental impact. The study built a conceptual framework to explain how green manufacturing improves environmental sustainability. This study tries to review and synthesize issues such as green manufacturing, environment, sustainability, and supply chain. The study contributes to theory by way of establishing a framework that explains the role of green manufacturing in improving environmental sustainability and finally recommends that practitioners and policymakers invest in green strategies so as to enhance the eco-friendly resilience of the nation's environment.

Keywords: green manufacturing, environment, sustainability, conceptual framework

1. Introduction

Adopting sustainable environmental practices has become very crucial in today's conversation, as apprehensions about climate change, resource depletion, and environmental degradation have increasingly heightened globally. Environmental problems have been linked to the global increase in industrialization, and urbanization, which has left humanity facing catastrophic environmental effects. Manufacturing companies continue to be vital engines of economic growth, making substantial contributions to the GDP, supplying necessities, and creating a vast number of job opportunities. Despite these efforts, Nigeria's manufacturing sector nevertheless faces a disturbing reality, especially with regard to the environmental impact of the sector (Afum, 2020). Similar data from other parts of Africa support this worry; for example, the United Nations Environment Programme (UNEP, 2013) stated that manufacturing subsector contributes the most greenhouse gases. The biophysical underpinnings required for human existence and development are provided by the natural environment, making environmental sustainability crucial. According to Rockström et al. (2020), Earth's life-support systems such as climate control, hydrological cycles, and ecosystem functioning, form the safe operating environment that allows humankind to flourish. The Millennium Ecosystem Assessment (2005) previously confirmed that ecological services like soil creation, water control, purifying air, and

biodiversity protection are essential to all social, economic, and biological activities. More recently, Díaz et al. (2019) emphasized that ecosystem services are still essential for maintaining food security, economic stability, and global health, stressing that environmental deterioration jeopardizes the systems that sustain human life. The operations of manufacturing companies continue to jeopardize environmental quality in spite of several warnings. While respiratory disorders, waterborne infections, and starvation are associated with environmental deterioration, a healthy environment offers clean air, safe water, and uncontaminated food supplies. Furthermore, pollution continues to pose a serious threat to ecological and human well-being worldwide. According to the World Economic Forum (2022), air pollution is the main cause of the 9 million premature deaths that occur each year, or one in six fatalities worldwide. Similarly, 14–17% of the world's farmland (242 million hectares) has been contaminated by soil and cropland pollution, endangering food systems and putting 900 million to 1.4 billion people at risk from exposure to hazardous heavy metals (Săd, The Guardian, 2026).

The severity of industrial contamination is further demonstrated by local data. Long-term exposure to industrial dust poses serious health concerns, according to a 2024 study of communities close to a cement manufacturing factory in Sokoto State. Residents close to industrial areas like Obajana and Sokoto, as well as workers in cement, textile, and industrial processing facilities, were disproportionately impacted. For instance, 31.9% of people living close to cement plants had pre-diabetes and 52.8% had diabetes, suggesting a connection between metabolic illnesses and long-term exposure to cement dust (Lala, 2025). According to Oriental News Nigeria (2025), the Institute for Statistical Research (ISR) found that manufacturing's reliance on generators leads to excessive emissions, with an estimated 38 million tons of carbon monoxide released as a result of insufficient electrical supply. According to Landrigan et al. (2017), environmental pollution results in over 9 million premature deaths each year, highlighting the detrimental effects of unsustainable ecosystems on human health. According to the WHO and Lancet Countdown

(2025), ambient air pollution in Nigeria resulted in about 21,100 deaths in 2021 from particulate matter (PM_{2.5}) exposure, which was mostly caused by industrial emissions and led diseases like lower respiratory infections, lung cancer, ischemic heart disease, and Chronic Obstructive Pulmonary Disease (COPD). Adopting green manufacturing has become a crucial approach to mitigate the harm industrial operations cause to the environment, given these dire consequences. In the 1990s, green manufacturing became a well-known system-wide, and economically motivated strategy to cut or eliminate waste in product design, production, use, and disposal (Sezen, 2013). It entails implementing cutting-edge production techniques and technologies that reduce energy and resource consumption, lower pollution, and improve recycling and waste management.

According to Sarker (2024), green manufacturing is becoming more widely acknowledged for its capacity to reduce carbon emissions, wastewater discharge, and other environmental harms connected to conventional manufacturing. In a similar vein, Khan (2017) highlights that green production entails minimizing the production of hazardous waste while planning, monitoring, and lowering resource use, including raw materials, electricity, and water. Thus, green manufacturing is an essential means of mitigating the negative environmental effects of manufacturing sectors and promoting sustainable industrial growth. There is dearth in research on green manufacturing and sustainable environment in the developing countries and Nigeria in particular, and therefore, this study is situated to bridge this gap.

2. Literature Review

2.1 Sustainable environment

From a conceptual standpoint, environmental sustainability is the ability of natural systems to remain resilient, diverse, and productive over time while meeting human demands without compromising ecological integrity. To prevent current resource use from endangering future generations' demands, scholars emphasize that environmental sustainability entails preserving ecosystems' capacity for regeneration, assimilation, and support (Khan et al., 2022). In order to prevent permanent environmental degradation, this idea

represents long-term ecological balance in which natural resources such as forests, air, biodiversity, and water are preserved (Agyeman & Evans, 2023). Additionally, environmental sustainability includes the preservation of ecosystem services that support economic systems and human well-being, such as pollination, nutrient cycling, carbon sequestration, and climate regulation. In order to preserve ecological stability, Abubakar and Bala (2023) contend that sustainable environmental practices aim to lower pollution, limit waste, support renewable energy, and improve resource efficiency. This is consistent with international guidelines for sustainability that promote less human pressure and better biodiversity health (UNEP, 2022). By encouraging institutional and policy frameworks that strike a balance between environmental preservation and human development, environmental sustainability also incorporates social and economic aspects. According to recent studies, long-term ecological resilience depends on multilevel governance, stakeholder participation, and science-based environmental management (Owusu & Asumadu, 2023). The term "sustainability," which is commonly used in debates today, refers to the essential endeavor of satisfying current requirements without jeopardizing the capacity of future generations to satisfy their own needs (Ukpoju, 2024). The environmental aspect of sustainability is crucial in addressing the complex interactions between human activity and the natural world. It entails upholding ecological balance, protecting biodiversity, and guaranteeing ecosystem resilience, all of which contribute to the preservation of the environment's integrity. According to Ram (2025), environmental sustainability is the proper and unquestionably responsible use of our surroundings with the goal of preserving ecological balance and life both now and in the future. This idea focuses on successfully striking a balance between the natural environment's capacity to support life and the many requirements of humans, particularly in light of the severe environmental degradation that is acknowledged in the current world. However, our capacity to monitor ecosystem-related sciences has been seriously impeded by industrialization, deforestation, and overconsumption (World

Commission on Environment and Development, 1987).

2.2 Green manufacturing

Globally, the idea of "green manufacturing or green production" has attracted a lot of interest. To help enforce green production in various industries, several countries have implemented legislation pertaining to environmental safety. For instance, the Rio Declaration, the Kyoto Protocol, the Johannesburg Declaration on Sustainable Development, the Montreal Protocol on Ozone Layer Depletion, ISO 14000 on Environment Management Systems and Standards, restrictions on the use of hazardous substances, eco-design requirements for product use, chemical registration, evaluation, and authorization, and waste packaging regulations (Chuang & Yang, 2014). Similarly, green manufacturing refers to practices related to environmental issues that consistently use environmentally friendly production techniques for products. It entails converting raw resources into highly efficient final products with less environmental risks. According to Handfield et al. (1997), green manufacturing is an economically motivated, system-wide, integrated approach to the reduction and elimination of all waste streams related to the design, manufacture, use, and/or disposal of products and materials. A green production plan should use the production technology program and process route that uses the least amount of energy and resources and pollutes the environment as little as possible, in accordance with the reality of the manufacturing system. According to Gao et al. (2009), green manufacturing requires zero potential safety issues, zero health risks to product consumers and operators, and zero environmental contamination, waste recycling, and waste disposal during the production process as much as possible. Green manufacturing, according to Cortellini (2001), is a production technique that reduces waste and pollution, slows the depletion of natural resources, and reduces the large volumes of waste that end up in landfills. This entails effective production methods that include recycling, resource

conservation, and green design. Green manufacturing, according to the Confederation of Indian Industry (CII), is a sustainable industrial activity that entails changing industrial operations in three ways: (1) utilizing green energy; (2) creating and marketing green products; and (3) implementing green processes in commercial operations. Hicks and Dietmar (2007) emphasize design enhancement, the use of clean energy and raw materials, and the application of cutting-edge procedures, tools, and technologies. Green manufacturing can result in cheaper raw materials, more production efficiency, fewer costs for occupational safety and the environment, and a better reputation for the company. Carter et al. (2000), Rao and Holt (2005), and Zhu and Sarkis (2004) discovered that green efforts significantly improve an organization's economic and environmental performance. Additionally, practices like waste management and minimization (dust), energy efficiency and fuel substitution (kilowatts of electricity), process design, modifications, and upgrades (recycled waste) are all part of green manufacturing (Eshikumo, 2017). In order to become more environmentally friendly, Green Manufacturing (GM) is a new manufacturing paradigm that integrates several green strategies (objectives and principles), drivers (motivators and important success elements), and methodologies (technology and innovations). Designing and manufacturing green products or processes that use less energy and materials, replacing inputs (such as non-toxic for toxic, renewable for non-renewable), lowering undesired outputs (such as waste and carbon emissions), and encouraging material reuse and recycling are all examples of GM.

2.3 Benefits of Green Manufacturing

For the manufacturing sector to achieve operational objectives such as cost reduction, a positive corporate image, fewer environmental health risks, and competitiveness, green manufacturing is crucial. The public and private sectors of any economy stand to gain much from green manufacturing. Adopting and putting into practice a green manufacturing strategy will provide the government with three main advantages. Based on the notion that company performance should be assessed from three

perspectives, such as economic development, environmental protection, and social well-being, these advantages are economic, environmental, and social (job creation and poverty eradication). Economic advantages include the effective utilization of resources through the application of techniques like recycling, recovery, and reuse. When resources are used effectively and efficiently, the total demand for energy, water, and other virgin resources is decreased, which lowers government spending on investments in new energy and water supply sources as a result of rising demand. For example, it has been projected that for every \$1 invested in demand-side electricity management, the power sector in underdeveloped nations can save about \$3 (UNIDO, 2011). Additionally, efficient production systems and processes result in lower costs, more savings, and better adherence to international standards, which boosts investment, output, and productivity and, ultimately, increases competitiveness in both domestic and export markets, which generates foreign exchange and income for the economy. Green manufacturing and environmental sustainability are closely related and reinforce one another. Green manufacturing offers manufacturing companies a strategic strategy to improve their environmental performance, reduce ecological damage, and support more general sustainability objectives. Sustainability indicators including lower carbon footprints, better resource efficiency, and improved ecosystem protection are directly supported by practices like energy-efficient machinery, green supply chain integration, recycling systems, and cleaner technology adoption (Singh et al., 2022). Therefore, it is possible to think of green manufacturing as an antecedent that influences the results of environmental sustainability.

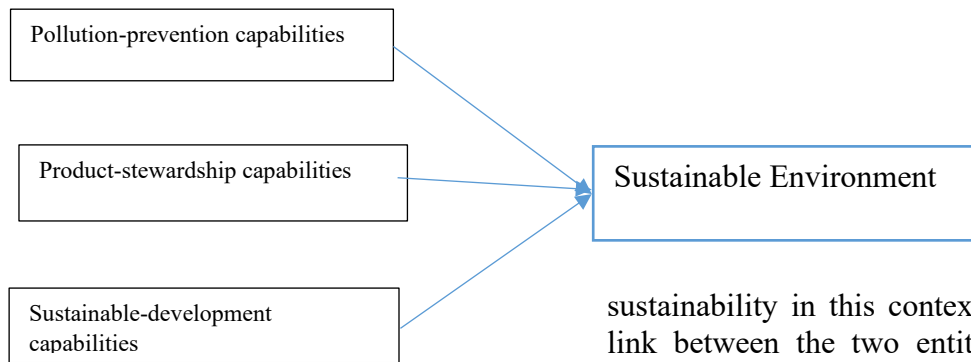
3. Theoretical framework

This study employs a theory to support its focus on green manufacturing and environmental sustainability. Stuart L. Hart created the Natural Resource-Based View (NRBV) hypothesis in 1995. It builds upon the conventional resource-based view of the corporation by highlighting the strategic significance of environmental capabilities. Using capabilities that lessen environmental effect through

green manufacturing techniques that enhance sustainability performance is essential for businesses to have a competitive edge. According to recent research, environmental skills including resource efficiency, eco-innovation, and pollution prevention are strategic assets that enhance organizational and environmental performance (Singh et al., 2022). According to the NRBV, green manufacturing is a collection of skills that help businesses reduce emissions, preserve natural resources, and improve ecological resilience—all of which contribute to environmental sustainability. Aragón-Correa's (2007) study aims to investigate how proactive environmental initiatives affect manufacturing companies' business and environmental performance. According to the inference, companies that adopted green manufacturing techniques had improved environmental performance and competitive advantages, indicating that environmental capabilities such as pollution control and sustainable resource use—contribute to long-term competitive advantage. In a similar vein, Testa et al. (2018) used NRBV to examine how green innovation tactics and environmental management systems impact sustainability results in European manufacturing firms. When NRBV was applied, it made it easier to understand why companies with better environmental capabilities utilize more sustainable manufacturing techniques. Environmental performance and corporate reputation were found to be enhanced by resource-efficient environmental practices. Essentially, the NRBV framework also offers interpretive clarity regarding the ways in which green manufacturing supports sustainability. Product stewardship capabilities guarantee environmentally friendly product design, pollution prevention capabilities lower emissions at the source, resource efficiency, and sustainable development capabilities promote long-term ecological conservation (Hart & Dowell, 2011). These capacities create the means by which environmentally sustainable manufacturing practices impact the environment. Thus, green manufacturing is proposed in the conceptual model as an antecedent construct that activates environmental capacities in line with sustainable environmental outcomes.

The model is as seen below

Proposed Model



sustainability in this context. Thus, the conceptual link between the two entities is formed by their common goal of minimizing environmental harm.

Source: Researchers' Model (2026)

4. Discussion

In today's industrial discourse, green production and environmental sustainability are increasingly acknowledged as mutually reinforcing ideas. In order to lessen the ecological impact of industrial activities, green manufacturing places a strong emphasis on redesigning production processes to decrease waste output, reduce emissions, and increase resource efficiency. According to current research, green manufacturing is seen as a calculated reaction to stakeholder expectations for environmentally responsible production, legal obligations, and environmental pressures (Agyabeng-Mensah et al., 2020). This approach presents green manufacturing as an organizational philosophy that incorporates environmental considerations into the fundamental structure of production processes, rather than only as an operational technique. As a result, green manufacturing offers businesses a useful way to convert sustainability concepts into workable plans. The goal of environmental sustainability, on the other hand, is to preserve ecological balance by making sure that natural resources are used in a way that protects the quality of the environment for both current and future generations. The fundamental idea is that industrial activity must stay within the bounds of natural systems' limited capacities in order to avoid irreversible deterioration (Mensah, 2019). Because it guarantees that production processes run within the limits of environmental carrying capacity, the adoption of green manufacturing methods becomes a direct enabler of environmental

5. Implication of the study

Several significant theoretical, managerial, and policy implications are presented in this work on green manufacturing and sustainable environments. The claim that implementing green manufacturing techniques is essential to attaining ecologically sustainable results in contemporary industrial systems gives rise to these implications. By showing how green manufacturing may be viewed as a crucial environmental capability that supports long-term sustainability performance, the study theoretically strengthens and expands the Natural Resource-Based View (NRBV). It demonstrates how eco-innovation, resource efficiency, and pollution control are examples of environmental skills that serve as tactical links between ecological results and manufacturing processes. By combining sustainability and manufacturing theories, the study fills in gaps in the literature and provides academics with a more thorough framework for examining environmentally friendly production systems. The study's managerial consequence is that managers should see green manufacturing as a strategic opportunity rather than just a matter of compliance. According to the survey, companies that make investments in eco-design, energy-efficient equipment, recycling systems, and clean technology will gain a competitive edge through decreased waste, cheaper operating costs, and improved brand recognition. According to the conceptual model, companies that include sustainability into their production processes are better able to minimize environmental hazards, cut emissions, and satisfy consumer demands for environmentally friendly

production. Once more, managers need to foster cultures that are focused on sustainability and promote innovation, environmental consciousness, and continual development. This encourages resilience and long-term environmental management. The study emphasizes the significance of regional and national environmental regulations that promote the use of green technologies by manufacturing companies. Stricter emission regulations, environmental taxes, subsidies for clean production equipment, and incentives for businesses that embrace sustainable practices are all options available to policymakers. The study's societal implications emphasize how green manufacturing immediately lowers pollution, enhances the quality of the air and water, and protects ecological systems. Communities become healthier as a result, and public health spending decreases. However, manufacturing companies promote a circular economy by encouraging consumers to adopt more sustainable lifestyles through the production of eco-friendly products. Furthermore, the study suggests that expanding green manufacturing across industries can significantly contribute to reducing climate change, preserving natural resources, and guaranteeing that future generations inherit a stable and healthy environment.

6. Conclusion and Recommendation

In order to achieve long-term ecological balance and industrial resilience, environmentally responsible production techniques are crucial. This conceptual study explored the relationship between green manufacturing and a sustainable environment. The study, which is based on the Natural Resource-Based View (NRBV), found that green manufacturing is a collection of environmental capabilities, including resource efficiency, pollution prevention, and eco-innovation, that allow businesses to improve their operational efficacy while reducing ecological degradation. The conceptual research also demonstrated that switching from conventional manufacturing methods to more environmentally friendly production frameworks is favorable from a strategic and environmental standpoint for businesses looking to stand out in a global market. According to the study's findings, green

manufacturing contributes significantly to environmental sustainability through waste reduction, emissions reduction, energy conservation, and responsible resource use. It also confirms that incorporating green practices into manufacturing processes helps achieve global sustainability objectives, such as pollution management, resource conservation, and climate action. Overall, the conceptual connection made in this research supports the claim that firms looking to align themselves with society expectations for ecological stewardship and global environmental concerns must adopt green manufacturing techniques. The following recommendations were given at the end of the study as follows, by implementing ecologically friendly technology such as energy-efficient machinery, renewable energy systems, waste recycling facilities, and pollution control equipment, industrial companies can institutionalize green manufacturing. Additionally, management should establish corporate cultures that encourage environmental responsibility and fund ongoing training for staff members on sustainable practices. Businesses are urged to use life-cycle assessment instruments to monitor and reduce environmental effects throughout their value chains. Governments should create and implement environmental laws that encourage businesses to use green manufacturing techniques. Stricter pollution regulations, tax breaks for adopting clean technology, green investment incentives, and the availability of green financing tools like green bonds are a few examples. Green manufacturing should be incorporated into national industrial policy as a key component for advancing sustainable economic growth and fulfilling international environmental obligations. To direct industrial companies, regulatory agencies should set up precise environmental performance measures and compliance frameworks. Industry-wide adoption will be promoted by developing uniform standards for green production and certifying businesses that satisfy sustainability requirements. To promote the spread of eco-innovations, regulators should also encourage collaborations between industrial companies and research institutes. Advocacy for responsible consumption and cleaner production should be stepped up by civil society organizations.

Campaigns to raise public knowledge of the advantages of eco-friendly products and environmental stewardship can boost demand for items made sustainably, encouraging businesses to adopt green manufacturing techniques more quickly.

7. Limitations and Areas of Future Research

Several limitations should be noted, despite the fact that this study offers a thorough conceptual investigation of the connection between green manufacturing and a sustainable environment. First, the study is conceptual rather than empirical, which means that in order to validate the suggested links, it depends on theoretical reasoning and previously published literature rather than direct data. This makes it more difficult to extrapolate the findings to other industries, geographical areas, or company sizes. Second, the study makes extensive use of the Natural Resource-Based View (NRBV), which is generally acknowledged but may not adequately account for the impact of outside factors on the adoption of green manufacturing practices, such as financial constraints, regulatory pressure, technological maturity, and cultural considerations. Therefore, the range of interpretations may be constrained by this theoretical focus. Third, the study does not differentiate between sub-sectors like food processing, textiles, automobiles, or medicines; instead, it focuses on manufacturing companies in general. How green manufacturing contributes to sustainability may vary depending on industry-specific differences in environmental effect, technical maturity, and regulatory exposure. Lastly, the literature used in this conceptual analysis is susceptible to publication bias because academic publications frequently highlight the advantages of green manufacturing, thereby underrepresenting studies that discuss difficulties, setbacks, or unforeseen repercussions. There are a number of possibilities for further scholarly investigation based on the constraints noted. First, the conceptual model presented in this paper needs to be tested through empirical research, both qualitative and quantitative. Researchers can look into how much environmental sustainability results in different industrial sectors are directly impacted by green manufacturing practices. Further understanding of how consistent

adoption of green practices leads to long-term environmental advantages would be possible through longitudinal research. Again, moderating and mediating factors that could improve or worsen the connection between green manufacturing and environmental sustainability should be investigated in future studies. Environmental regulations, corporate culture, firm size, technological capabilities, and the availability of green funding are all potential moderators. Similarly, more research should be done on mediating elements including supply-chain cooperation, environmental management systems, and green innovation capacity. Furthermore, studies comparing established and emerging economies may reveal contextual variations in the uptake and efficiency of green manufacturing. The institutional, economic, and cultural elements that influence environmental sustainability outcomes would be identified with the use of such study. Nevertheless, by examining the differences in resource consumption, environmental effect, and technology readiness among different industrial subsectors, industry-specific research can offer a more detailed insight.

Finally, future researchers might investigate the socioeconomic ramifications of green manufacturing, such as how it affects customer behavior, job trends, cost structures, and community health. The conversation will be further enhanced by broadening the research's focus to include social sustainability and circular economy paradigms.

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