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Sustainable Processes and Manufacturing and their Environmental Impact

By

Tony Aku Amba

Institute of Natural Resources, Environment and Sustainable Development; University of Port- Harcourt , Rivers State
ORCID ID: 0000-0002-8104-8756

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Abstract

Sustainable processes and manufacturing have emerged as critical approaches for reducing environmental degradation associated with industrialization, urbanization, and construction activities across the world. Traditional manufacturing systems are heavily dependent on fossil fuels, intensive resource extraction, and linear production models that generate excessive waste, greenhouse gas emissions, and ecological destruction. Consequently, industries are increasingly adopting sustainable manufacturing processes that emphasize energy efficiency, waste reduction, recycling, cleaner production technologies, and circular economy principles. This study examines sustainable processes and manufacturing and evaluates their environmental impacts with particular focus on Nigeria and Jos metropolis in Plateau State. The study adopts an empirical research design involving questionnaires, interviews, field observations, and secondary data obtained from manufacturing firms, environmental agencies, and construction professionals. Findings reveal that sustainable manufacturing practices such as recycling, green supply chain management, closed-loop construction, renewable energy utilization, and low-carbon material production significantly reduce environmental pollution, conserve natural resources, and improve industrial efficiency. The study further reveals that industries adopting sustainable technologies experience reduced waste generation, lower carbon emissions, and improved environmental performance. However, challenges such as inadequate government policies, poor technical expertise, weak environmental enforcement, high implementation costs, and low public awareness continue to hinder effective adoption of sustainable manufacturing systems in Nigeria. The study concludes that sustainable processes and manufacturing provide viable pathways for achieving environmental sustainability, climate resilience, and resource conservation within Nigeria's industrial and construction sectors. The paper recommends stronger environmental regulations, investment in green technologies, institutional support for sustainable industries, and public sensitization programs to enhance sustainable manufacturing practices across Nigeria.

Keywords: *Sustainable manufacturing, Green production processes , Environmental impact, Resource efficiency and Environmental sustainability*

INTRODUCTION

Industrialization and manufacturing activities have become central drivers of economic growth and infrastructural development globally. However, conventional manufacturing processes have contributed significantly to environmental degradation through excessive resource extraction, greenhouse gas emissions, waste generation, and pollution. Across the world, industries consume enormous quantities of fossil fuels and raw materials, thereby accelerating climate change, biodiversity loss, and ecological instability. The United Nations and other global environmental organizations have increasingly advocated for sustainable production systems capable of balancing economic development with environmental protection. Sustainable manufacturing processes such as cleaner production technologies, renewable energy integration, recycling systems, and circular economy models are therefore gaining global attention as practical solutions for reducing industrial environmental impacts. Globally, sustainable manufacturing has become a key strategy for achieving the Sustainable Development Goals (SDGs), particularly those related to climate action, responsible production, and sustainable cities. Recent studies indicate that industries adopting sustainable production systems experience lower carbon emissions, improved energy efficiency, and reduced environmental risks compared to conventional industries. Sustainable manufacturing also supports resource conservation through recycling, waste minimization, and efficient material utilization. Furthermore, advancements in green technologies, digital manufacturing systems, and environmentally friendly supply chains continue to transform industrial operations worldwide.

Across Africa, rapid urbanization, industrial growth, and population increase have intensified pressure on natural resources and ecosystems. Many African industries still rely

*Corresponding Author: **Tony Aku Amba**

heavily on outdated production systems characterized by inefficient energy use, poor waste management, and excessive pollution. Cement production, mining, quarrying, and chemical manufacturing continue to contribute significantly to air pollution, land degradation, and water contamination across the continent. Consequently, African governments and environmental researchers increasingly advocate for sustainable industrial processes capable of reducing environmental degradation while supporting economic growth and employment generation. Green manufacturing technologies, renewable energy systems, and sustainable supply chain practices are gradually emerging within African industrial policies and environmental management frameworks. In Nigeria, manufacturing and construction industries contribute significantly to economic development but also represent major sources of environmental pollution. Traditional industrial systems within the country are associated with high energy consumption, excessive greenhouse gas emissions, industrial waste generation, and unsustainable resource extraction. Cement manufacturing, quarrying, mining, and construction activities have intensified environmental degradation in many Nigerian cities. Nevertheless, recent studies indicate growing awareness regarding sustainable manufacturing and low-carbon production systems within Nigeria's industrial sector. Industries are increasingly adopting recycling technologies, green construction systems, energy-efficient manufacturing processes, and environmentally sustainable supply chain models.

Regionally, North-Central Nigeria has experienced extensive environmental challenges associated with industrialization, mining, and quarrying activities. Plateau State in particular has faced severe ecological degradation arising from decades of tin mining, quarrying, and construction material extraction. These activities have contributed to land degradation, erosion, water pollution, air contamination, and destruction of vegetation cover across several communities. Researchers have therefore emphasized the importance of sustainable manufacturing and closed-loop construction systems in reducing pollution and promoting environmental restoration within the region. Jos metropolis represents one of the major urban and industrial centers in Plateau State with increasing demand for housing, industrial production, and infrastructural development. Manufacturing activities, quarrying operations, and construction projects within Jos continue to generate substantial environmental challenges including dust pollution, waste accumulation, and landscape degradation. However, recent awareness regarding environmental sustainability has encouraged interest in cleaner production systems, recycling practices, and sustainable construction technologies within the city. Sustainable manufacturing therefore presents an important opportunity for reducing environmental degradation while promoting resilient urban development within Jos metropolis and Nigeria generally.

Statement of the Problem

The increasing rate of industrialization and manufacturing activities across Nigeria has intensified environmental degradation through pollution, waste generation, greenhouse gas emissions, and excessive resource consumption. Traditional manufacturing processes depend heavily on fossil fuels, inefficient technologies, and unsustainable extraction of natural resources. Consequently, industrial activities contribute significantly to climate change, land degradation, air pollution, and ecosystem destruction. In Nigeria, poor environmental management and weak enforcement of industrial regulations have further worsened environmental problems associated with manufacturing and construction industries. In Plateau State and Jos metropolis particularly, mining, quarrying, and manufacturing activities have resulted in severe environmental impacts including abandoned mining pits, deforestation, dust pollution, and contamination of water bodies. Although sustainable manufacturing systems such as recycling, cleaner production technologies, renewable energy integration, and closed-loop construction practices are increasingly recognized globally, their adoption within Nigeria remains limited. Industries continue to operate largely under linear production systems that intensify waste generation and environmental pollution. Furthermore, there is inadequate empirical research focusing specifically on sustainable manufacturing processes and their environmental impacts within Jos metropolis. Existing studies largely emphasize theoretical discussions without adequately examining stakeholder perceptions, practical implementation challenges, and environmental realities within local industrial systems. This gap in knowledge limits effective policy formulation and sustainable industrial planning. Therefore, this study investigates sustainable processes and manufacturing and evaluates their environmental impacts within the context of Nigeria and Jos metropolis.

Aim and Objectives of the Study

The aim of this study is to examine sustainable processes and manufacturing and evaluate their environmental impacts within the context of sustainable industrial and construction practices in Nigeria, with particular focus on Jos metropolis. The specific objectives are to:

i. Identify major sustainable manufacturing processes used within industrial and construction sectors.

ii. Examine the environmental impacts of sustainable manufacturing practices.

iii. Assess the level of adoption of sustainable manufacturing systems in Jos metropolis.

iv. Identify challenges affecting the implementation of sustainable manufacturing practices.

Literature Review

Concept of Sustainable Manufacturing

Sustainable manufacturing refers to production processes that minimize environmental harm while conserving energy and natural resources. It emphasizes cleaner production systems, efficient resource utilization, recycling, and waste minimization throughout industrial operations. Sustainable

*Corresponding Author: **Tony Aku Amba**

manufacturing integrates environmental, economic, and social considerations into industrial production systems to ensure long-term sustainability. Researchers argue that sustainable manufacturing is critical for addressing global environmental challenges associated with industrialization and climate change. Recent studies indicate that sustainable manufacturing systems improve industrial efficiency while reducing environmental pollution and operational costs. Cleaner production technologies, renewable energy systems, and green supply chain practices are increasingly recognized as effective approaches for achieving sustainable industrial development. These systems reduce dependence on fossil fuels and encourage circular economy practices within manufacturing industries. In Nigeria, sustainable manufacturing remains relatively underdeveloped despite growing environmental concerns. Studies reveal that poor environmental regulations, inadequate technological infrastructure, and weak institutional support continue to hinder widespread adoption of sustainable industrial practices. Nevertheless, industries are gradually integrating sustainable technologies due to increasing awareness regarding climate change and environmental conservation.

Sustainable Production Processes

Sustainable production processes involve industrial systems designed to minimize waste generation, pollution, and energy consumption while maximizing efficiency and environmental protection. These processes include recycling, renewable energy integration, waste recovery systems, eco-design, and closed-loop production systems. Sustainable production emphasizes continuous improvement and environmental responsibility throughout the manufacturing cycle. Researchers emphasize that closed-loop manufacturing systems significantly reduce industrial waste and environmental pollution by encouraging material reuse and recycling. Green supply chain management also promotes sustainable sourcing, environmentally friendly transportation systems, and efficient distribution networks. Such practices improve environmental performance while reducing operational costs within industries. In Nigeria, sustainable production systems are increasingly promoted within the construction and manufacturing sectors. Recycling of construction waste, utilization of locally sourced materials, and adoption of low-carbon technologies are gradually emerging as sustainable industrial practices. However, implementation remains constrained by limited technical capacity and inadequate government support.

Environmental Impacts of Conventional Manufacturing

Conventional manufacturing systems contribute significantly to environmental degradation through excessive energy consumption, waste generation, and greenhouse gas emissions. Industrial activities such as cement production, mining, chemical manufacturing, and quarrying release pollutants that contaminate air, water, and soil resources. These environmental impacts threaten ecosystem stability and public health globally. Traditional manufacturing processes also intensify climate change through carbon dioxide emissions associated with fossil fuel consumption and industrial operations. Researchers reveal that industrial pollution contributes to respiratory diseases, water contamination, and destruction of biodiversity. In many developing countries, weak environmental regulations further worsen industrial environmental degradation. In Jos metropolis, quarrying and mining activities linked to manufacturing and construction material production have resulted in severe land degradation, erosion, and dust pollution. Abandoned mining sites and poor waste disposal practices continue to threaten environmental sustainability within Plateau State. Consequently, sustainable manufacturing systems are increasingly viewed as necessary strategies for reducing industrial environmental impacts within the region. Green Supply Chain and Circular Economy Green supply chain management refers to environmentally responsible approaches to sourcing, production, transportation, and distribution within industrial systems. It integrates environmental considerations into supply chain operations to reduce pollution, waste generation, and carbon emissions. Circular economy principles further encourage reuse, recycling, and recovery of materials rather than linear “take-make-dispose” production systems. Studies reveal that industries implementing green supply chain systems achieve improved environmental performance and resource efficiency. Reverse logistics, green procurement, and eco-friendly transportation systems contribute significantly to sustainable industrial operations. Researchers further emphasize that circular economy practices reduce landfill waste and promote resource conservation within manufacturing industries. Within Nigeria, green supply chain management remains relatively limited due to poor environmental governance and inadequate industrial awareness. Nevertheless, recent studies indicate increasing interest in sustainable procurement and recycling systems among construction and manufacturing firms. These developments demonstrate gradual progress toward sustainable industrial systems within the Nigerian economy.

Challenges of Sustainable Manufacturing

Despite its environmental benefits, sustainable manufacturing faces several challenges particularly within developing economies. One major challenge is the high initial cost associated with sustainable technologies, renewable energy systems, and environmentally friendly production equipment. Many industries lack sufficient financial capacity to invest in sustainable industrial transformation. Poor policy implementation and weak environmental regulations also hinder sustainable manufacturing adoption in many developing countries. Researchers argue that inadequate institutional support and poor enforcement of environmental laws continue to encourage unsustainable industrial practices. Additionally, lack of technical expertise and insufficient environmental education limit effective implementation of sustainable production systems. In Jos metropolis, poor waste management systems, inadequate recycling infrastructure, and low awareness regarding sustainable industrial practices continue to hinder environmental sustainability. Consequently, industries remain heavily dependent on environmentally harmful production systems despite increasing evidence of their ecological impacts. Addressing

*Corresponding Author: **Tony Aku Amba**

these barriers is therefore essential for achieving sustainable industrial development within Nigeria.

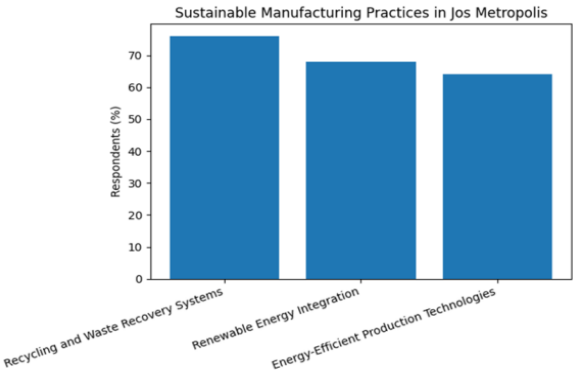
Methodology

This study adopted an empirical research design involving both quantitative and qualitative methods. The study area was Jos metropolis in Plateau State, Nigeria. Primary data were obtained from manufacturing firms, construction companies, environmental officers, and industrial workers through questionnaires, oral interviews, and field observations. A total of 150 respondents were selected using purposive and stratified sampling techniques to ensure adequate representation of relevant industrial stakeholders. Secondary data were sourced from journals, environmental reports, government publications, and previous academic studies relating to sustainable manufacturing and environmental sustainability. The questionnaire focused on awareness of sustainable manufacturing systems, environmental impacts of industrial processes, adoption levels of sustainable technologies, and challenges affecting implementation. Data collected were analyzed using descriptive statistical techniques including percentages, frequency distribution tables, and mean score analysis. The empirical approach aligns with the objectives of the study because it enables direct assessment of stakeholder perceptions and environmental realities associated with manufacturing processes within Jos metropolis. Field observations were conducted around quarrying zones, industrial sites, and construction environments to assess visible environmental impacts such as pollution, waste accumulation, and land degradation. Findings obtained from field observations were integrated with questionnaire responses to improve reliability and validity of the study.

Results and Discussion Results and Discussion Tables and Charts

Table 1: Sustainable Manufacturing Practices

Practices	Respondents (%)
Recycling and Waste Recovery Systems	76
Renewable Energy Integration	68
Energy-Efficient Production Technologies	64



The findings presented in Table 1 reveal that recycling and waste recovery systems constitute the most recognized sustainable manufacturing practice within Jos metropolis, with 76% of respondents affirming their prevalence. This indicates an increasing awareness among industries and construction stakeholders regarding the importance of waste minimization and resource recovery in promoting environmental sustainability. Recycling practices help reduce the volume of industrial waste disposed into the environment while simultaneously conserving raw materials and reducing production costs. The relatively high recognition of renewable energy integration and energy-efficient production technologies further suggests that industries within Jos are gradually embracing cleaner production approaches aimed at reducing environmental pollution and energy consumption. The findings correspond with earlier studies which emphasize that sustainable manufacturing systems contribute significantly to environmental protection, energy conservation, and efficient resource utilization within developing economies. The adoption of renewable energy technologies such as solar-powered systems and energy-efficient machinery demonstrates growing concern for reducing greenhouse gas emissions associated with industrial activities. Despite these positive developments, the findings also imply that sustainable manufacturing adoption remains at a developing stage within Jos metropolis, as some industries still rely heavily on conventional production systems. Therefore, there is a need for increased governmental support, industrial awareness programs, and technological innovation to encourage wider implementation of sustainable industrial practices.

Chart 2: Environmental Degradation Factors

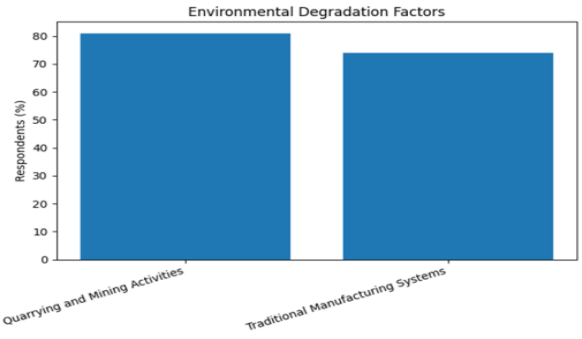
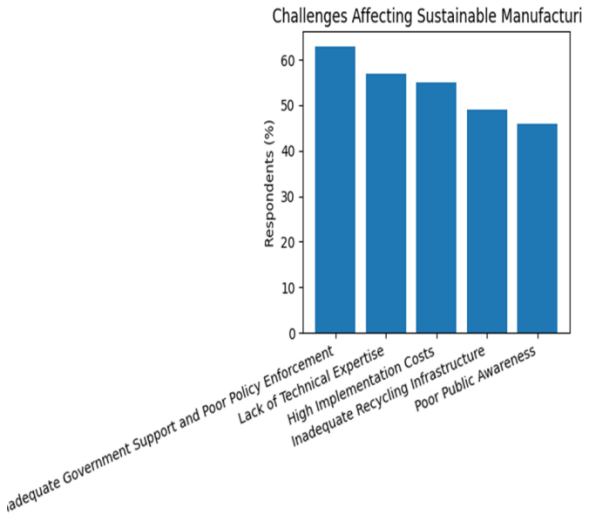


Table 2 shows that quarrying and mining activities were identified by 81% of respondents as the major contributors to land degradation and dust pollution within Jos metropolis. This finding reflects the long-standing environmental challenges associated with mining and quarrying activities in Plateau State, where abandoned mining pits, erosion, and land surface destruction remain visible across several communities. Mining activities often expose soil surfaces, destroy vegetation cover, and generate particulate matter that negatively affects air quality and public health. Similarly, 74% of respondents associated traditional manufacturing systems with excessive greenhouse gas emissions and industrial waste generation, indicating growing public concern regarding the environmental consequences of unsustainable

*Corresponding Author: **Tony Aku Amba**

industrial processes. The findings align with previous environmental studies conducted within Plateau State and other developing urban centers where industrial and extractive activities have contributed significantly to ecological degradation. Field observations supporting the presence of polluted drainage systems and poorly managed industrial waste further validate respondents' opinions concerning environmental deterioration. The excessive generation of industrial waste without proper management systems contributes to water contamination, soil pollution, and public health hazards. These findings therefore highlight the urgent need for stricter environmental regulations, rehabilitation of degraded mining sites, and the promotion of cleaner production technologies capable of reducing industrial pollution and improving environmental quality within Jos metropolis.

Chart 3: Challenges Affecting Sustainable Manufacturing



The results in Table 3 indicate that inadequate government support and poor environmental policy enforcement represent the most significant barriers affecting the adoption of sustainable manufacturing systems within Jos metropolis, as identified by 63% of respondents. This suggests that despite increasing awareness regarding environmental sustainability, institutional and regulatory weaknesses continue to hinder effective implementation of sustainable industrial practices. Weak policy enforcement often allows industries to operate without compliance with environmental standards, thereby encouraging continued dependence on environmentally harmful production methods. Respondents also identified lack of technical expertise, high implementation costs, inadequate recycling infrastructure, and poor public awareness as additional challenges limiting sustainable manufacturing adoption. These findings are consistent with studies conducted in developing economies where financial limitations, technological gaps, and weak institutional frameworks often constrain environmental sustainability initiatives. The high cost of acquiring green technologies and sustainable production equipment discourages many small and medium-scale industries from transitioning to cleaner production systems. Furthermore, inadequate public awareness regarding the long-term economic and environmental benefits of sustainable manufacturing reduces societal support for environmentally responsible industrial practices. Nevertheless, respondents strongly agreed that effective environmental policies, investment in green technologies, and industrial training programs would significantly improve sustainable manufacturing adoption. This implies that stronger institutional commitment, increased environmental education, and government incentives could play critical roles in promoting sustainable industrial development and environmental protection within Jos metropolis.

Conclusion

This study examined sustainable processes and manufacturing and evaluated their environmental impacts with particular focus on Jos metropolis, Plateau State, Nigeria. The study established that conventional manufacturing systems contribute significantly to environmental degradation through pollution, greenhouse gas emissions, waste generation, and unsustainable resource extraction. The research further identified recycling systems, renewable energy integration, green supply chain management, and closed-loop construction practices as major sustainable manufacturing approaches capable of reducing environmental impacts within industrial systems. The empirical findings revealed that sustainable manufacturing systems possess substantial environmental, economic, and social benefits including reduced pollution, resource conservation, waste minimization, and improved industrial efficiency. However, the study also established that adoption of sustainable manufacturing systems within Jos metropolis remains relatively low due to poor policy implementation, inadequate technical expertise, insufficient recycling infrastructure, and weak environmental governance. The study concludes that sustainable manufacturing and industrial processes represent viable pathways for achieving environmental sustainability, climate resilience, and responsible industrial development in Nigeria. Adoption of cleaner production technologies and sustainable industrial systems would significantly reduce ecological degradation associated with manufacturing and construction activities in Jos metropolis and beyond. Therefore, integrating sustainable manufacturing policies into industrial planning and environmental management is essential for achieving sustainable development in Nigeria.

Recommendations

Government at federal, state, and local levels should formulate and enforce comprehensive environmental policies promoting sustainable manufacturing systems within Nigeria. Environmental regulations should encourage industries to adopt cleaner production technologies, renewable energy systems, and recycling practices while discouraging environmentally harmful industrial activities. Incentives such as tax reductions, grants, and subsidies should also be provided to industries implementing sustainable manufacturing technologies. Educational institutions, research organizations, and professional bodies should intensify research, training, and awareness programs on sustainable

*Corresponding Author: **Tony Aku Amba**

manufacturing and environmental management. Universities and polytechnics should integrate sustainable industrial practices into engineering, environmental management, and industrial technology curricula to improve technical expertise within Nigeria's industrial sector. Public sensitization campaigns should also be organized to promote awareness regarding the environmental benefits of sustainable production systems. Furthermore, environmental agencies and industrial regulators within Plateau State should strengthen monitoring and enforcement of environmental standards within manufacturing and construction industries. Sustainable waste management systems, recycling infrastructure, and green supply chain practices should be encouraged within Jos metropolis. Effective collaboration between government agencies, industries, research institutions, and environmental stakeholders is necessary for promoting sustainable manufacturing and environmental sustainability in Nigeria.

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