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# Sustainable Manufacturing Practices Adopted by Selected Manufacturing Firms for Sustainable Development in South-East Nigeria

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**Abstract:** The study explored the extent sustainable manufacturing practices are adopted by selected manufacturing firms for sustainable development in South-East, Nigeria. Three research questions and three null hypotheses guided the study and descriptive survey research design was adopted by the researchers. The population consisted of 186 managers and 742 employees of selected pharmaceutical, food and beverages and automobiles firms operating in South-East, Nigeria. A sample size of 387 (127 managers and 260 employees) of selected pharmaceutical, food and beverages and automobiles firms operating in South-East, Nigeria was selected for the study using Taro Yamane formula. The instrument for data collection was validated by three experts and the reliability was established using Cronbach alpha statistic which yielded a coefficient of 0.78. Mean and standard deviation were used to answer the research questions while Analysis of Variance was used to test the null hypotheses at 0.05 level of significance. Findings of the study revealed that manufacturing firms adopt sustainable manufacturing practices for sustainable development at a low extent in South-East, Nigeria. Furthermore, the outcome of the study revealed that staff of pharmaceutical, food and beverages and automobiles firms did not differ significantly in their mean ratings on extent to which sustainable manufacturing practices are adopted for sustainable development in South-East, Nigeria. The study concluded that manufacturing industries in South-East, Nigeria are not actively integrating sustainable manufacturing practices into their operations and positioning themselves for sustained success that aligns with global sustainability goals and regulatory standards. Among others, it was recommended that Federal, State and Local Government should strengthen the regulatory framework with clear guidelines, regular inspections, and stricter penalties for non-compliance in order to encourage manufacturing industries in South-East, Nigeria to adopt sustainable manufacturing practices in their operational activities.

**Key words:** Sustainable manufacturing practices, Energy-efficient processes, Waste minimization practices, Sustainable supply chain management practices

## INTRODUCTION

Like in other nations, the manufacturing sector is the engine block of national transformation because it facilitates not only the creation of wealth and jobs for citizens and but also the reduction of poverty and unemployment. The Nigerian manufacturing industry includes different segments that encompass food and beverage processing serves as a dominant sector that keeps expanding due to increasing population and rising urbanization (Nigerian Economic Summit Group, 2018). The manufacturing products exist in dairy items, beverages, packaged foods and confectionery. Nigeria demonstrates a prolonged textile background while local demand for domestic fabrics and clothes continues to rise in the market. The sector experiences expansion because healthcare demands continue growing and the government shows support for developing pharmaceutical facilities within the nation (Afolabi & Laseinde, 2019). Local automotive assembly operations in Nigeria continue to



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expand because national manufacturing sites produce automobiles as part of partnerships between Nigerian facilities and international automobile firms (Chukwu & Nduka, 2022). Building materials along with cement form major elements of Nigerian production because the construction sector drives robust demand patterns (Olowu, Ropheka & Iyakwari, 2023) and due to existing crude oil resources the nation has succeeded in increasing petrochemical output for producing plastics and synthetic materials.

The Nigerian manufacturing industry's advancement and contributions have been pivotal to the country's development, driving significant economic growth. The Nigerian manufacturing sector accounts for approximately 10 percent of Nigeria's total Gross Domestic Product (GDP), employs approximately 12 percent of the labour force in the nation's formal economy (Ogundipe, 2022). Despite the industry contribution to national development, there is a consistent concern that manufacturing processes and procedures have resulted into lots of environmental problems among which include pollution, ecological deterioration and resource depletion. In the Nigerian context, the processes of manufacturing focuses more on economic, financial aspects and bottom lines without giving much consideration to environmental impacts. This phenomenon has engendered a surge in environmental burdens, ecological deterioration, environmental contamination and the exhaustion of valuable resources.

No wonder, there is a progressive shift in the manufacturing industry globally towards sustainable manufacturing. Sustainable manufacturing is one of the components of sustainable development. The emergence of the concept of sustainable development can be traced to the 1970s and 1980s in response to increasing awareness and concern over the environmental impact of economic growth and global expansion of business trade (Bastas, 2021). One industrial strategy that focuses on reducing waste and improving efficiency while also reducing environmental impact is sustainable manufacturing practices (Agbejule, 2016). Sustainable manufacturing practices are becoming increasingly important as manufacturers strive to become more sustainable and reduce their environmental footprint (Adedokun, Owamah, & Abolade, 2017). The goals of sustainable manufacturing practices are to reduce waste, improve efficiency and reduce environmental impact while improving product quality and achieving customer satisfaction (Adeyemi, Oduyemi & Lawal, 2020).

Sustainable manufacturing practices deals with using economically sound processes to create products from processes of manufacturing to minimize environmental impact while conserving natural resources and energy for safety of the produced products. Adekunle and Dakare (2020) posited that sustainable manufacturing practices involve implementing environmentally friendly practices throughout the production process to minimize negative environmental impacts and conserve resources. Sustainable manufacturing practices as described by International Trade Administration in Adekunle and Elaho (2024) entail the creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resource are safe for employees, communities and consumers and are economically sound. This approach integrates sustainable design, energy-efficient manufacturing processes, and responsible disposal practices to align with broader sustainability goals.

Sustainable manufacturing practices aim at minimizing negative environmental impacts through practices such as waste reduction, emission control and resource conservation. Embracing sustainable manufacturing practices is essential for maintaining the balance between economic progress and the well-being of both the ecosystem and the population, ultimately supporting the country's long-term sustainable development. Although, there are numerous sustainable manufacturing practices, the researchers focused on energy-efficient processes, waste minimization and sustainable supply chain management practices. Energy-efficient processes in manufacturing aim to reduce energy consumption through various strategies such as the adoption of energy management systems, process integration with energy-efficient technologies, and the utilization of renewable energy sources like solar and wind power (Wei & Sun, 2021). The rising demand for energy and increased greenhouse gas emissions underscores the need for energy efficiency, especially in the era of rising energy shocks with great impacts on households, firms and economies (Gershon & Agbene, 2019). Slama (2023) asserted that this can be done by improving existing processes (reducing non-value-adding energy) or by replacing the current equipment and design with more energy-efficient alternatives (reducing value-adding energy but low efficiency).

Minimizing waste at all stages of production, from raw materials to the final product, is another fundamental practice of sustainable manufacturing. Waste minimization in manufacturing involves strategies like lean manufacturing and design for environment to reduce waste and enhance efficiency (Wei and Sun, 2021). Waste reduction and recycling are integral facets of environmentally conscious practices, with the primary objective of mitigating the volume of waste directed towards landfills and fostering the principles of a circular economy (Sharma & Deshmukh, 2018). To achieve effective execution of these stages of waste management, manufacturing industries need to understand the waste management hierarchy that serves as a guideline in waste management. This indicates that waste minimization should be the foundation of any management strategy, followed by reuse, recycling, incineration and land disposal as a last resort (Fuior & Puia, 2017).

Sustainable supply chain management practices integrate environmental, social, and economic considerations into supply chain operations to enhance long-term viability and ethical business practices. Sustainable supply chain management has become a cornerstone of modern manufacturing, driven by increasing regulatory requirements, consumer demand for ethical products, and the need for long-term business resilience (Okwara, Asiegbu, Amade & Enyinna, 2025). In today's globalized economy, manufacturers face mounting pressure to reduce environmental footprints, optimize resource efficiency, and ensure fair labour practices while maintaining profitability (Kumar, Singla & Namboodri, 2024). Sustainable supply chain management integrates environmental, social and economic sustainability principles into traditional supply chain operations, ensuring that business processes minimize negative ecological impacts, promote social equity and maintain long-term profitability (Ali, Majeed, Latif & Aldrickzler, 2024).

The Nigerian manufacturing industry which includes industries such as food and beverages, textiles, chemicals and automotive is highly concentrated in South-East, Nigeria. South-East Nigeria, comprising states such as Abia, Anambra, Ebonyi, Enugu and Imo, hosts a thriving manufacturing sector dominated by small and medium-sized enterprises (SMEs) specializing in textiles, automotive parts, food processing and machinery (Okafor, 2018). As the Nigerian manufacturing industry continues to be a driving force in economic growth, the adoption of sustainable manufacturing practices that are currently gaining traction in South-East, Nigeria is the crux of this study.

**Statement of the Problem**

The concept of sustainable manufacturing practices aimed at reducing the environmental impact of production processes, enhancing environmental performance, and achieving economic goals and has been expounded and implemented in leading economies of the world. However, the need to holistically analyze the sustainable manufacturing practices of industries in South-East, Nigeria in pursuit of achieving the Sustainable Development Goals (SDGs) of ensuring availability and sustainable management of the environment for all serves as the gap this study sought to fill. This study, therefore, examined the extent to which sustainable manufacturing practices such as practices energy-efficient processes, waste minimization and sustainable supply chain management are adopted by selected manufacturing firms that could promote the sustainability of the industry in South-East, Nigeria.

**Research Questions**

The following research questions guided the study.

1. To what extent do manufacturing firms adopt energy-efficient processes for sustainable development in South-East, Nigeria?
2. To what extent do manufacturing firms adopt waste minimization practices for sustainable development in South-East, Nigeria?
3. To what extent do manufacturing firms adopt sustainable supply chain management practices for sustainable development in South-East, Nigeria?

**Hypotheses**

**$H_{01}$:** There is no significant difference in the mean ratings of staff of selected manufacturing (pharmaceutical, food and beverages and automobiles firms) on the extent to which energy-efficient processes are adopted for sustainable development in South-East, Nigeria

**$H_{02}$:** There is no significant difference in the mean ratings of staff of selected manufacturing (pharmaceutical, food and beverages and automobiles firms) on the extent to which waste minimization practices are adopted for sustainable development in South-East, Nigeria

**$H_{03}$:** There is no significant difference in the mean ratings of staff of selected manufacturing (pharmaceutical, food and beverages and automobiles firms) on the extent to which sustainable supply chain management practices are adopted for sustainable development in South-East, Nigeria

## METHODS

The study adopted descriptive survey research design. Descriptive survey research design makes it possible for the researchers to collect the opinions or perceptions from a sample of managers and employees on the extent to which sustainable manufacturing practices are adopted in South East, Nigeria. The population of the study comprised 186 managers and 742 employees of selected pharmaceutical, food and beverages and automobiles firms operating in South-East, Nigeria (The researcher's fieldwork survey, 2026). Simple random sampling technique was used to select a sample size of 387 (127 managers and 260 employees) of selected pharmaceutical, food and beverages and automobiles firms operating in South-East, Nigeria was selected for the study using Taro Yamane formula. A structured questionnaire developed by the researchers titled 'Adopted Sustainable Manufacturing Practices for Sustainable Development (ASMPSD)' consisting of 16 items, structured on a five-point rating scale of Very High Extent, High Extent, Moderate Extent, Low Extent and Very Low Extent was used for data collection. To ascertain the face validity of the questionnaire, it was validated by three experts, two Technology Education lecturers and one Educational Technology lecturer all in the University of Nigeria, Nsukka.

Copies of the instrument were administered to 10 managers and 10 employees in pharmaceutical, food and beverages and automobiles firms in South-South, Nigeria who were not part of the research population. Data collected were analyzed using Cronbach's alpha statistic to determine the internal consistency of the instrument and co-efficients of 0.83, 0.79 and 0.71 for clusters B1, B2 and B3 respectively were obtained. This is high enough for the instrument to be considered reliable as suggested by Nworgu (2015) that a reliability co-efficient of 0.70 and above is an acceptable reliability value. Copies of the questionnaire were administered to the respondents in their offices personally by the researchers with five trained research assistants and the data were collected within two weeks. Out of the 387 copies of the questionnaire administered, only 352 copies (representing 91%) were successfully retrieved and used for data analysis.

Mean and standard deviation were used to answer the research questions and determine the homogeneity or otherwise of the respondents' views. Decisions on the research questions were based on the grand mean in relations to the real limits of numbers. Therefore, items with mean ratings of 1.00 - 1.49 are rated Very Low Extent, those with 1.50 - 2.49 are Low Extent, items with mean ratings of 2.50 - 3.49 are rated Moderate Extent, those with 3.50 - 4.49 are rated High Extent and items with mean ratings of 4.50 - 5.00 are rated Very High Extent. Analysis of Variance (ANOVA) was used to test the null hypotheses at 0.05 level of significance. A hypothesis was accepted where the p-value is greater than the alpha level of 0.05 ($p > 0.05$), at an appropriate degree of freedom; otherwise, the null hypothesis was rejected. Data collected were analysed using SPSS version 23.0

## RESULTS

**Extent manufacturing firms adopt energy-efficient processes for sustainable development in South-East, Nigeria**

**Table 1: Mean ratings on the extent manufacturing firms adopt energy-efficient processes**

| S/N | To what extent do you adopt the following? | $\overline{X}$ | SD | Remarks |
|---|---|---|---|---|
| 1 | Use solar sunlight for energy processes | 1.73 | .67 | Low Extent |
| 2 | Use turbines for energy processes | 1.89 | .43 | Low Extent |
| 3 | Use hydropower for energy process | 2.02 | .70 | Low Extent |
| 4 | Use biomass for energy process | 1.96 | .56 | Low Extent |
| 5 | Use geothermal for energy process | 2.25 | .81 | Low Extent |
| **Cluster Mean** | | **1.97** | | |

Data in Table 1 show that all the listed energy-efficient processes with mean ratings ranging from 1.73 to 2.25 were adopted at a low extent by respondents. The cluster mean of 1.97 indicates that manufacturing firms adopt energy-efficient processes for sustainable development at a low extent in South-East, Nigeria. The standard deviations for the items are within the same range which shows that the respondents are homogeneous in their opinions.

**Hypothesis 1**

There is no significant difference in the mean ratings of staff of selected manufacturing (pharmaceutical, food and beverages and automobiles firms) on the extent to which energy-efficient processes are adopted for sustainable development in South-East, Nigeria

**Table 2: ANOVA summary of mean ratings on the extent energy-efficient processes**

| Source of Variance | Sum of Squares | Df | Mean Square | F | P-value | Decision |
|---|---|---|---|---|---|---|
| Between Groups | 207.46 | 2 | 40.07 | .101 | .287 | Accepted |
| Within Groups | 982.81 | 349 | 77.13 | | | |
| Total | 1036.39 | 351 | | | | |

Data in Table 2 show that the F-value of 0.101 with p-value of 0.287 at degree of freedom of 2 and 349 is greater than the criterion value of 0.05 (p>0.05). The null hypothesis was accepted. This means that staff of pharmaceutical, food and beverages and automobiles firms did not differ significantly in their mean ratings on extent to which energy-efficient processes are adopted for sustainable development in South-East, Nigeria.

**Extent manufacturing firms adopt waste minimization practices for sustainable development in South-East, Nigeria**

**Table 3: Mean ratings on the extent manufacturing firms adopt waste minimization practices**

| S/N | To what extent do you adopt the following? | $\bar{X}$ | SD | Remarks |
|---|---|---|---|---|
| 6 | Reuse of direct waste | 2.19 | .63 | Low Extent |
| 7 | Recycle of indirect waste | 1.81 | .49 | Low Extent |
| 8 | Use biological process for processing waste waters | 2.14 | .51 | Low Extent |
| 9 | Redesign of components to reduce solid waste | 1.86 | .45 | Low Extent |
| 10 | Donate of waste and by-products to other industries | 2.03 | .79 | Low Extent |
| | **Cluster Mean** | **2.01** | | |

Data in Table 3 show that all the listed waste minimization practices with mean ratings ranging from 1.81 to 2.19 were adopted at a low extent by respondents. The cluster mean of 2.01 indicates that manufacturing firms adopt waste minimization practices for sustainable development at a low extent in South-East, Nigeria. The standard deviations for the items are within the same range which shows that the respondents are homogeneous in their opinions.

**Hypothesis 2**

There is no significant difference in the mean ratings of staff of selected manufacturing (pharmaceutical, food and beverages and automobiles firms) on the extent to which waste minimization practices are adopted for sustainable development in South-East, Nigeria

**Table 4: ANOVA summary of mean ratings on the extent waste minimization practices**

| Source of Variance | Sum of Squares | Df | Mean Square | F | P-value | Decision |
|---|---|---|---|---|---|---|
| Between Groups | 86.17 | 2 | 28.52 | .122 | .089 | Accepted |
| Within Groups | 399.53 | 349 | 82.76 | | | |
| Total | 754.02 | 351 | | | | |

Data in Table 4 show that the F-value of 0.122 with p-value of 0.089 at degree of freedom of 2 and 349 is greater than the criterion value of 0.05 (p>0.05). The null hypothesis was accepted. This

means that staff of pharmaceutical, food and beverages and automobiles firms did not differ significantly in their mean ratings on extent to which waste minimization practices are adopted for sustainable development in South-East, Nigeria.

**Extent manufacturing firms adopt sustainable supply chain management practices for sustainable development in South-East, Nigeria**

**Table 5: Mean ratings on the extent manufacturing firms adopt sustainable supply chain management practices**

| S/N | To what extent do you adopt the following? | $\bar{X}$ | SD | Remarks |
|---|---|---|---|---|
| 11 | Design products for re-use | 2.17 | .26 | Low Extent |
| 12 | Source for recycled products | 1.81 | .53 | Low Extent |
| 13 | Source for upcycled products | 1.99 | .69 | Low Extent |
| 14 | Use low-emission transport | 2.10 | .41 | Low Extent |
| 15 | Use low-carbon materials for production | 2.01 | .22 | Low Extent |
| 16 | Use eco-friendly packaging for products | 2.25 | .50 | Low Extent |
| **Cluster Mean** | | **2.06** | | |

Data in Table 5 show that all the listed sustainable supply chain management practices with mean ratings ranging from 1.81 to 2.25 were adopted at a low extent by respondents. The cluster mean of 2.01 indicates that manufacturing firms adopt sustainable supply chain management practices for sustainable development at a low extent in South-East, Nigeria. The standard deviations for the items are within the same range which shows that the respondents are homogeneous in their opinions.

**Hypothesis 3**

There is no significant difference in the mean ratings of staff of selected manufacturing (pharmaceutical, food and beverages and automobiles firms) on the extent to which sustainable supply chain management practices are adopted for sustainable development in South-East, Nigeria.

**Table 6: ANOVA summary of' mean ratings on the extent sustainable supply chain management practices**

| Source of Variance | Sum of Squares | Df | Mean Square | F | P-value | Decision |
|---|---|---|---|---|---|---|
| Between Groups | 102.44 | 2 | 39.16 | .114 | .108 | Accepted |
| Within Groups | 521.89 | 349 | 72.08 | | | |
| Total | 1063.40 | 351 | | | | |

Data in Table 6 show that the F-value of 0.114 with p-value of 0.108 at degree of freedom of 2 and 349 is greater than the criterion value of 0.05 ($p>0.05$). The null hypothesis was accepted. This means that staff of pharmaceutical, food and beverages and automobiles firms did not differ significantly in their mean ratings on extent to which sustainable supply chain management practices are adopted for sustainable development in South-East, Nigeria.

**DISCUSSION**

The findings of the study showed that manufacturing firms adopt energy-efficient processes for sustainable development at a low extent in South-East, Nigeria. This means that most manufacturing firms in South-East, Nigeria seldom invest in measures or technologies that enhance energy end-use efficiency. The finding corresponds with Ifeanyi-Obi, Issa, Aderinoye-Abdulwahab, Ayinde, Umeh and Tologbonse (2022) that industries in South-East, Nigeria continue to utilize older machines that lack modern energy-saving technologies. The finding of this study supports, Gershon, Umoidem and Olaifa (2024) which discovered that many small and medium scale enterprises in Nigeria do close to nothing in terms of improving energy efficiency in their daily operations even the basic practices and affordable measures that can yield energy savings concerning lighting and ventilation systems are not adequately adopted. This supports the earlier findings of Gershon and Agbene (2021) that few manufacturing companies in Nigeria are using energy efficient conversion devices in their factories' lighting and cooling

systems incorporating sensor controlled lighting and standard energy-saving practices and behaviours. The researchers believed that manufacturing firms are not embracing energy-efficient technologies and integrating renewable energy sources in order to ameliorate their ecological footprints in South-East, Nigeria because they are still reliant on traditional methods of production.

The findings of the study showed that manufacturing firms adopt waste minimization practices for sustainable development at a low extent in South-East, Nigeria. This means that most manufacturing firms in South-East, Nigeria are yet to develop robust waste management systems for recycling and safe disposal practices. The findings also corroborate with Nwamekwe, Igbokwe, Ono, Nwabunwanne and Aguh (2025) that local industries in South-East, Nigeria notably have limited wastewater treatment systems in place that threatens to the environment and hinders the overall sustainability of industrial practices. This finding is in agreement with Nwamekwe, Ewuzie, Igbokwe, Chukwuebuka and Nwabueze (2024) which reported that many manufacturing firms in South-East, Nigeria discharge untreated or inadequately treated wastewater directly into rivers and streams, leading to the contamination of water sources that are vital for both human consumption and aquatic life. The researchers believed that manufacturing firms in South-East, Nigeria do not have the required technical-expertise to minimized and convert hazardous and non-hazardous waste products into useful resources.

The findings of the study showed that manufacturing firms adopt sustainable supply chain management practices for sustainable development at a low extent in South-East, Nigeria. This means that most manufacturing firms in South-East, Nigeria are not to enhance their supply chain efficiency through optimized logistics and reduced transportation emissions that can lower the environmental impact. The finding of this study tallies with Ugochukwu, Onwosi and Eze (2022) which reported that majority of manufacturing firms in South-East, Nigeria are experiencing financing constraints to adopt sustainable supply chain management practices and provide adequate training on sustainable supply chain management practices to their staff. The finding of the study corresponds with Ibemesi and Ekenta (2019) that most of the manufacturing firms in South-East, Nigeria resist long-term sustainability investments in supply chain management practices like biodegradable packaging, sustainable textiles, and plant-based plastics due to short-term profit focus. The researchers believed that manufacturing firms in South-East, Nigeria are not ready to incorporate green procurement practices, encompassing sustainable sourcing and the utilization of eco-friendly packaging into our operational business framework.

Furthermore, the outcome of the study revealed that staff of pharmaceutical, food and beverages and automobiles firms did not differ significantly in their mean ratings on extent to which energy-efficient processes, waste minimization practices and sustainable supply chain management practices are adopted for sustainable development in South-East, Nigeria. This finding means that managers and employees, irrespective of their industry share the same position that sustainable manufacturing practices are not adopted for sustainable development in South East, Nigeria. This result tallies with Adeyemi, Oduyemi and Lawal (2020) and Nwamekwe, Igbokwe, Ono, Nwabunwanne and Aguh (2025) which reported that the adoption of energy-efficient processes, waste minimization practices and sustainable supply chain management practices by pharmaceutical, food and beverages and automobiles firms in South-East, Nigeria is slow, mainly due to a lack of knowledge, resources, and technology. In line with this finding, the researcher believed that without investment in smart technologies, manufacturing industries in South-East, Nigeria may struggle to effectively adopt energy-efficient processes, waste minimization practices and sustainable supply chain management practices toward sustainable industrial development.

## CONCLUSION

Globally, the adoption of sustainable manufacturing practices is generally accepted in the industrial landscape because they significantly enhances an organization's reputation and image and fosters positive public perceptions. However, the study concluded that manufacturing industries in South-East, Nigeria are not actively integrating sustainable manufacturing practices into their operations and positioning themselves for sustained success that aligns with global sustainability goals and regulatory standards.

**RECOMMENDATIONS**

Based on the findings and conclusion of this study, the following recommendations are made:

1. Federal, State and Local Government should strengthen the regulatory framework with clear guidelines, regular inspections, and stricter penalties for non-compliance in order to encourage manufacturing industries in South-East, Nigeria to adopt sustainable manufacturing practices in their operational activities.
2. Investment from both the government and private sectors should be encouraged in establishing the needed infrastructure and resources such as renewable energy installations, energy-efficient machinery, waste-to-energy facilities, and recycling plants for manufacturing industries in South-East, Nigeria to reduce their dependency on polluting fossil fuels and pave the way for cleaner, more resilient industries.
3. Government agencies, industry associations, and academic institutions can play a significant role by developing training programmes that cover topics such as energy-efficient processes, waste minimization practices and sustainable supply chain management practices to equipped manufacturing industries in South-East, Nigeria with the knowledge and skills necessary to adopt sustainable manufacturing practices.

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