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Environmental Sustainability Practices at Lagos Port Complex, Apapa, Nigeria: A Stakeholders' Perception Study

Adedotun Adenigbo[1*], Haruna Adamu[2], and Ikpechukwu Njoku[1]
[1]Department of Logistics and Transport Technology, Federal University of Technology, Akure, Nigeria
[2]Department of Nautical Science, Admiralty University of Nigeria, Asaba, Nigeria

*Corresponding Author
Email: ajadenigbo@futa.edu.ng

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Abstract

Seaports are critical revenue-generating infrastructure that contribute to environmental pollution through their operations. The economic benefits of seaports make it impossible to halt port operations to eliminate their negative environmental impact on society. This study examined the environmental sustainability practices in the Lagos Port complex, Apapa, Nigeria. The sustainability practices assessed for adoption in the study were extracted from the International Organisation for Standardisation (ISO 14001) environmental management framework. Data for the study were collected using a well-designed questionnaire with a five-point Likert scale. The survey was conducted using a combination of stratified and random sampling among stakeholders at the Lagos Port Complex (LPC) in Apapa. A total of 201 responses were collected for exploratory factor analysis to reduce and group the variables into common environmental sustainability practices in the seaport. The study found that two criteria, including waste reception facilities and cold ironing, do not contribute to the common environmental sustainability practices at LPC, Nigeria. The study further identified eight (8) practices as adopted sustainability practices. However, the three (3) common sustainability practices at the seaport include clean technology, recycling, and shipboard waste. The findings revealed the need for increased investment in infrastructure and technology, supported by an improved institutional and policy framework for the adoption and operation of environmental sustainability practices. The findings underscore the need for the seaport authority to enhance sustainability practices across the board to improve environmental quality. The study recommends adopting all sustainability strategies to advance environmental sustainability in the seaport.

Keywords: Clean Technology, Seaports, Recycling, Ship Board Waste, Sustainability Practices

INTRODUCTION

Seaports are critical maritime transport infrastructures that play a vital role in international trade, serving as points of interchange and gateways for the shipment of goods, resources, and services. Consequently, they serve as a basis for measuring nations' economic wealth (Ogunsiji & Ogunsiji, 2010). Seaports comprise ships, handling equipment, and intermodal connectivity facilities that enhance import and export operations across international borders, foster economic growth, and determine the efficiency and productivity of ports (Prashanth *et al.*, 2015). In 2018, approximately 11 billion tons of seaborne trade were carried by ships, representing about 80% of global trade by volume (UNCTAD, 2019). However, despite their contribution to national economic growth, seaport operations generate significant environmental externalities that are detrimental to human health and contribute to global warming (Dinwoodie *et al.*, 2012). These externalities arise from land-based infrastructure, cargo-handling operations, vessel emissions, and waste generated by ships and terminals (Akankali & Elenwo, 2015; Ng & Song, 2010). The concept of seaport sustainability, or green port operations, has gained global prominence amid concerns about seaports' environmental impacts (Lam & Notteboom, 2014). This movement emphasises the need to incorporate environmental sustainability into port operations, planning, and stakeholder relationships (Acciaro *et al.*, 2014; Denktas-Sakar & Karatas-Cetin, 2012). The growing adoption of environmental sustainability initiatives in seaports aims to achieve ecologically responsible systems (Chiu *et al.*, 2014).

Sustainability is defined as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland, 1987). The European Union Directive on green port development highlights that environmental protection and energy efficiency require special attention. Moreover, the concepts of sustainability and green ports are mutually interdependent (Bouman *et al.*, 2017). According to Satir and Doğan-Sağlamtimur (2018), a green port is a sustainable, environmentally friendly seaport that focuses on reducing pollution, using renewable energy, promoting material recycling, protecting aquatic life, and maintaining the cleanliness of harbours and coastal waters. Globally, ports in countries such as South Korea, Turkey, and across Europe have implemented structured frameworks to assess and improve environmental sustainability (Oh *et al.*, 2018; Satir & Doğan-Sağlamtimur, 2018; Lawer *et al.*, 2019). These practices include monitoring greenhouse gas emissions, improving waste management systems, adopting clean energy technologies, and promoting eco-friendly logistics (Puig *et al.*, 2014; Park & Yeo, 2012). In the United Kingdom, a sustainability ranking framework has been developed to evaluate ports' environmental performance (Asgari *et al.*, 2015). Against this background, seaport owners are responsible for aligning their operations with the United Nations Sustainable Development Goals (SDGs) and the International Maritime Organisation (IMO) sustainability agenda, rather than focusing solely on logistics and cargo handling (Alamoush *et al.*, 2023; Islam & Wang, 2023).

In contrast, Nigerian seaports face significant challenges in implementing environmental sustainability practices. Research has shown that vessel operations in Lagos and Tin Can Island Ports are major contributors to greenhouse gas emissions, raising concerns about air quality and public health (Olukanni & Esu, 2018; Jimoda *et al.*, 2017). Furthermore, marine pollution from ship-based discharges, oil spills, and plastic waste poses serious threats to coastal ecosystems (Onwuegbuchunam *et al.*, 2017; Akankali & Elenwo, 2015). Marine pollution from heavy metals, ship-borne sewage, oil spills, and industrial discharge continues to endanger Nigeria's marine and coastal environments (Akpan, 2022). The lack of adequate port reception facilities and weak enforcement of environmental regulations further exacerbate these challenges (Carpenter, Nitonye, & Umo, 2015).

Most existing literature on environmental sustainability in Nigerian ports focused on emission inventories, marine pollution, and ship waste (Olukanni & Esu, 2018; Onwuegbuchunam *et al.*, 2017; Jimoda *et al.*, 2017). However, studies on the adoption of sustainability practices in Nigerian seaports remain unexplored. Hence, this study is important as it fills the knowledge gap about which sustainability practices are being practised at seaports in Nigeria.

The main question of this study is which environmental sustainability practices are adopted in seaport operations in Nigeria? Therefore, the specific objective of the study is to:
identify the major environmental sustainability practices adopted at Lagos Port Complex (LPC), Apapa in Nigeria; and determine their effects on mitigating negative environmental impacts in the study area.

The study contributes to the existing knowledge by highlighting the need to integrate strategic sustainability practices into seaport operations in Nigeria. The remaining sections of the paper are as follows. Section 2 focuses on the literature review. Section 3 presented the methods adopted to conduct the research. Section 4 presents the study's results and discussion. Section 5 concludes the paper with recommendations.

LITERATURE REVIEW

The study presents the literature review under two major headings: conceptual and empirical.

Conceptual Review: Seaport Sustainability

Port sustainability has become increasingly important as port organisations seek viable ways to enhance performance by integrating port activities holistically within their supply chain systems while adapting to environmental demands and business growth (Denktas-Sakar & Karatas-Cetin, 2012; Oh *et al.*, 2018). Seaport operations encompass terminal handling, warehousing and storage activities, vessel operations, hinterland transport, and various industrial operations (PIANC, 2014; IMO, 2018; Notteboom *et al.*, 2020). In addition, seaports provide vessels, vehicles, and shuttles for the transfer, storage, and nautical services to ships, tugboats, and towboats. It is important to note that these activities rely heavily on fossil fuels such as diesel and liquefied natural gas, which, in turn, generate environmental, economic, and social externalities. For example, cruise ship activities generate sewage and solid waste; liquid bulk ships are often responsible for oil spills; and auxiliary engines on ocean-going vessels produce emissions, particularly when berthed (Alamoush *et al.*, 2020). To address these challenges, sustainable methods are now widely adopted as a standard in port operations. Sustainability in ports is defined as organisational initiatives and activities that meet current and future port needs without compromising human and natural resources (Oh *et al.*, 2018).

Seaports must recognise that their current actions influence both future generations and the environment. Hence, a port can only operate sustainably if its development considers the economic, social, and environmental dimensions collectively known as the Triple Bottom Line (TBL) of sustainability. This implies that port sustainability encompasses more than just environmental aspects (Lim *et al.*, 2019). The economic dimension of sustainability involves ensuring profitability and efficiency through investments in port facilities, infrastructure, and dredging activities that enhance performance. The environmental dimension focuses on mitigating negative externalities, including noise pollution, water contamination, air emissions, waste disposal, and ballast water discharge. The social dimension relates to the port's contribution to employment, corporate social responsibility, port-city interaction, and the livability of communities surrounding the port (Oh *et al.*, 2018). It is important to emphasise that these dimensions of sustainability do not function independently. The social dimension may depend on environmental initiatives, while environmental progress is often influenced by a port's economic strength (Alamoush *et al.*, 2020). For instance, ports such as Los Angeles, Hamburg, Antwerp, and Rotterdam have successfully implemented sustainability strategies to improve air quality despite increasing general cargo throughput (Acciaro *et al.*, 2014; Poulsen *et al.*, 2018). Larger, economically sustainable ports are typically better positioned to implement social and environmental initiatives due to greater financial capacity (Kuznetsov *et al.*, 2015).

Over the years, however, port operations and development have been observed to exert significant negative effects on the environmental systems of port cities. These impacts include degradation of water, air, and soil quality, as well as increased noise pollution in port vicinities (Roh *et al.*, 2016). Since port activities vary from one location to another, port authorities and industry stakeholders are increasingly recognising the importance of adopting sustainability practices. Consequently, they are being encouraged, and in some cases mandated, to align their management strategies with the Sustainable Development Goals by balancing the economic, social, and environmental dimensions of port operations (Puig *et al.*, 2015; Oh *et al.*, 2018).

Environmental Sustainability Practices at Seaports

Environmental concerns have remained globally unaddressed amid rapid economic development and the growing efforts to mitigate climate change. In 2015, the member states of the United Nations adopted the 2030 Agenda for Sustainable Development, with the 13th Sustainable Development Goal (SDG) focusing on Climate Action, which aims to mitigate climate change and reduce its impact on the environment (Shen *et al.*, 2025). In this context, environmental sustainability has become a key driver in addressing global environmental challenges. Environmental sustainability refers to the responsible management of the planet's resources to meet present needs without compromising future generations' ability to meet their own needs, thereby maintaining ecological balance and protecting ecosystems (Jaszczak, 2020). According to Kaswan *et al.* (2019), meeting current needs should not deteriorate environmental quality, underscoring the importance of preserving ecosystems for future generations.

At seaports, construction activities and port operations generate significant environmental externalities, including wastewater, exhaust gases, solid waste, and greenhouse gas emissions from auxiliary engines of ships docked at ports, all of which pose serious threats to the surrounding environments (Li *et al.*, 2024). One of the major environmental issues at ports is air pollution, which often arises from emissions from ship traffic and cargo-handling equipment, including sulfur oxides, nitrogen oxides, carbon monoxide, and particulate matter (Notteboom *et al.*, 2020; Roh *et al.*, 2016). It is estimated that across East Asia, Europe, and South Asian coastlines, over 60,000 people die annually from cardiovascular and lung cancer diseases linked to particulate matter and emissions from commercial ships (Corbett *et al.*, 2007). To mitigate these externalities, sustainability practices have emerged as viable approaches to ensuring environmentally friendly and efficient port operations.

According to Kang and Kim (2017), sustainability practices are sets of policies or initiatives designed to achieve sustainable development goals, ensuring that port operations do not harm the environment while preserving economic and social well-being in the long term. Similarly, Tan *et al.* (2011) asserted that adopting sustainability practices fosters economic stability and improves port performance within the framework of environmental regulations. Gimenez *et al.* (2012) noted that environmental sustainability practices also address social externalities such as safety risks, health concerns, and noise pollution affecting port vicinities and nearby communities.

Efficient environmental management is therefore essential for the sustainable development of seaports and their surrounding environments (Bouman *et al.*, 2017). In this regard, the European Sea Ports Organisation (ESPO) launched the EcoPorts project to promote coexistence between ports and the environment, emphasising environmental awareness and improvements in environmental management (Darbra *et al.*, 2004; Shen *et al.*, 2025). The Environmental Ship Index (ESI) has been widely adopted by European and Asian ports to help reduce greenhouse gas emissions from ships (Lister *et al.*, 2015). Several initiatives have been implemented globally to reduce environmental externalities. Notable examples include the European Union's Eco-Management and Audit Scheme (EMAS), the ESPO Self-Diagnosis Method (SDM), the Port Environmental Review System (PERS), and the EcoPorts initiative, which incorporates the generic requirements of international environmental management standards such as ISO 14001. Additionally, ports such as Antwerp, Valencia, Rotterdam, Genoa, Dover, and Livorno have addressed energy management and auditing through ISO 50001 certification (ESPO, 2018).

In the West African subregion, major hub ports such as Tema Port, Lagos Port, and the Port of Abidjan account for nearly half of the region's maritime trade by volume (Lawer *et al.*, 2019). These ports have adopted various environmental frameworks to address transboundary environmental issues and promote eco-friendly port operations (UNEP, 2011). The Nigerian Ports Authority (NPA), Port of Abidjan, and the Ghana Ports and Harbours Authority (GPHA) are implementing major strategic initiatives that have significantly reduced waste generation and contributed to economic growth but have made limited progress in improving air quality (Lawer *et al.*, 2019).

Empirical Review

Empirical studies on environmental sustainability practices in seaport operations have grown considerably in recent years, offering valuable insights into how ports manage environmental challenges across regions worldwide. This section reviews selected empirical studies examining port-related pollution, green port strategies, and environmental management frameworks.

Park and Yeo (2012) developed a fuzzy set approach to evaluate the "greenness" of Korean ports by analysing environmental performance indicators, including energy use, emissions, and waste handling. Their empirical model showed that only a few ports scored highly on green port criteria, and the authors stressed the importance of regulatory pressure and technological innovation in driving sustainability.

In another study, Chiu *et al.* (2014) used the Fuzzy Analytic Hierarchy Process (AHP) to rank green port performance factors in Asia. Their results indicated that energy efficiency, emission control, and stakeholder participation were the most critical elements in sustainable port operations. Oh *et al.* (2018) assessed seaport sustainability in South Korea using a multidimensional framework that considered economic, environmental, and social indicators. Their study empirically demonstrated that integrated policy frameworks and institutional support were key to successful sustainability practices.

In one of the few quantitative studies in Nigeria, Olukanni and Esu (2018) estimated greenhouse gas (GHG) emissions from port vessel operations at Lagos and Tin Can Island ports. Their empirical findings showed that cargo vessels were the primary contributors to GHG emissions, with carbon dioxide accounting for over 95% of total emissions. The study highlighted the lack of emission reduction strategies and the need for regulatory enforcement of cleaner fuels and vessel retrofitting. Similarly, Jimoda *et al.* (2017) conducted an emission inventory of Tin Can Island Port, estimating criteria air pollutants such as NOx, SOx, and PM from port activities. Their findings confirmed dangerously high levels of air pollutants, exceeding permissible limits. These emissions were attributed to the use of aged vessels, poor port infrastructure, and minimal environmental oversight. Onwuegbuchunam *et al.* (2017) empirically examined the types and causes of marine pollution in Nigerian ports, finding that oil spills, waste discharge, and ship-sourced pollution were prevalent. Their analysis identified a lack of functional port reception facilities, poor monitoring by port authorities, and weak adherence to international maritime regulations like MARPOL Annexes I and V.

In a broader context, Gobbi *et al.* (2019) used Data Envelopment Analysis (DEA) to assess the efficiency of plastic waste management in Brazilian ports. Their findings revealed significant variation in environmental management efficiency across ports, underscoring the importance of consistent monitoring and stakeholder engagement to achieve sustainability. Though conducted in Brazil, the methodology and recommendations are relevant to Nigeria, where plastic pollution remains largely untracked and unregulated (Akankali & Elenwo, 2015).

The literature review highlights an important difference between global best practices and the current state of environmental sustainability in Nigerian ports. While international ports have made significant progress in adopting and implementing environmental sustainability initiatives, such as the Green Port Initiative. Nigerian ports are still facing significant pollution and a weak environmental framework. On this note, there is a need for an in-depth evaluation of the extent of adoption of the current sustainability practices at seaports in Nigeria, as a roadmap to achieving sustainable seaport operations.

DATA AND METHOD

The study employed a survey research design for data collection and quantitative analysis on the extent of adoption of sustainability practices aimed at improving environmental sustainability at a Nigerian seaport. The adoption of a survey research design was intended to capture the perspectives of key port stakeholders on the extent to which sustainability practices are implemented in Nigerian seaports. To achieve the study's objective, a positivist philosophy was adopted for data collection, analysis, and interpretation. According to Adenigbo (2024), the positivist philosophical approach provides a framework for generating factual knowledge acquired through observation and supports primary data collection using questionnaires for quantitative analysis.

To collect data for the study, key stakeholders involved in operations and regulatory activities at the Lagos Port Complex in Lagos, Nigeria, were contacted. The Lagos seaport was selected as the study area because it is Nigeria's major port, handling over 70% of the nation's cargo throughput. Consequently, it faces significant environmental challenges resulting from intensive operational activities. Lawer *et al.* (2019) also described Lagos Port Complex, Apapa, as a regional hub port, accounting for nearly half of West Africa's maritime trade volume. The study population comprised staff of Integrated Logistics Services Limited (INTELS), the Nigerian Maritime Administration and Safety Agency (NIMASA), the Nigerian Shippers' Council (NSC), and Greenview Development Nigeria Limited (GDNL). The study treated the population as infinite, as the study could not find available figures on the stakeholders of the study population operating at the seaports.

A sample size of 384 was thus obtained for the study using the Cochran formula for calculating sample size when the population is infinite. The study employed stratified random sampling to administer the questionnaire. The choice of this technique is justified by the heterogeneous nature of the study population, which comprises distinct groups, including staff of the Nigerian Port Authority (NPA), Nigerian Maritime Administration and Safety Agency (NIMASA), Nigerian Shippers Council (NSC), Integrated Logistics Service Limited, and Green View Development Nigeria Limited. The stratification ensures that each subgroup is adequately represented in the sample. Stratified sampling improves statistical efficiency by reducing sampling error when subgroups differ (Lohr, 2019) and produces more accurate estimates than basic random sampling (Levy & Lemeshow, 2013). The requirements for probability sampling are also met by random selection within each stratum, ensuring that each element in the population has a known, non-zero probability of selection. By enabling the researcher to extrapolate results from the sample to the larger population with quantifiable degrees of confidence, this enhances the validity of inferential statistical analyses (Cochran, 1977).

Stratified random sampling also has the benefit of being compatible with sophisticated statistical methods, such as regression analysis and exploratory factor analysis (EFA). According to Tabachnick and Fidell (2019), probability-based sample strategies enhance the generalisability and robustness of multivariate statistical findings. Furthermore, stratified random sampling ensures a representative distribution of sample units across strata, which is crucial in research where certain subgroups may be under-represented. This improves the study's analytical depth by preventing bias and enabling insightful subgroup analysis.
The questionnaire was administered for three (3) weeks through face-to-face contacts with stakeholders in the port system. The level of willingness among stakeholders to complete the questionnaire was low, as everyone seemed busy with their daily business transactions. They consider that the time they will spend completing the questionnaire will be wasted, since there will be no direct, immediate benefit from participating in the survey. In the end, the survey recorded a 52.3 per cent success rate, having collected 201 valid responses. The distribution of the respondents for the survey is presented in Table 1. The study, therefore, considered a sample size of 201 as appropriate, following the recommendation that a sample of at least 200 respondents is ideal to ensure stable factor structures and reliable estimates (Hair *et al.*, 2019; MacCallum *et al.*, 1999).

The questionnaire was designed with two sections – A and B. The first section focused on respondents' demographic data, while the second section assessed the extent of adoption of environmental sustainability practices. A five-point Likert scale was adopted in designing the questionnaire, with response options ranging from 1 (not agreed) to 5 (highly agreed), denoted as: NA (not agreed), LA (least agreed), FA (fairly agreed), A (agreed), and HA (highly agreed). The questionnaire consists of 10 items derived from the environmental sustainability criteria in ISO 14001, which are core requirements and principles an organisation must meet to effectively manage environmental impacts and improve sustainability performance. The items were extracted from the ISO 14001 environmental management framework and adapted to the study to serve as sustainability practices at seaports. ISO 14001 is a framework that establishes environmental sustainability criteria through policy, planning, implementation, monitoring, and continuous improvement. The adoption of ISO 14001 improves environmental sustainability through structured practices such as waste management, energy efficiency, and compliance management. Other practices, such as pollution control, resource efficiency, and monitoring systems, are key to ISO 14001 implementation (Schalterggger & Wagner, 2006).

Table 1: Questionnaire Distribution to Respondents

Respondents	**Number of Responses**	**Percentage of Response**
Nigerian Port Authority	40	19.9
Nigerian Maritime Administration and Safety Agency	45	22.4
Nigerian Shippers Council	12	5.9
Integrated Logistics Service Limited	54	26.9
Green View Development Nigeria Limited	50	24.9
Total	**201**	**100**

An exploratory factor analysis (EFA) was used to analyse the primary data collected to address the study's objectives. The purpose of employing this statistical technique was to identify and reduce variables into factors that explain the environmental sustainability practices adopted at seaports in Nigeria, thereby mitigating externalities generated by port operations. These factors were selected based on their loadings or eigenvalues, meaning that variables with a loading of at least 0.4 were retained as factors. Certain procedures were followed to ensure that the data were suitable and adequate for EFA, thereby guaranteeing the reliability of the results for interpretation. These procedures include:

1. Correlation matrix
2. KMO and Bartlett's test of data adequacy and suitability
3. Communalities before and after extraction
4. Total variance explained with eigenvalue greater than 1
5. Rotated factor matrix

The rotated factor matrix forms the final output of EFA for discussion and interpretation. The rotated factor matrix usually groups items with similar characteristics to identify the dimensions that form the reduced factors. The goal of the exploratory factor analysis is to reduce the 10 sustainability practices in the questionnaire to a few orthogonal factors that can identify the significant sustainability practices at seaports in Nigeria.

RESULTS AND DISCUSSION

Exploratory Determination of Sustainability Practices at Seaports in Nigeria

A questionnaire was administered to participants at the Lagos Port Complex, Apapa, in Nigeria, to collect data for the study. Exploratory factor analysis was performed on the dataset. The test results indicate that the data are 78.8% sufficient for an exploratory factor analysis, with a sample adequacy score of 0.788. For data to be deemed appropriate for exploratory factor analysis, the KMO test value must be 0.5 or greater, and the Bartlett's test must be significant at $p < 0.05$ (Adenigbo, 2024). As seen in Table 2, the Bartlett's test of sphericity yielded a chi-square value of 263.09, which was significant at $p < 0.000$, suggesting that the data are appropriate for exploratory factor analysis. Additionally, the analysis's findings are trustworthy and useful for determining how widely Nigerian seaports have adopted sustainability practices.

Table 2: KMO and Bartlett's Test of Data Adequacy and Suitability

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.788
Bartlett's Test of Sphericity	Approx. Chi-Square	263.09
	Df	45
	Sig.	0.000

Table 3 presents the variance of items suitable for association with the common factors that describe the environmental sustainability practices adopted at seaports in Nigeria. The communalities show the percentage of variance explained and are the total of the squared loadings for each variable. Since they estimate the variation in each variable accounted for by all factors in the primary axis analysis, the initial communalities are always set to one. On the other hand, the extraction values indicate how much of each variable's variance is accounted for by the shared components. Therefore, at the extraction level, the components' communalities were considered (see Table 3).

Eight (8) of the items in Table 3 have values greater than 0.400 after extraction, indicating acceptable variance and significant contributions to the common factors explaining the adoption of environmental sustainability practices at seaports in Nigeria. There are two (2) items, waste reception facilities and use of cold ironing, with values less than 0.400. These items will contribute very little to the extracted common factors underlying environmental sustainability practices at seaports in Nigeria. It implies that the two items provide a very weak explanation of the common factors underlying environmental sustainability practices at the Lagos Port Complex, Apapa.

Table 3: Communalities of Environmental Sustainability Practices at Seaports

Variables	Initial	Extraction
Oil Spillage Control	0.482	0.832
Air Pollution Control	0.421	0.479
Sewage Control	0.443	0.472
Use of electrically powered machines	0.664	0.752
Waste Reception Facilities	0.218	0.229
Waste Recycling Management	0.204	0.598
Waste Water Control	0.412	0.516
Solid Waste Management	0.335	0.512
Ballast Water Control	0.338	0.449
Use of cold ironing	0.239	0.198

Extraction Method: Principal Axis Factoring

Table 4 presents the number of common factors that underlie the significant environmental sustainability practices at the seaport, along with their respective eigenvalues. Moreover, these factors represent the main environmental sustainability practices adopted at seaports in Nigeria. This was determined by assessing the total variance explained by the variables that constitute seaport environmental sustainability practices. The analysis output indicates that three (3) factors were extracted, each with eigenvalues greater than one (1), from a total of ten (10) variables included in the analysis. The cumulative percentage of the environmental sustainability practices at Nigerian seaports accounted for a moderate 44.8% of the total variance after extraction.

The Principal Axis Factoring extraction method with Varimax rotation and Kaiser normalisation was used to identify common environmental sustainability practices. The rotation arranges the variables by their loading factors and suppresses those with loading values below 0.400. Three (3) common environmental sustainability practices at Nigerian seaports were identified, as shown in Table 5. The rotated factor matrix highlights the proportions of variance accounted for by the major environmental sustainability practices currently adopted in Nigerian seaports. It was observed that variables with loading factors below the threshold in Table 3 did not load onto the common factors and have been removed from the list in Table 5. These variables include waste reception facilities and cold ironing, as indicated in Table 5. Factor 1 comprises oil spillage control, sewage control, air pollution control, and the use of electrically powered machines. Factor 2 consists of waste recycling management and wastewater control, while Factor 3 includes solid waste management and ballast water control, both of which are significant environmental sustainability practices at the Lagos Port Complex, Apapa Seaport.

The Factors 1–3 in Table 5 were named clean technology, recycling, and shipboard waste, respectively. These were identified as the significant environmental sustainability practices at Lagos Port Complex, Apapa, Nigeria.

The primary objective of this study was to identify the environmental sustainability practices adopted by seaports in Nigeria and to assess their extent of adoption. This objective was achieved through three key findings of the study. Firstly, as shown in Table 5, clean technology, recycling and shipboard waste were identified as the major environmental sustainability practices in LPC, Apapa. This finding aligns with the results of Elzarka and Elgazzar (2015) and Jimoda *et al.* (2017). These practices emerged from efforts by port authorities, policymakers, port operators, and other relevant stakeholders to achieve environmentally friendly ports that promote economic growth and social prosperity.

Table 4: Total Variance Explained for Environmental Sustainability Practices

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings	
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	Cumulative %
1	3.527	35.274	35.274	3.046	30.46	30.46	2	19.294
2	1.369	13.686	48.96	0.863	8.632	39.091	1	33.765
3	1.011	10.111	59.071	0.574	5.735	44.826	1	44.826
4	0.976	9.762	68.832					
5	0.724	7.243	76.075					
6	0.688	6.879	82.955					
7	0.519	5.192	88.145					
8	0.471	4.714	92.859					
9	0.385	3.851	96.71					
10	0.329	3.295	100					

Extraction Method: Principal Axis Factoring

Table 5: Rotated Factor Matrix of EFA for Environmental Sustainability Practices

Variables	**1**	**2**	**3**
Oil Spillage Control	0.904		
Air Pollution Control	0.555		
Sewage Control	0.551		
Use of electrically powered machines	0.407		
Waste Recycling Management		0.749	
Waste Water Control		0.636	
Solid Waste Management			0.770
Ballast Water Control			0.410
Factor Name	Clean Technology	Recycling	Shipboard Waste

Extraction Method: Principal Axis Factoring; Rotation Method: Varimax with Kaiser Normalization; Rotation converged in 6 iterations

According to Chiu *et al.* (2014), environmental initiatives contribute to the development of functional and sustainable ports while sustaining economic growth by mitigating externalities generated from port operations, such as water pollution, greenhouse gas emissions, noise pollution, dust, and solid waste disposal. Similarly, Islam and Wang (2023) confirmed that these factors negatively impact the seaport environment and cause irreparable damage.

Table 5 shows that reception facilities, as part of sustainability practices, make a very weak contribution to common sustainability practices at LPC, Nigeria. This finding supports Onwuegbuchunam *et al.* (2017), who reported that Nigerian seaports lack adequate waste reception facilities, which often encourage illegal discharge at sea. This may be attributed to the limited capacity of the government agencies and port authorities to acquire and effectively manage waste reception facilities for environmental sustainability at the seaport. In other countries with adequate waste reception facilities, effective use has remained a concern due to costs, awareness, and operational limitations (Fahmi *et al.*, 2025). Regarding costs, De Langen and Nijdam (2008) found that high user charges and cost-recovery systems discourage ship operators from using reception facilities. Also, weak operational systems have been a key challenge to the capacity and efficiency of reception facilities at seaports (Fahmi *et al.*, 2025; Onwuegbuchunam *et al.*, 2017). The fact that reception facilities are not included among the items for the extracted environmental sustainability practices in this study is due to their inadequacy and low utilisation levels resulting from limited funding for seaport facilities in Nigeria. Thus, while waste reception facilities are essential for reducing marine pollution and ensuring environmental sustainability compliance, their effectiveness is constrained by inadequate infrastructure, high user costs, low utilisation rates, and weak institutional and operational frameworks (Carpenter & Macgill, 2003; Onwuegbuchunam *et al.*, 2017; Fahmi *et al.*, 2025).

As highlighted in Table 5, the Lagos port complex does not practice cold ironing as an environmental sustainability practice, in line with Anyanwu *et al.* (2022). The inability of port authorities to practice cold ironing can be attributed to infrastructural deficits and unreliable power supply, as Nigeria frequently experiences power grid failures. Cold ironing (onshore power supply) can only function effectively when there is a stable electricity supply. Arduino *et al.* (2018) posited that the comparative cost of fuel and electricity, high hardware investment costs, and weak legislative support have been major barriers to the adoption of cold ironing in seaports worldwide. Similarly, Williamsson *et al.* (2022) identified technological and operational limitations, institutional challenges, economic constraints, and stakeholder-related issues as key barriers to its adoption. Empirical studies demonstrate that cold ironing significantly reduces port-related emissions and improves environmental sustainability, but its large-scale adoption is constrained by high infrastructure costs, energy price differentials, and challenges with technical standardisation (Zis *et al.*, 2019; Pruyn & Willeijns, 2022; Reusser & Pérez, 2021).

The findings in Table 5 indicate that oil spill control, with the highest loading of 0.904, is a significant environmental sustainability practice at the seaport, highlighting efforts to manage oil spill incidents in Nigeria. But the inadequate application of clean technology to reduce environmental damage at the seaport amid increasing oil spill incidents persists. The consequences of oil spills include pollution of the seaport environment, particularly contamination of water bodies, leading to the destruction of aquatic life (Jacob *et al.*, 2024). This finding aligns with that of Ifelebuegu *et al.* (2017), who reported significant deterioration in river water quality due to pollution from oil production activities. Similarly, Igbani *et al.* (2024) supported this view, stating that the presence of toxic chemical compounds in oil spills adversely affects coastal and marine habitats. The adoption of clean technologies to mitigate oil spills in LPC is limited due to the high capital requirements for their acquisition and operation. This aligns with the empirical studies, which indicate that clean technology adoption in seaports is primarily driven by regulatory pressures and economic incentives, while high capital costs, infrastructure limitations, and lack of standardisation remain major barriers, particularly in developing regions (Le, 2024a; Le, 2024b; Lawer *et al.*, 2019; Zis *et al.*, 2019).

CONCLUSION

Environmental sustainability is not only a concern for Nigerian seaports but a global issue that requires attention, especially as seaport operations continue to increase due to growing global trade, driven primarily by globalisation and industrialisation. Despite the growing pressure on policymakers and port authorities to adopt environmental sustainability practices, environmental challenges at seaports persist due to multi-faceted issues such as infrastructure deficits, regulatory gaps, and energy instability.

This study assessed the perceived adoption of ten (10) environmental sustainability practices extracted from the ISO 14001 framework at the Lagos Port Complex, Apapa, using a questionnaire to collect data. Exploratory Factor Analysis (EFA) was utilised as an analytical technique, and the items were reduced to eight (8) key variables. The study found that two (2) items, cold ironing and waste reception facilities, do not significantly contribute to the common sustainability practices at Nigerian seaports. However, the eight (8) items identified as perceived adopted practices were grouped into three (3) common factors, namely, clean technology, recycling, and shipboard waste.
The adoption of clean technologies to mitigate oil spills in LPC is limited by the high capital

requirements for their acquisition and operation. This aligns with the empirical studies, which indicate that clean technology adoption in seaports is primarily driven by regulatory pressures and economic incentives, while high capital costs, infrastructure limitations, and lack of standardisation remain major barriers, particularly in developing regions (Le, 2024a; Le, 2024b; Lawer *et al.*, 2019; Zis *et al.*, 2019). Across the literature, recycling in seaports is highly effective when supported by proper segregation systems, digital coordination, and circular-economy integration, but remains constrained at the Lagos Port Complex and in many regions by infrastructure gaps, weak governance, and high operational costs. Shipboard waste is diverse, increases with vessel activity, and is often only partially treated on board, with a significant proportion still discharged at sea, highlighting persistent gaps in monitoring, infrastructure, and regulatory enforcement (Sanches *et al.*, 2020; Swamy, 2012; Argüello, 2020). Cold ironing and waste reception facilities that do not significantly contribute to the extracted common factors are also constrained by costs, infrastructure, standardisation, low utilisation, and weak institutional and regulatory frameworks. Thus, the findings underscore the need for stringent actions to manage oil spills and protect the seaport environment.

The following recommendations are drawn from the findings of this study:

- The Nigerian Port Authority, in collaboration with terminal operators and other stakeholders, should increase its investment in port infrastructure that supports advanced environmental sustainability practices.
- There is a need for the port stakeholders to formulate and implement strategic efforts to improve the clean technology mechanisms that will significantly reduce pollution at the seaport.
- The seaport authority and other stakeholders should increase activities for shipboard waste and recycling management to effectively improve environmental sustainability.

In conclusion, since sustainability is a global issue that requires best-practice approaches, this study examines the perceived adoption of environmental sustainability practices at a seaport in Nigeria, which can serve as a model for other similar ports in developing economies. The study contributes to knowledge by highlighting clean technology, recycling, and shipboard control as significant sustainability practices for improving seaport environmental quality. The study provides preliminary empirical evidence on perceived sustainability practices at the Lagos Port Complex and highlights areas requiring stronger environmental infrastructure, regulatory enforcement, and stakeholder coordination to improve the seaport's environmental sustainability.

This study is limited to the perceived adoption of environmental sustainability practices at the Lagos Port Complex, Apapa, Nigeria. The study is based on stakeholders' perceptions of sustainability practices, rather than actual adoption backed by quantitative data at LPC. The same methodology can be applied to research on environmental sustainability practices in seaports in other countries, and future research may consider a broader range of practices.

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Conflict of Interest
The authors declare no conflict of interest whatsoever with the research.

Authors' Contribution

- Adamu: Conceptualisation, data curation; data analysis, and writing original draft.
- Njoku: Supervision, and review.
- Adenigbo: Conceptualisation, supervision, methodology, data analysis, review, and editing.

Consent and Responsibility
All authors have agreed to submit the manuscript for publication after a detailed review.

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