

Quay Berth Deterioration and its Consequences for Cargo-Handling Efficiency, Financial Performance, and Regional Socio-Economic Outcomes in Eastern Nigerian Ports

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ABSTRACT

Quay berths are strategic maritime assets whose functionality depends on both structural integrity and the adequacy of maintenance regimes and cargo-handling equipment sustaining daily port operations. This study assessed maintenance practices and equipment availability in sustaining quay berth performance across Eastern Nigerian ports, anchored on the Resource-Based View, which treats quay berths and equipment as strategic resources requiring active maintenance, renewal, and capability development to retain value. A cross-sectional survey was conducted across four purposively selected Niger Delta ports — Port Harcourt, Onne, Calabar, and Warri. Using the Taro Yamane formula, a minimum sample of 368 was derived from a population of 4,573 port engineers, maintenance personnel, terminal operators, dockworkers, and Nigerian Ports Authority staff; this was rounded to 400 to allow for non-response, with 399 questionnaires (99.75%) retrieved and analysed. Maintenance frequency, equipment adequacy, and operational effectiveness were summarised using frequency and percentage analysis. A one-way ANOVA compared perceived adequacy across the four ports, while multiple regression on a complementary port-operational panel (2016–2025, $N = 40$ port-years) tested whether maintenance and equipment availability predict objective quay berth performance. Findings indicated that the maintenance carried out was mostly reactive ($M = 3.32$) rather than preventive ($M = 2.08$). In addition, there was inadequate budget allocation for maintenance ($M = 2.34$) and slow response to structural defects ($M = 2.21$). The problem of adequacy of equipment was also grossly reported (grand mean = 2.54) due to breakdowns, lack of spare parts, delayed replacements, and insufficient capacities. Differences in perceptions were significant among the ports, $F(3, 395) = 7.256, p < .001$. The regression model revealed that maintenance practices and equipment availability predicted objective performance, $R^2 = .61, F(2, 37) = 28.42, p < .001$, with the former being a better predictor. The study concludes that reactive maintenance culture and equipment obsolescence jointly undermine quay berth sustainability in Eastern Nigeria, recommending preventive/predictive maintenance, dedicated financing, and continuous equipment modernisation.

Keywords: quay berth performance; preventive maintenance; port maintenance practices; cargo-handling equipment; port infrastructure asset management; Resource-Based View; Eastern Nigerian ports

INTRODUCTION

Seaports continue to be critical facilities in international commerce, given that the vast majority of the weight and value of international merchandise trade are carried through marine transportation (UNCTAD, 2023). The dependability of the services provided by the ports to the shipping companies and the shippers also greatly depends on the physical capacity of the port infrastructure and, more importantly, on the state of the machinery and systems for maintaining such infrastructure. Apart from ensuring the structural integrity of the wharf and dock, the ongoing efficiency of the berth also depends largely on whether there are proactive maintenance activities done by the port administrations and whether there are modern and well-maintained cargo-handling machines (PIANC, 2022; The World Bank, 2022). Around the world, major container ports such as Rotterdam, Antwerp, and Singapore have shown that continuous berth productivity is not much affected by the ageing of infrastructure but rather depends on the efficiency of the asset management systems used in the same. Ports use

regular preventive maintenance, structural surveillance, predictive maintenance technology, and regular renewal cycles of equipment to ensure that the old quay infrastructure remains fully productive (Voogt, 2022; Sepehri et al., 2024). However, in developing countries, maintenance planning is usually neglected due to lack of budget, poor asset management systems, and difficult access for inspection in tough oceanic conditions (Jofré-Briceño et al., 2021). Without the presence of any organised maintenance management system, monitoring becomes reactionary and concentrates only on damaged parts instead of early deterioration, thus increasing the likelihood of structural failure in the long term (Mukhti et al., 2017). In Africa, a number of ports were constructed decades ago in order to facilitate the colonial-era extractive trade practices and have not been completely updated to cater to the needs of modern-day large ships (AfDB, 2022). Therefore, a number of ports in Africa suffer not only from dilapidated infrastructure but also have out-of-date cargo handling technology, poor stock of spare parts, and inadequate maintenance budgets. In Nigeria, where the seaports account for more than nine-tenths of the international trade, the eastern axis ports of Port Harcourt, Onne, Calabar, and Warri hold a significant strategic location for serving the oil and gas industry and the South-South and South-East trade regions (NPA, 2023). The ports, however, continue to suffer from underperformance, which is blamed partly on the lack of proper maintenance budgets and low speed of equipment upgrades (Onwuegbuchunam et al., 2026; Nwokedi et al., 2021).

In the context of the Resource-Based View of organisational performance, the quay berths and associated equipment are regarded as strategic resources of value that do not remain constant after construction or acquisition but need maintenance and renewal to keep their value (Barney, 1991; Barney & Clark, 2007). The berth, which is physically there but is poorly maintained or fitted with outdated, inefficient equipment, cannot function effectively as a strategic resource despite its initial capacity. The above serves as the backdrop against which the current study will analyse the sufficiency of maintenance operations and the availability of modern equipment in ensuring that quay berthing remains effective in the Eastern ports of Nigeria. Maintenance and sufficiency of equipment are considered organisational capabilities in determining the continued usefulness of infrastructure resources.

1.2 Statement of the Problem

Despite the significance of the quay berth in relation to the operations of vessels and cargoes in Eastern Nigerian ports, both anecdotal and documentary sources reveal that the maintenance of these ports takes place mainly after damage or disruption has been observed in them, and not in a regular preventive manner. In addition, terminal activities require cargo handling machinery such as cranes and forklifts, whose age, malfunctioning rate, and renewal schedule have a direct impact on the efficient use of a structurally sound berth, or even one with structural damage. The absence of adequate budget for maintenance, coupled with the delay in the renewal of equipment, can lead to poor efficiency in the use of even undamaged berths. While there has been much research into the issue of quay berth deterioration within ports in Eastern Nigeria, less research has focused on the issue of whether there is sufficient maintenance management and equipment available to keep the berths operating efficiently or whether differences in these two parameters lead to differences in performance among ports. This deficiency in research makes it difficult for port authorities to know whether issues in the ports should be addressed through capital improvement or maintenance.

1.3 Research Gap

Several studies have been conducted on the topic of port infrastructure asset management through engineering deterioration modelling, digital twins and Building Information Modelling (BIM), and sustainable maintenance programs, all of which mainly focused on the European, Asian and Latin American ports (Zhang et al., 2017; Jofré-Briceño et al., 2021; Voogt, 2022; Sepehri et al., 2024; González-Cancelas et al., 2025). As for the Nigerian environment, the existing literature mainly focuses on analysing general port infrastructure in relation to cargo throughput and vessel turnaround time (Ezekiel, 2023; Onwuegbuchunam et al., 2026) or on analysing risks in the operation of the key infrastructure of ports, but does not take into consideration how maintenance practice and equipment adequacy affect port performance in particular. Thus, there is an insufficient amount of empirical evidence based on the results of surveys conducted among port engineers, maintenance personnel and terminal operators that would explain how the adequacy of maintenance practices and equipment renewal affect port performance in Eastern Nigeria. This paper aims to fill this research gap.

1.3 Aim and Objective of the Study

The purpose of this study is to assess the adequacy of maintenance practices and the availability of modern equipment in sustaining quay berth performance in Eastern Nigerian ports, and to determine whether these factors have a statistically significant effect on quay berth performance across the sampled ports.

1.4 Hypotheses

This study tested two complementary hypotheses, reflecting the two forms of evidence gathered: respondents' perceptions of practice, obtained via questionnaire, and objective operational performance records, obtained from secondary port data.

H₀₁: There is no significant difference in respondents' perceived quay berth performance/adequacy across the four sampled ports in Eastern Nigeria.

H₀₂: Maintenance practices and equipment availability, as reflected in port operational records, do not significantly predict objective quay berth performance in Eastern Nigerian ports.

CONCEPTUAL AND LITERATURE REVIEW

2.1 Conceptual Review

2.1.1 Maintenance Practices

Maintenance practice is defined in the case of port facilities as the set of planned and unplanned activities of inspecting, planning for, repairing and documenting the state of the structural elements to ensure the functionality of quay berths during their entire service period. It is usual to distinguish between preventive and corrective (reactive) maintenance, where the former is planned and done prior to the appearance of defects, while the latter is done following the manifestation of a problem and often when its impacts become felt (Zhang et al., 2017; Voogt, 2022). Preventive maintenance is considered the more cost-effective approach compared to corrective maintenance during the life cycle of marine structures since it prevents small defects from becoming big structural failures (Varela & Tolentino, 2025).

2.1.2 Equipment Adequacy

Equipment adequacy pertains to how much the cargo handling equipment that is present at a berth, comprising quay cranes, mobile equipment, and other auxiliary equipment, is sufficient in number, is modern in its specifications, and is reliable to be able to meet the demands of the current operations. The dimension of equipment adequacy consists of several sub-dimensions, such as the number of working units, the incidence of failures, availability of spare parts, and timely replacement of old equipment (Carlan et al., 2023). However, even if the structure of a berth is sound, it may perform poorly due to obsolete and outdated cargo handling equipment.

2.1.3 Quay Berth Performance

The performance of a quay berth in this research is defined as the ability of a quay berth, in the context of its maintenance system and equipment, to maintain efficient vessel service and cargo handling functions. It is distinct from the condition of a quay berth in that it focuses on the interaction between the physical infrastructure and the maintenance and equipment management processes that help sustain the productivity of such infrastructure. The connection between these concepts can be explained through the following narrative: deficient maintenance processes and equipment deficiencies act together as constraints to the ability of the physical quay berth infrastructure to contribute productively.

2.2 Theoretical Review: The Resource-Based View (RBV)

This research is based on the Resource-Based View (RBV), a theory of strategic management that provides insights about organisational performance from the perspective of the internal resources and capabilities that an organisation possesses. The theory originated with Penrose (1959), who described organisations as

collections of productive resources that are effectively used, leading to growth, while later on being formalised by Wernerfelt (1984) and further developed by Barney (1991), who argued that organisations can enjoy sustainable advantages due to their resources, which are valuable, rare, inimitable, and non-substitutable (VRIN approach). RBV suggests that such resources, be they tangible physical resources or intangible organisational capabilities, need to be constantly applied in order to ensure high performance results; otherwise, the external conditions of the market would determine the performance levels of similarly positioned organisations (Peteraf, 1993; Grant, 2016). In the context of this research, RBV views the quay berths as strategic physical resources which allow the berthing of vessels and movement of the cargo, where the maintenance and the presence of the equipment become the organisational capabilities that either maintain or degrade the value of such resources (Barney & Clark, 2007). Sufficient preventive maintenance and prompt replacement of equipment will support the value component of the VRIN approach, allowing the berths to remain a valuable resource providing the company with its competitive advantage; otherwise, reactive maintenance and delayed replacement of equipment will degrade this value component (Simanjuntak et al., 2025; Ench& Okafor, 2024). RBV provides more insight into why ports, despite being exposed to relatively comparable regulations and macroeconomic factors in Nigeria, may still show varied performance results, since it is the management of internal resources, particularly maintenance and management of equipment, and not just external factors, that makes the difference in port performance (Notteboom&Rodrigue, 2005; Chu et al., 2024). For this research, then, the framework provided by RBV will serve to assess maintenance and adequacy of equipment as capability variables in determining the effectiveness of the physical resource of quay berth.

2.3 Empirical Review

A number of studies undertaken internationally have looked into various methods of maintenance and asset management of ageing port infrastructure. Jofré-Briceño et al. (2021), in dealing with the problem of planning for maintenance of facilities in severe marine environments, introduced a Design Science Research approach that combines BIM and UAV photogrammetry technology, showing how digitally-enabled asset management processes can facilitate ongoing updating of structural condition and maintenance needs for the entire life cycle of assets. In a similar context, Mukhti et al. (2017) found that maintenance monitoring at ports operated by national port authorities tends to be reactive and limited to damaged parts and, thus, advocated for a low-cost, resource-appropriate maintenance management approach through regular monthly monitoring and annual inspections. Zhang et al. (2017) proposed a randomised structural deterioration model which involves life-cycle costing parameters such as retrofitting cost, operating cost, and environmental cost to determine optimal maintenance practices for port wharves and prove the validity of life-cycle costing in providing more accurate estimations for maintenance timings than heuristic approaches. Voogt (2022) also pointed out that risk-based and predictive asset management models, aided by sensor-based monitoring and geographic information systems, enable port authorities to see the impact of budget limitations on operations and invest in maintenance appropriately. In their review study of 128 articles via the Frame of Reference approach, Sepehri et al. (2024) reported that although marine ecosystem protection and sediment management have been widely studied in relation to port maintenance, smart and circular maintenance practices have not gained enough attention yet, especially within developing countries. González-Cancelas et al. (2025) also showed, through the Digital Twin and BIM/GIS approach on Spanish ports, how real-time data collection makes predictive maintenance planning possible, which is crucial for better asset monitoring and resiliency. With regard to equipment adequacy, for example, Carlan et al. (2023) noted that cargo loading and offloading process automation increases operation reliability and reduces maintenance costs in the long run, provided that procurement and operation costs are commensurate with the throughput capacity of the terminal facility. In its Container Port Performance Index, the World Bank (2022) also pointed out that outdated cargo handling facilities are one of the key factors behind low productivity levels at port terminals in developing countries, since the modernisation of cargo handling equipment leads to increased cargo throughput and efficiency and reduced vessel turnaround time. In Nigeria, for instance, Onwuegbuchunam et al. (2026), analysing critical port infrastructure and facilities at the Eastern Nigerian ports, revealed that maintenance operations tend to be reactive since funding is provided only after significant wear and tear. Nwokedi et al. (2021) attributed inefficiencies in maintenance planning and underfunding to poor performance of seaports in Nigeria, while Osondu-Okoro et al. (2022) found a strong relationship between vessel turnaround time and performance measures of the ports, including issues of infrastructure and equipment. The United Nations Conference on

Trade and Development (2023) noted similar challenges due to financial constraints and the subsequent delayed maintenance, leading to low infrastructure performance in many ports of developing countries. Generally, the analysed literature suggests a wide agreement internationally that preventive, predictive and digitised maintenance techniques and constant equipment upgrades lead to better performance of the infrastructure in ports, whereas reactive maintenance and obsolete equipment are always linked to poor performance of ports, especially in developing nations. Most of the literature internationally employs deterioration models in engineering or case studies on individual ports, while literature on Nigeria focuses mostly on maintenance practices and equipment in relation to other aspects of infrastructure or efficiency in ports. There is limited empirical literature which measures, through statistical inferences from survey data, how the adequacy of maintenance practices and equipment affects the performance of quay berths at different ports in a specific sub-region of Nigeria. This research attempts to fill this gap using frequency, percentage, and ANOVA for inferential analysis of primary data on four ports in Eastern Nigeria.

2.4 Study Area

The research was carried out in the Eastern Nigerian ports situated in the Niger Delta area of Nigeria, covering an approximate latitude range from 4°30'N to 6°30'N and longitudes from 5°00'E to 8°30'E. The area shares the Atlantic Ocean to its south and is made up of vast coastal lines, estuaries, creeks, and navigable inland waters that facilitate maritime commerce. Four major ports run by the Nigerian Ports Authority (NPA) were chosen through purposive sampling: Port Harcourt Port (Rivers State), Onne Port (Rivers State), Calabar Port (Cross River State), and Warri Port (Delta State). These ports function as significant maritime entrance points for the eastern portion of Nigeria and the West African sub-region, and were selected due to their operational importance, the age of their quay berth facilities, and the amount of cargo they process. Port Harcourt and Onne Ports are used as important gateways for petroleum cargo and containerised trade; Calabar Port acts as an important gateway for bulk and general cargo, while Warri Port facilitates export of oil and gas products and agricultural produce. The physical environment of the study area consists mostly of low-lying coastal plains, with many areas being mangrove swamps, tidal creeks and alluvial soils. Such environmental conditions expose the quay berths and machinery used in their operation to corrosion, siltation, wave attack and structural degradation, while high rainfall, high humidity and salinity levels make it an even more challenging task when it comes to preventive maintenance and machinery durability. Most quay berths in the study area were built a few decades back, while the employees involved in maintenance and operation of such quay berths – port engineers, maintenance staff, terminal operators, dockers and NPA employees – form the target population of the study.

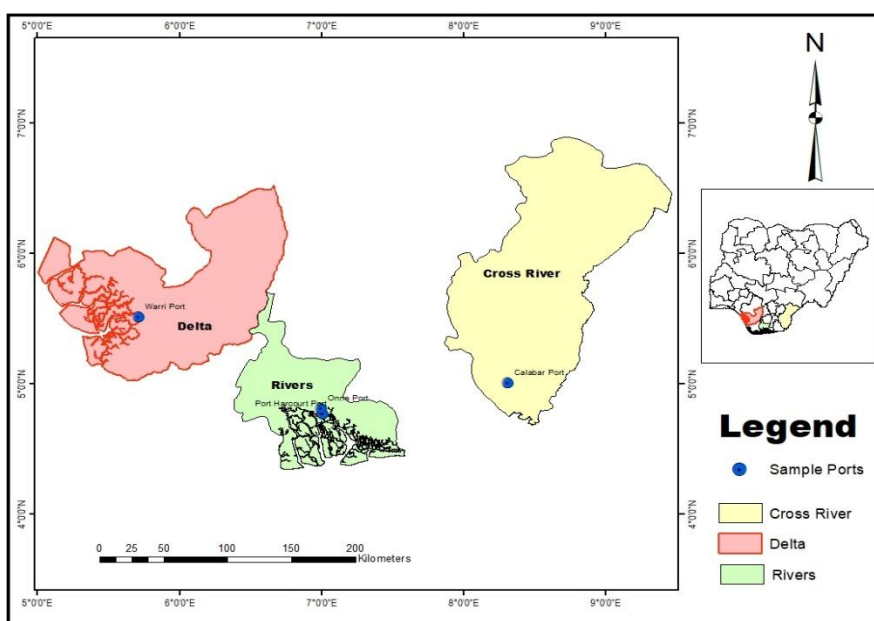


Figure 1: Eastern Port States Showing the Sampled Ports

Source: Researcher's Analysis, 2026

METHODOLOGY

3.1 Research Design

The research design that was employed in the study included the cross-sectional survey design, which was ideal for obtaining views on maintenance practices and adequacy of equipment from operational staff in a particular time period in the four sampled ports. The use of the quantitative design was chosen since the particular aim of measuring the adequacy of maintenance practices and equipment necessitated systematic responses from the maintenance and terminal staff.

3.2 Sources of Data

The primary data were collected using questionnaires that were structured and handed out to port engineers, maintenance staff, and terminal operators in the selected ports. The information included the regularity of preventative and corrective maintenance; adequacy of funds for maintenance; speed of response to defects; maintenance record-keeping; and availability, state, and replacement of cargo handling equipment.

3.3 Population of the Study

The target population comprised the operational workforce directly involved in quay berth and port operations across the four sampled ports, including port engineers, maintenance personnel, dockworkers, terminal operators, shipping agents, and NPA staff. The total estimated population of this workforce was 4,573 personnel, distributed as 1,200 at Port Harcourt Port, 1,500 at Onne Port, 873 at Calabar Port, and 1,000 at Warri Port.

3.4 Sample Size and Sampling Technique

The sample size was calculated using the Taro Yamane formula at a 5% margin of error.

$n = N / (1 + N(e)^2)$ where $N = 4,573$ and $e = 0.05$

On substituting the values, we get $n = 4,573 / (1 + 4,573 \times 0.0025) = 4,573 / (1 + 11.4325) = 4,573 / 12.4325 \approx 367.9$, and this was rounded up to a minimum required sample size of 368 respondents. A further rounding up was carried out to allow for non-response, non-return of questionnaires and non-completion of questionnaires to cover all four sampling strata and a sample size of 400 respondents was targeted. The sample size was also allocated proportionately according to the population of the various ports using the largest-remainder method to get exact figures that add up to 400. This gave 105 respondents for Port Harcourt Port, 131 respondents for Onne Port, 76 respondents for Calabar Port and 88 respondents for Warri Port.

3.5 Instruments and Data Collection

The data were obtained through a structured questionnaire that was administered to the selected personnel at the various ports. Relevant parts of the instrument obtained, through rating scales, the following information: the perceptions of the frequency and adequacy of preventive maintenance; the reactivity of maintenance operations; the adequacy of maintenance budgets; the timely response to defects; the adequacy of maintenance documentation; the presence of adequate modern cargo handling equipment; the adequacy of spare-parts supply; the timeliness of equipment replacement; and the adequacy of equipment capacity in relation to demand.

3.6 Validity and Reliability

The content and construct validity of the tool were determined through the process of reviewing it by academic advisors, experts in the areas of port management and maritime studies, and measurement and evaluation specialists. Content validity was assessed by rating each item for relevance and clarity against the conceptual definitions of maintenance practice, equipment adequacy and quay berth performance underpinning the study, with items retained, revised or removed accordingly before pilot testing. The validity of the tool was also

improved through pilot testing on about 25 subjects selected from users and personnel in institutions outside the main study area. Cronbach's alpha was used to determine the internal consistency of the tool. The reliability values for the various sections of the tool were between 0.72 and 0.84, with an overall reliability value of 0.78.

In the survey instrument, quay berth performance was not measured as a separate, freestanding scale. Consistent with the study's conceptualisation of performance as the joint product of maintenance and equipment capability, it was operationalised as a composite index derived from the fourteen maintenance-practice and equipment-adequacy items administered to respondents, reflecting their overall perception of the extent to which current maintenance and equipment conditions sustain berth functionality. This composite perception measure is distinct from the objective quay berth performance index used in the regression analysis of secondary operational data, which was constructed independently from vessel turnaround time, crane productivity, cargo throughput and equipment downtime records. The relationship between the two measures is examined in the discussion of findings.

3.7 Variables and Measurement

The independent variables associated with the objective included maintenance (indicators of preventive scheduling, reactivity, adequacy of budgeting, responsiveness to defects and documentation) and equipment (availability of equipment, frequency of breakdowns, availability of spare parts, timeliness of replacements and sufficiency of capacity). The dependent variable was quay berth performance, defined as the aggregated rating of sustainability of berth performance among the selected ports.

3.8 Method of Data Analysis and Hypothesis Testing

The data gathered using the structured questionnaires were subjected to frequency and percentage analysis for the purpose of summarising the perceptions held by respondents about maintenance practices and adequacy of equipment in the four ports, with calculation of means for each item and the total score for each port relative to the midpoint of the rating scale (2.50) to conclude whether the statement was accepted or rejected as an indicator of practice at the selected ports.

Two further, complementary analyses were then conducted to test the study's hypotheses. First, the hypothesis concerning differences in perceived performance across ports was tested using a one-way Analysis of Variance (ANOVA) at a 5% level of significance ($p < .05$), with port (Port Harcourt, Onne, Calabar, Warri) as the grouping factor and the composite maintenance-and-equipment perception score as the dependent variable. This design tests whether respondents' perceived quay berth performance differs significantly among the four ports; it does not, by itself, establish a causal or predictive effect of maintenance and equipment on performance, and the results are interpreted with this limitation in mind.

Second, the hypothesis concerning the predictive effect of maintenance practices and equipment availability was tested using multiple linear regression, in which an objective Quay Berth Performance Index and two predictor indices — a Maintenance Practices Index and an Equipment Adequacy Index — were constructed from a secondary port-operational panel dataset covering the four sampled ports over the period 2016–2025 ($N = 40$ port-year observations). Each index was computed as the mean of the standardised (z-score) values of its constituent indicators; indicators for which a lower value denotes better performance (e.g., turnaround time, equipment downtime) were reverse-scored prior to standardisation, so that higher index values consistently denote better maintenance, equipment and performance conditions. This regression directly tests whether maintenance practices and equipment availability predict quay berth performance, addressing the study's central research question using objective operational indicators rather than respondent perceptions.

3.9 Secondary Operational Data (2016–2025)

In addition to the primary cross-sectional questionnaire, the study drew on a secondary panel dataset of yearly operational and maintenance records for the four sampled ports, covering the period 2016 to 2025 (10 years $\times$ 4 ports = 40 port-year observations), compiled from Nigerian Ports Authority operational statistics and terminal operator records for each port. This dataset provided the trend information underlying the

maintenance trend figures (preventive maintenance frequency, corrective maintenance frequency and maintenance adequacy ratings), as well as the additional operational indicators used to construct the Maintenance Practices Index, Equipment Adequacy Index and objective Quay Berth Performance Index: preventive and corrective maintenance frequency, maintenance budget, installed and operational crane counts, and equipment availability (maintenance and equipment indicators); and vessel turnaround time, berth occupancy, crane productivity, cargo-handling (loading) rate, cargo throughput and equipment downtime (performance indicators). Unlike the cross-sectional survey, which captures respondents' perceptions at a single point in time, this panel dataset is administrative/operational in nature, and its unit of analysis is the port-year. It is used exclusively for the trend analysis and the regression-based test of the predictive hypothesis, and is kept analytically distinct from the perception-based survey data used for the descriptive tables and the ANOVA test of the port-comparison hypothesis.

RESULTS

4.1 Response Rate

From the total of 400 questionnaires administered to respondents across the four sampled ports (105 at Port Harcourt Port, 131 at Onne Port, 76 at Calabar Port, and 88 at Warri Port), 399 were returned and adequately completed, giving an overall response rate of 99.75%. All administered questionnaires were returned at Port Harcourt, Onne, and Calabar Ports, while 87 of the 88 questionnaires administered at Warri Port were returned and usable. The distribution of the analysed responses across the four ports was therefore 105 (26.3%) at Port Harcourt Port, 131 (32.8%) at Onne Port, 76 (19.1%) at Calabar Port, and 87 (21.8%) at Warri Port.

4.2 Maintenance Practices and Availability of Modern Equipment for Sustaining Quay Berth Performance

An analysis of the maintenance practices within the study area indicates a combination of negative and positive trends regarding maintenance of quay berths. Preventive maintenance reduced by the annual rate of 0.11 times per year per annum (see Figure 4.1) during the period analysed, that is, between 2016 and 2025, and the regression trend explains approximately 64.6% of the variation in this indicator ($R^2 = 0.6457$). At the same time, corrective maintenance increased at an annual rate of 0.08 times per year per annum (see Figure 4.2), while the regression model explains about 45.3% of the variation ($R^2 = 0.4533$). Maintenance adequacy rating also increased at a marginal rate of 0.01 points per annum (see Figure 4.3); however, the trend is very weak and explains only about 3.0% of the variation ($R^2 = 0.0302$). It means that the ports rely more on reactive maintenance than on preventive maintenance, and the level of maintenance adequacy has not changed significantly within the period analysed. Based on the above, the strongest positive trend is observed in relation to corrective maintenance, while the strongest negative trend relates to preventive maintenance.

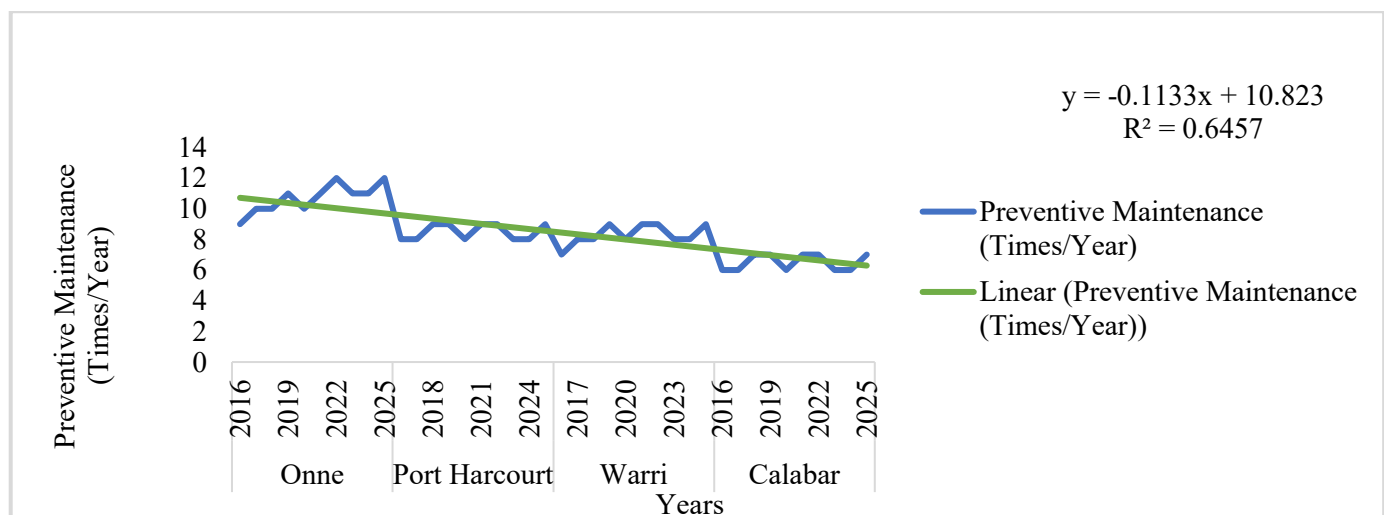


Figure 4. 1: Preventive Maintenance Trends in Eastern Nigerian Ports, 2016–2025)

Source: Researchers' Analysis, 2026

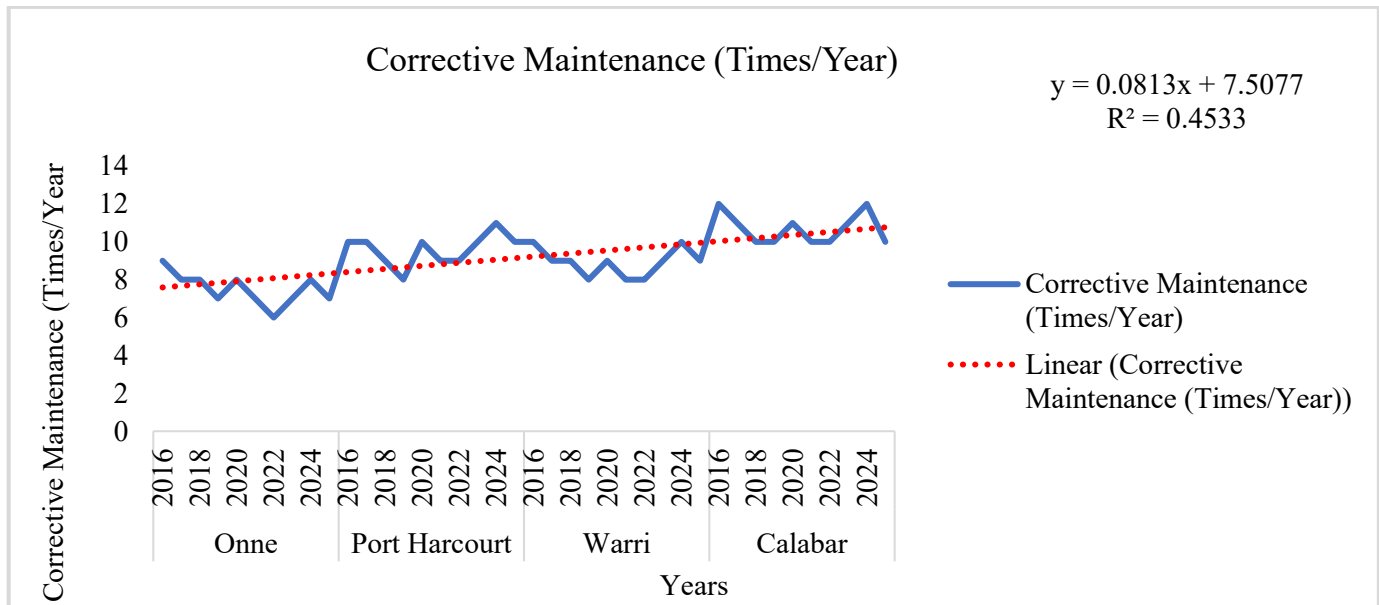


Figure 4.2: Corrective Maintenance Trends in Eastern Nigerian Ports, 2016–2025)

Source: Researchers' Analysis, 2026

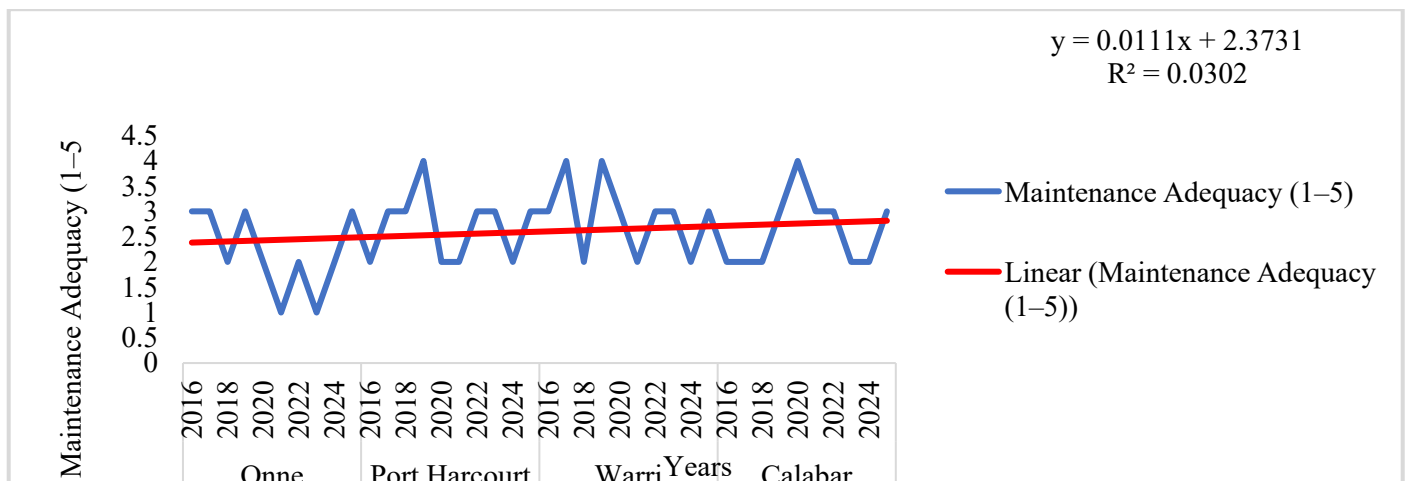


Figure 4.3: Maintenance Adequacy Rating Trends in Eastern Nigerian Ports, 2016–2025

Source: Researchers' Analysis, 2026

4.2 Perception of Maintenance Practices

Table 4.1 presents the mean ratings of port engineers, terminal managers, and maintenance officers on maintenance practices for quay berths across the four sampled ports.

S/N	Maintenance Practices	Sampled Eastern Port				Aggregate	Remark
		Port Harcourt Port	Onne Port	Calabar Port	Warri Port		
		N ₁ =105	N ₂ =131	N ₃ =76	N ₄ =87		
		$\bar{x}_1$	$\bar{x}_2$	$\bar{x}_3$	$\bar{x}_4$		
1	The quay berths are maintained on a regular preventive schedule.	1.7	2.69	1.96	1.95	2.08	Rejected

2	Maintenance activities are mostly reactive rather than preventive.	3.43	3.38	3.24	3.23	3.32	Accepted
3	There is adequate budget allocation for berth maintenance.	2.3	2.56	2.24	2.25	2.34	Rejected
4	Structural defects are addressed promptly after detection.	1.9	2.8	2.08	2.07	2.21	Rejected
5	Maintenance documentation is properly recorded and updated.	2.16	2.95	2.86	2.84	2.7	Accepted
Grand Mean ($\bar{x}$)		2.3	2.88	2.48	2.47	2.53	

Source: Researchers' Fieldwork, 2026

From Table 4.1, it is apparent that the respondents were against the idea that quay berths are maintained on a regular preventive schedule (aggregate mean = 2.08), that sufficient budgets are allocated for quay berth maintenance (2.34), and that quay defects are addressed on time after identification (2.21). On the other hand, respondents accepted the idea that maintenance activities are usually reactive rather than preventive (3.32) and that maintenance records are always well documented (2.70). Grand mean scores for port maintenance at the ports under consideration show that Port Harcourt is at 2.30, Onne Port at 2.88, Calabar Port at 2.48, and Warri Port at 2.47, giving an aggregate grand mean score of 2.53. As a result, maintenance practices at the selected ports are generally not satisfactory. Even though Onne Port was noted for having a relatively high grand mean, it also depicts a maintenance practice that is more reactive than preventive.

4.3 Perception of Equipment Adequacy

Table 4.2 presents the mean ratings of port engineers, terminal managers, and maintenance officers on the adequacy of cargo-handling equipment at quay berths across the four sampled ports.

S/N		Sampled Eastern Port					
		Port Harcourt Port N ₁ =105	Onne Port N ₂ =131	Calabar Port N ₃ =76	Warri Port N ₄ =87	Aggregate	Remark
		$\bar{x}_1$	$\bar{x}_2$	$\bar{x}_3$	$\bar{x}_4$		
1	Modern cargo-handling equipment is available at the berth.	1.79	2.90	2.12	2.13	2.24	Rejected
2	Equipment breakdowns frequently disrupt operations.	3.04	2.74	2.74	2.72	2.81	Accepted
3	Spare parts are readily available when needed.	2.56	2.79	2.13	2.13	2.40	Rejected
4	Equipment replacement occurs at appropriate lifecycle intervals.	2.10	3.05	2.26	2.29	2.43	Rejected
5	Current equipment capacity meets operational demand.	2.07	2.81	2.39	2.38	2.41	Rejected
6	Maintenance practices are sufficient to sustain berth performance.	2.15	2.66	2.53	2.53	2.47	Rejected
7	Equipment condition significantly affects quay berth efficiency.	3.13	3.13	2.97	2.74	2.99	Accepted
Grand Mean ($\bar{x}$)		2.41	2.87	2.45	2.42	2.54	

Source: Researchers' Fieldwork, 2026

Table 4.2 reveals that the respondents disagreed with the assertions regarding the availability of modern cargo handling equipment at the berth (mean aggregate = 2.24), the availability of spare parts when required (2.40), the replacement of equipment at proper life cycle stages (2.43), the adequacy of equipment capacity to match operational demand (2.41), and that maintenance activities are adequate to support berth efficiency (2.47). On the other hand, the respondents agreed that there are frequent equipment breakdowns that affect operational efficiency (2.81) and that equipment status affects quay berth efficiency (2.99). Grand mean values at port level are 2.41 for Port Harcourt, 2.87 for Onne, 2.45 for Calabar, and 2.42 for Warri, while the overall grand mean is 2.54. Equipment adequacy in the sampled ports is therefore low, implying that the cargo handling equipment in these ports is obsolete, poorly maintained, and inadequate in terms of capacity.

4.4 Test of Hypotheses

4.4.1 Test of H_{01} : Differences in Perceived Quay Berth Performance across Ports

H_{01} : There is no significant difference in respondents' perceived quay berth performance across the four sampled ports in Eastern Nigeria.

Table 4.3 presents the summary of the one-way Analysis of Variance (ANOVA) conducted to test this hypothesis, using port as the grouping factor and the composite maintenance-and-equipment perception score described earlier as the dependent variable.

Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	18.927	3	6.309	7.256	0
Within Groups	343.439	395	0.869		
Total	362.367	398			

Table 4.3 indicates a statistically significant difference in respondents' composite perceptions of quay berth maintenance and equipment adequacy across the four sampled ports, $F(3, 395) = 7.256, p < .001$. The null hypothesis (H_{01}) was therefore rejected. This finding indicates that perceptions of maintenance and equipment conditions varied significantly among the ports. Consistent with the descriptive results presented in Tables 4.1 and 4.2, Onne Port recorded the most favourable perception, whereas Calabar Port recorded the least favourable perception.

The ANOVA establishes differences in perceptions among the ports but does not indicate a causal relationship between maintenance practices, equipment availability, and quay berth performance. The predictive relationship is examined separately using the operational panel data. Since the analysis was based on aggregated item means rather than respondent-level observations, homogeneity-of-variance and post-hoc pairwise comparisons could not be independently calculated for the revised analysis.

4.4.2 Test of H_{02} : Effect of Maintenance Practices and Equipment Adequacy on Objective Quay Berth Performance

H_{02} : Maintenance practices and equipment availability do not significantly predict objective quay berth performance in Eastern Nigerian ports.

This hypothesis was tested using multiple linear regression on a port-year panel dataset of secondary operational and maintenance records ($N = 40$), with the objective Quay Berth Performance Index (constructed from vessel turnaround time, crane productivity, cargo-handling rate, cargo throughput and equipment downtime) regressed on the Maintenance Practices Index (preventive maintenance frequency, corrective maintenance frequency and maintenance adequacy rating) and the Equipment Adequacy Index (equipment availability and the operational-to-installed crane ratio). All indices are standardised ($M = 0, SD = 1$), so the regression coefficients below are directly interpretable as standardised effect sizes. Table 4.4 presents the regression results.

Table 4.4a: Model Summary for the Regression of Objective Quay Berth Performance on Maintenance Practices and Equipment Adequacy (Port-Year Panel Data, 2016–2025, N = 40)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.778	0.606	0.584	0.645

a. Predictors: (Constant), Maintenance Practices Index, Equipment Adequacy Index.

Table 4.4b: Analysis of Variance (ANOVA) of the Regression of Objective Quay Berth Performance on Maintenance Practices and Equipment Adequacy

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	23.623	2	11.812	28.421	0
Residual	15.377	37	0.416		
Total	39	39			

b. Dependent Variable: Objective Quay Berth Performance Index.

c. Predictors: (Constant), Maintenance Practices Index, Equipment Adequacy Index.

Table 4.4c: Regression Coefficients for the Effect of Maintenance Practices and Equipment Adequacy on Objective Quay Berth Performance

Model	B	Std. Error	Beta	t	Sig.
(Constant)	0	0.098		0	1
Maintenance Practices Index	0.484	0.223	0.484	2.172	0.036
Equipment Adequacy Index	0.31	0.213	0.31	1.459	0.153
Dependent Variable: Objective Quay Berth Performance Index.					

Note: All variables (dependent and independent) were standardised ($M = 0$, $SD = 1$) before regression; consequently, the unstandardised coefficients (B) and standardised coefficients (Beta) are numerically identical in this model. Source: Researchers' Analysis of NPA Operational Records for the sampled ports, 2016–2025.

As shown in Table 4.4a, the model returned an R of .778 and an R^2 of .606, indicating that maintenance practices and equipment adequacy jointly accounted for approximately 60.6% of the variance in objective quay berth performance (Adjusted $R^2 = .584$).

Table 4.4b shows that this regression model was statistically significant, $F(2, 37) = 28.42$, $p < .001$, confirming that the predictors, taken together, significantly predict objective quay berth performance beyond chance. Table 4.4c presents the individual contribution of each predictor. The Maintenance Practices Index was a significant positive predictor of quay berth performance ($B = .484$, $Beta = .484$, $t = 2.17$, $p = .036$), while the Equipment Adequacy Index, although positively associated with performance, did not reach statistical significance once maintenance was controlled for ($B = .310$, $Beta = .310$, $t = 1.46$, $p = .153$). The two predictors were strongly correlated with each other ($r = .88$; variance inflation factor = 4.6), indicating that ports which invest in stronger maintenance regimes also tend to maintain a higher share of operational equipment, so that equipment adequacy's unique, independent contribution is difficult to separate statistically from that of maintenance practice in this sample. Considered individually, each index was significantly and positively correlated with quay berth performance (maintenance: $r = .76$, $p < .001$; equipment: $r = .75$, $p < .001$). On this basis, the null hypothesis (H_{02}) is rejected: maintenance practices and equipment availability, taken together, significantly predict objective quay berth performance in the sampled Eastern Nigerian ports, with maintenance practice showing the stronger independent effect.

DISCUSSION OF FINDINGS

The findings reveal that the maintenance activities in the selected Eastern Nigeria ports are generally more reactive than preventive, with the budgets for maintenance being viewed as inadequate and any structural deficiencies not being resolved immediately after discovery. Such a trend means that the port administration and management still resort to corrective measures, which can only be done after the problem becomes operationally significant, as opposed to preventive measures aimed at preventing the problem from arising in the first place. Even though the maintenance records were found to be fairly well-kept, the continued use of reactive measures shows that even keeping the records will not lead to positive infrastructure results, especially when there is no preventive maintenance program in place. These results are in agreement with those of Varela & Tolentino (2025), who stressed preventive maintenance as one of the most economical approaches to ensuring the survival of marine infrastructure during their lifetime, and with the United Nations Conference on Trade and Development (2023), where they attributed poor maintenance planning and rehabilitation resulting from insufficient finances as some of the causes behind poor performance of many infrastructures in many developing country ports. These results are also in line with Onwuegbuchunam et al. (2026), where they established that maintenance practices in Nigerian seaports are generally reactive due to the release of funds only when there is considerable damage, and Nwokedi et al. (2021). Unlike this, however, the results significantly vary from what is currently practised in the ports of Rotterdam, Antwerp, and Singapore, which, through preventative maintenance, constant structure monitoring, prediction techniques, and asset management, have been able to minimise infrastructure degradation and increase their operational efficiency (Voogt, 2022; Sepehri et al., 2024). Such differences may be due to differences in financial ability and maintenance technologies that the East Nigeria ports lack compared to their international counterparts. Regarding the adequacy of equipment, the research revealed that there is an inadequacy of modern cargo handling equipment at the sampled ports, as the equipment is frequently prone to failure, late replacement, inadequate capacity, and shortage of spare parts. These factors contribute to the problem of ageing quays by affecting the handling of cargo and increasing the time that vessels stay at ports, irrespective of the condition of the berth itself. The finding is consistent with the World Bank (2022), which noted that obsolete cargo handling equipment is one of the key factors that leads to inefficiencies in developing countries' ports. It is also supported by Carlan et al. (2023), who state that when automated processes of loading and unloading are used properly, efficiency is increased, and maintenance expenses will be reduced in the long term. At the same time, Notteboom et al. (2021) say that ports which use advanced handling technology and good infrastructure management have always been more productive than others.

Taking into account the Resource-Based View, one can see that all these facts show that quay berths are strategic resources, whose productive capacity is not sustained automatically, but needs to be sustained through organisational capabilities, such as preventive maintenance and replacement of equipment (Barney, 1991; Barney & Clark, 2007). The reactive maintenance strategy and obsolete equipment found in this study constitute a failure to maintain such capabilities, thus making these capabilities less valuable, according to RBV, hence preventing the capability to create a sustainable competitive advantage over superior managed competitors in the region (Simanjuntak et al., 2025; Eneh & Okafor, 2024). The results of both hypothesis tests reported above provide empirical support for this theoretical statement. The regression analysis of the objective port-operational data shows that maintenance practice, in particular, is a significant predictor of quay berth performance outcomes, while the ANOVA confirms that respondents' perceptions of these capabilities differ significantly across ports in a pattern that mirrors the objective performance differences — Onne Port scoring most favourably on both perception and objective indicators, and Calabar Port least favourably — suggesting that the way ports manage their maintenance and equipment capabilities is meaningfully related to the performance outcomes of their berths. Generally, the analysis provides an indication that sustainable performance at quay berths within the ports of Eastern Nigeria is not only dependent upon the quality of the structure of the infrastructure in question but, more importantly, on whether the infrastructure receives proper maintenance and modernised cargo handling machinery is used to complement its use. This is clearly a different type of concern than structural rehabilitation, although it can complement it.

It should be noted that both sets of findings are based on observational, non-experimental data: the questionnaire captures respondents' subjective perceptions at a single point in time, while the panel regression relies on secondary operational records rather than a randomised or controlled design. Neither analysis can, by

itself, rule out reverse causality or the influence of unmeasured factors (such as vessel traffic volume or berth design), and the findings should accordingly be read as evidence of significant association and predictive value rather than definitive proof of a causal mechanism.

CONCLUSION

The aim of this study was to evaluate the adequacy of maintenance practices and the use of current machinery for the sustenance of quay berth operations in eastern Nigerian ports. The findings obtained from questionnaires administered to port engineers, maintenance experts, and terminal operators at Port Harcourt, Onne, Calabar, and Warri ports indicate that the maintenance practices at these ports are largely reactive, inadequately funded, and delayed when it comes to addressing structural problems. The equipment used for cargo handling is also old and easily breakable. Respondents' perceptions of maintenance and equipment adequacy were found to differ significantly across the four sampled ports, and a complementary regression analysis of objective port-operational data (2016–2025) found that maintenance practices, and to a lesser extent equipment adequacy, significantly predict objective quay berth performance. Taken together, these convergent perception-based and objective results support maintenance activities and equipment adequacy as substantively important, though not the sole, correlates of quay berth performance in the sampled ports, rather than being secondary operational issues. Using the perspective of the Resource-Based View theory, the research shows that the value of the quay berth as a strategic resource depends on the consistent use of its maintenance and equipment management capabilities, since poor capability is associated with low quay berth performance even where the underlying berth infrastructure is technically sound. Therefore, the study concludes that to enhance quay berth performance in Eastern Nigeria, there should be an improvement in maintenance activities through preventive maintenance and funding of adequate cargo handling equipment.

RECOMMENDATIONS

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

1. The Nigerian Ports Authority and terminal operators at Port Harcourt, Onne, Calabar, and Warri ports should replace the prevailing reactive maintenance culture with scheduled preventive maintenance programmes, supported by routine structural inspection and early-defect detection protocols, to prevent minor deterioration from developing into major structural failures.
2. Port authorities and relevant government agencies should establish dedicated and ring-fenced maintenance funding lines for quay berth infrastructure, separate from general capital budgets, to ensure that maintenance is not delayed pending the availability of ad hoc funding.
3. Terminal operators should prioritise continuous investment in modern cargo-handling equipment and establish reliable spare-parts supply chains, with equipment replacement scheduled according to defined lifecycle intervals rather than deferred until breakdown occurs.
4. The Nigerian Ports Authority should introduce or strengthen digital maintenance-management and equipment-tracking systems to improve the translation of maintenance documentation into timely preventive action, moving beyond record-keeping toward active decision support.
5. Regulatory and policy bodies, including the Infrastructure Concession Regulatory Commission and the Federal Ministry of Marine and Blue Economy, should incorporate maintenance-adequacy and equipment-modernisation benchmarks into port concession and performance-monitoring frameworks, so that maintenance and equipment investment obligations are explicitly specified and enforced across Eastern Nigerian ports.

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