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MARINE NAVIGATIONAL INFRASTRUCTURE AND SAFETY STANDARD COMPLIANCE IN NIGERIAN SEAPORTS: CHALLENGES AND POLICY IMPLICATIONS

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Abstract

This study examined marine navigational infrastructure and safety standard compliance in Nigerian seaports, with a focus on Apapa Port Complex. Specifically, it assessed the effects of navigational equipment availability, radar and communication functionality, GPS/electronic chart use, maintenance of aids to navigation, and staff competence on accident prevention and compliance with port safety regulations. The study was guided by two hypotheses and adopted a quantitative survey design. Primary data were collected through a structured questionnaire administered to 360 personnel and stakeholders involved in marine navigation, vessel traffic management, safety regulation, and navigational support services at Apapa Port Complex, using both paper-based and Google Forms instruments. Secondary data were obtained from relevant literature and port-related materials. The data were analysed with multiple linear regression at the 0.05 significance level. Findings showed that the combined predictors explained 74.6% of the variance in accident prevention and 49.8% of the variance in compliance with port safety regulations. The ANOVA results confirmed

that both regression models were statistically significant, while the coefficient estimates showed that all predictors positively influenced the two dependent variables. Maintenance of navigational aids and staff competence emerged as the strongest predictors of accident prevention, while navigational equipment availability, GPS/electronic chart use, and aid maintenance were key determinants of regulatory compliance. The study concludes that marine navigational infrastructure and human competence are critical to safer vessel operations and stronger adherence to safety standards in Nigerian seaports. It recommends improved equipment provision, regular maintenance of navigational aids, continuous staff training, upgraded communication systems, and stricter enforcement of port safety regulations to enhance operational safety and reduce accidents.

Keywords: Navigational Infrastructure, Safety Compliance, Nigerian Seaports

Introduction

Marine transportation remains central to international trade, handling large cargo volumes, linking coastal economies, and underpinning port-based commerce. In Nigeria, seaports are vital gateways for imports, exports, petroleum logistics, industrial inputs, and regional maritime exchange; yet the efficiency of these ports, hinges on safe vessel movement within channels, approaches, anchorages, berths, and turning basins. Weak navigational safety increases the risk of grounding, collisions, contact damage, traffic delays, cargo loss, environmental pollution, and disruption of port services outcomes that undermine trade flows and raise economic and environmental costs (Nwaogbe, et al., 2023). Navigation has evolved from visual observation, paper charts, and manual fixes to integrated digital systems radar, Automatic Identification System (AIS), Global Positioning System (GPS), Electronic Chart Display and Information System (ECDIS), echo sounders, vessel traffic services (VTS), communications, and aids to navigation that collectively enable position fixing, traffic monitoring, hazard detection, instruction relay, and emergency response. Leite-Junior et al. (2021) emphasise that modern navigation depends on the integration of digital sensors and technologies, but these systems must be reliable, secure, and properly managed to deliver safety benefits. In constrained port environments, characterised by restricted manoeuvring space, shallow waters, dredged channels, pilotage, and traffic congestion, the relevance of these technologies is heightened: collision risk assessment and safe-path planning are critical where vessel density and limited water space increase navigational complexity (Yu et al., 2023). Despite technological progress, maritime accidents persist worldwide because factors beyond equipment such as human error, technical, organisational and environmental challenges contribute to incidents. Yıldırım et al., (2019) link collisions and groundings to decision errors, resource-management gaps, violations, miscommunication, adverse mental states, and technological conditions; Sakar et al. (2021) identify improper radar and ECDIS use, inadequate lookout, poor voyage planning, and weak watchkeeping as frequent causes of groundings.

In Nigeria, research on port safety often emphasises occupational safety, security, and emergency management (Abubakar et al., 2023; Onwuegbuchunam et al., 2021), leaving the role of marine navigational systems as core safety infrastructure underexamined. Given the Lagos port complex and other Nigerian waterways where navigational equipment availability, radar and communication functionality, GPS and ECDIS use, maintenance of aids to navigation, and personnel competence interact to determine safety outcomes, empirical assessment of these elements is necessary. This study therefore evaluates navigational infrastructure and compliance with safety standards in Nigerian seaports to determine how equipment availability, system functionality, maintenance, and staff competence influence accident prevention, regulatory compliance, emergency response readiness, vessel-movement safety, and grounding incidence.

Statement of the Problem

Nigerian seaports are expected to provide safe, reliable environments for vessel movement, yet persistent risks arise from inadequate equipment, human error, weak traffic coordination, poor maintenance, and limited emergency preparedness. In practice, safe navigation is undermined where radar and communication systems are unreliable, GPS and ECDIS are underused, navigational aids are poorly maintained, and personnel lack the competence to interpret and act on navigational information. Also, port waters are restricted and high- risk, such weaknesses can rapidly cause groundings, collisions, contact damage, delays, pollution, and operational disruption problems that amplify economic and environmental costs and strain port throughput. Although global studies link maritime accidents to interacting human, technical, organisational, and environmental factors (Chauvin et al., 2013; Dugan & Utne, 2014; Akyuz, 2015), and Nigerian research notes port safety concerns and pilot training needs (Lawal- Fagbo et al., 2023), there is limited empirical evidence in Nigeria on how specific navigational system variables jointly influence safety outcomes. This gap concerning the availability of equipment, radar and communication functionality, GPS/ECDIS adoption, maintenance of aids to navigation, and staff competence restricts regulators and port managers from prioritising interventions that would improve accident prevention, regulatory compliance, emergency readiness, and vessel- movement safety. This study therefore evaluates those variables to produce actionable evidence for enhancing navigational infrastructure and safety standard compliance in Nigerian seaports.

The study aimed to evaluate how marine navigational infrastructure and related human and technical factors influence compliance with safety standards and accident prevention in Nigerian seaports**.** The specific objectives of the study are to; **(i)** determine the impact of availability of navigational equipment, functionality of radar/communication systems, use of GPS/electronic chart systems, maintenance of navigational aids, and staff competence on accident prevention of Nigerian seaports. (ii) assess the effect of the availability of navigational equipment, functionality of radar/communication systems, use of GPS/electronic chart systems, maintenance of navigational aids, and staff competence on Compliance with port safety regulations of Nigerian seaports. The study therefore hypothesises that H_{01}: the availability of navigational equipment, the functionality of radar and communication systems, the use of GPS and electronic chart systems, the maintenance of aids to navigation, and staff competence have no significant influence on accident prevention in Nigerian seaports. H_{02}: the availability of navigational equipment, the functionality of radar and communication systems, the use of GPS and electronic chart systems, the maintenance of aids to navigation, and staff competence have no significant effect on compliance with port safety regulations in Nigerian seaports.

Review of Literatures

Availability of navigational equipment refers to the extent to which essential maritime navigation instruments and systems (such as radar, AIS, GNSS/GPS, ECDIS, echo sounders, VHF radios, buoys, beacons, lights, and VTS facilities) are adequately provided, properly installed, functional, and accessible to trained personnel for safe vessel movement and port operations. Modern navigation increasingly relies on integrated systems that combine radar, AIS, ECDIS, GPS, and other sensors to support accurate position fixing, traffic monitoring, hazard detection, and decision-making; where such equipment is unavailable, insufficient, or unserviceable, navigators experience reduced situational awareness and higher collision or grounding risk (Leite-Junior et al., 2021).

In restricted waters and ports, this availability must also extend to shore-based surveillance and vessel traffic management systems, as well as well-maintained aids to navigation, so that Nigerian ports can ensure accident prevention, regulatory compliance, and safe vessel movement. Navigational safety denotes the condition in which vessels are planned, operated, and monitored in ways that minimise the risk of collisions, groundings, contacts, and other navigation-related accidents across oceans, coastal waters, channels, harbour approaches, and port basins. It is anchored on accurate position fixing, continuous lookout, proper voyage planning, effective communication, collision avoidance in line with COLREGs, and correct use of navigational technologies, with heightened demands in restricted waters where vessels operate in shallow, congested channels near berths and other ships (Formela et al., 2018; Yu et al., 2023). In port environments such as Nigerian seaports, navigational safety depends on the integrated performance of shipboard systems (radar, AIS, GPS, ECDIS, VHF) and shore-based services (VTS, pilotage, aids to navigation), as well as competent personnel and compliance with port safety regulations, to prevent accidents and reduce grounding or collision incidents. Maintenance of navigational aids involves systematic inspection, servicing, repair, replacement, and monitoring of buoys, beacons, lighthouses, leading lights, racons, AIS aids, and other fixed or floating markers that guide vessels safely through waterways, harbour entrances, and port approaches. Effective maintenance ensures these aids remain correctly positioned, visible, and operational, thereby sustaining the quality and reliability of navigational information available to mariners; modern approaches include remote video surveillance and automated fault detection to enhance inspection efficiency (Chen et al., 2011).

Since environmental conditions such as fouling, currents, and weather can degrade aids' performance (Yoo et al., 2019), risk-based and continuous maintenance focusing on technical condition and key indicators like light range, rhythm, power supply, and structural integrity (Huang et al., 2024) is essential for Nigerian ports to support accident prevention, regulatory compliance, and safe vessel movements. Staff competence in marine safety encompasses the knowledge, technical skills, practical experience, decision-making ability, and professional attitudes required to operate, monitor, and maintain navigational systems while ensuring safe vessel movements in port environments. International frameworks such as the STCW Convention and related IMO instruments emphasise that the effectiveness of navigational technologies depends largely on the competence of officers, pilots, and VTS personnel to integrate information from radar, GPS, ECDIS, AIS, and communication systems, maintain situational awareness, and respond appropriately to changing conditions (IMO, 2017). Empirical evidence shows that competent personnel enhance compliance with safety regulations, reduce navigational errors, and strengthen safety culture (Batalden et al., 2014), underscoring the importance of education, certification, continuous training, and simulation-based exercises for Nigerian port and maritime personnel.

A marine accident is an unexpected event in maritime operations that results in loss of life, injury, or damage to vessels, cargo, port infrastructure, or the marine environment, including incidents such as collisions, groundings, fires, explosions, capsizing, machinery failures, and pollution. The IMO defines marine casualties and incidents as events directly connected with ship operations that cause serious consequences like death, vessel loss, or significant damage, reflecting the multifactorial nature of accidents involving human, technical, environmental, and organisational contributors (IMO, 2017). Studies consistently identify human error manifesting as poor situational awareness, inadequate communication, fatigue, insufficient training, or non-compliance with procedures as the predominant causal factor (Batalden et al., 2014), reinforcing the need for systems-based safety management that integrates reliable technology, competent personnel, robust organisational practices, and effective regulatory oversight in Nigerian seaports. Compliance with port safety regulations refers to the degree to which port authorities, terminal operators, shipping companies, and maritime personnel adhere to national and international laws, standards, and procedures designed to ensure safe vessel movement, protect life and property, and safeguard the marine environment. It is grounded in key IMO instruments such as SOLAS, the ISM Code, and the ISPS Code, which set minimum standards for vessel operations, safety management systems, risk assessment, training, and emergency response, while national regulators enforce complementary operational guidelines and inspections (IMO, 2021).

Beyond formal adherence, effective compliance requires a strong safety culture marked by management commitment, adequate resources, continuous training, and active hazard reporting (Batalden & Sydnes, 2014; Bhattacharya, 2012), enabling Nigerian ports to reduce accidents, improve emergency readiness, and maintain efficient and secure operations. Ground collision, or vessel grounding, occurs when a ship unintentionally hits the seabed, submerged rocks, sandbanks, or harbour structures, and is a common navigational accident in ports and coastal waters where channels are shallow and confined. Such incidents can cause structural damage, operational disruption, environmental pollution, and cargo loss, and are recognised by the IMO as serious marine casualties due to their potential consequences (IMO, 2021). Research indicates that groundings typically arise from combined technical, environmental, and organisational factors such as inadequate navigational aids, inaccurate hydrographic data, equipment failures, poor voyage planning, and weak communication highlighting the need for systems-based prevention approaches that integrate competent personnel, reliable navigational infrastructure, and robust risk management (Mazaheri et al., 2015; Schröder-Hinrichs et al., 2012; Kum & Sahin, 2015). Emergency response readiness describes the capability of ports, maritime organisations, and ship operators to prepare for, respond to, and recover from maritime emergencies in a timely, coordinated, and effective manner. It involves having trained personnel, clear contingency plans, reliable communication networks, search and rescue resources, fire-fighting and pollution-control equipment, and institutional arrangements that support coordinated action in incidents such as collisions, groundings, fires, and oil spills (IMO, 2018; IMO, 2022). Studies show that ports with comprehensive emergency management systems, regular drills, and continuous risk assessment achieve greater resilience and reduced accident consequences (Batalden & Sydnes, 2014), indicating that strengthening emergency readiness in Nigerian ports is essential for enhancing navigational safety and sustaining port operations after critical incidents.

Vessel movement safety refers to the safe and orderly navigation of ships through waterways, port channels, harbour basins, and terminal approaches, with minimal risk of collisions, groundings, and contact accidents, while maintaining operational efficiency. It is shaped by the combined performance of navigational technologies (radar, GPS, ECDIS, VTS), traffic management systems, human operators, and organisational procedures that support risk assessment, route planning, communication, and monitoring (Goerlandt & Montewka, 2015). As vessel sizes and traffic density increase, vessel movement safety becomes a multidimensional concept that depends on technological reliability, human competence, regulatory compliance, and effective safety management; strengthening these elements in Nigerian seaports contributes to accident prevention, improved throughput, and sustainable maritime transport (Formela et al., 2019). Leite-Junior et al. (2021) investigated cyber-attack risks in integrated navigational sensors, specifically radar, AIS, and ECDIS, and demonstrated that these systems can be exploited as channels for remotely triggering malicious commands on shipboard platforms, with high detection accuracy for simulated attacks. Their simulation-based findings underscore that the reliability, integrity, and security of marine navigational systems are critical to accident prevention, because compromised radar or AIS/ECDIS displays can mislead watchkeepers and pilots, thereby degrading situational awareness and increasing the likelihood of collisions or groundings. Although limited by its reliance on simulated rather than operational port data, the study highlights that safety in modern navigation is inseparable from the functional robustness and cyber resilience of navigational infrastructure.

A study on Lagos Port Complex further illustrates how deficiencies in navigational infrastructure and services can compromise accident prevention. Efeturi (2021) showed that Lagos operates only a partial VTS with inadequate radar, AIS, CCTV, hydrological sensors, and insufficiently certified staff, and recommended upgrading equipment, expanding coverage, and enhancing training to meet IMO/IALA standards. Similarly, Lawal-Fagbo et al. (2023) found that pilots' age, work experience, and readiness to use innovative navigational aids significantly influence the adoption of modern technologies, suggesting that human factors and willingness to embrace new systems are central to leveraging navigational technologies for safer pilotage and reduced operational risk. Other empirical studies emphasise the interplay between navigational technology, human factors, and risk modelling in accident prevention. Turna and Öztürk (2019) showed that ECDIS/ENC-related grounding accidents are dominated by human factors such as wrong safety-depth alarm settings, failure of audio alarms, unsuitable chart scales, and inadequate training, pointing to the need for better ECDIS familiarisation and cross-checks with radar and visual methods. Bojić et al. (2021) developed modular risk-parameter sets for port approaches using AIS-based data and fuzzy logic to capture traffic, environmental, and ship-related influences on accident risk, while Bye and Aalberg (2018) used accident reports and AIS data to identify vessel type, shorter length, poor visibility, and flags of convenience as key risk indicators for navigation accidents.

Collectively, these studies show that effective accident prevention in port and coastal waters depends on a combination of reliable navigational systems (radar, AIS, ECDIS, VTS), robust risk-assessment models, and competent human operators capable of correctly interpreting and acting on navigational information.

In addition, several studies highlight that current empirical evidence is either context-specific or limited in scope, creating gaps that are particularly relevant for Nigerian seaports (Nwaogbe, et al., 2020). Many investigations focus on individual technologies (such as ECDIS or AIS), specific traffic-service functions, or particular regions, often relying on accident reports, simulations, or data from advanced maritime administrations rather than developing comprehensive models for ports in developing economies (Omoke, 2017). Consequently, there is insufficient integrated evidence on how the combined availability, functionality, security, and human utilisation of marine navigational systems influence accident prevention in African port environments. The present study therefore extends the empirical literature by examining how navigational equipment, radar and communication systems, GPS/ECDIS usage, maintenance of aids to navigation, and staff competence jointly relate to accident prevention in Nigerian seaports, providing context-specific insights for improving maritime safety management. The following theories were relevant to this study because each provides a distinct but complementary lens for understanding how marine navigational systems and safety standards interact to produce navigational outcomes in Nigerian seaports. Human Factors Theory highlights that safety is shaped by human capabilities, limitations, behaviours, and organisational conditions including perception, communication, decision- making, fatigue, and training. In port navigation, many incidents stem not only from equipment faults but from misinterpretation of information, poor lookout, procedural lapses, or latent organisational weaknesses (Osadume, 2020). This theory therefore underpins the study's focus on staff competence, explaining how operator skills, training, and human performance influence accident prevention, emergency response readiness, vessel- movement safety, and compliance with safety standards. Systems Theory frames a seaport as an interconnected system of technical, human, procedural, and institutional subsystems whose interactions determine overall safety performance. Functional components (radar, AIS, GPS/ECDIS, VTS, aids to navigation, pilotage, maintenance units, and regulators) must operate coherently; isolated improvements such as installing radar without trained operators or maintaining buoys without reliable communication may not reduce accident risk. Systems Theory thus justifies the study's integrated examination of equipment availability, system functionality, maintenance, and personnel competence as interdependent determinants of safety.

The Technology Acceptance Model (TAM) was relevant because the study investigates uptake and use of digital navigational tools (GPS, ECDIS, AIS). TAM explains that perceived usefulness and perceived ease of use drive technology adoption (Osadume, 2020); hence, the mere presence of technology does not guarantee safety benefits unless users accept and properly employ it. Applying TAM helps interpret findings on under- use, misuse, or resistance to electronic charting and positioning systems among pilots, bridge teams, and VTS operators.VAccident Causation Theory (including Heinrich's sequence and Reason's Swiss- Cheese model) provided the causal framework for analysing how accidents arise from multiple, interacting failures across layers of defence technical, human, organisational, and environmental. This theory supports the study's multi- variable approach to identifying weak barriers (equipment gaps, procedural failures, maintenance lapses, and human errors) that permit groundings, collisions, and other marine casualties. High Reliability Organisation (HRO) Theory offers a prescriptive perspective on how hazardous organisations sustain very low accident rates through continual vigilance, preoccupation with failure, resilience, and respect for expertise (Osadume, 2020). Applied to Nigerian ports, HRO principles inform recommendations for maintenance regimes, continuous training, operational sensitivity, and robust monitoring to ensure navigational equipment, radar/communication systems, GPS/ECDIS use, and staff competence collectively uphold high safety standards and reduce ground- collision incidence.

Materials and Methods

This study adopted a descriptive survey design to capture first- hand perspectives from stakeholders directly or indirectly involved in marine navigation, vessel movement, port control, safety management, and the use of navigational equipment at the Ports. The descriptive survey approach is appropriate because it permits systematic collection of cross- sectional data from a defined respondent population (pilots, VTS operators, port control staff, terminal managers, and maintenance personnel), enabling measurement and explanation of relationships among navigational system variables and safety standards. By using structured instruments, the design supports reliable description of current practices, equipment status, human competence, and compliance behaviours, while also providing the empirical basis needed to test the hypotheses to establish the impact of independent variables (equipment availability, radar/communication functionality, GPS/ECDIS use, aids- to- navigation maintenance, staff competence) on safety outcomes. The study is quantitative, relying on a structured questionnaire and statistical analysis to test the stated hypotheses and quantify effects on outcomes such as accident prevention and regulatory compliance. Limiting the geographic scope to Apapa Port Complex is justified because it is Nigeria's largest, busiest seaport and presents a concentrated, high- traffic environment where navigational-system performance and human factors critically influence safety. Apapa port diverse facilities and intensive pilotage, berthing, and cargo operations provide a robust case setting for assessing how shore- based and shipboard systems interact under operational stress. Focusing on this complex therefore enhances internal validity for the study objectives while producing findings of direct relevance to policy and operational improvements in similar high- density Nigerian port environments. The study population comprises 360 personnel and stakeholders engaged in marine navigation, port operations, vessel-traffic management, safety regulation, and navigational support services at Apapa Port Complex. Key respondent categories include marine pilots, port control officers, VTS operators, safety officers, operations and terminal staff, maintenance/engineering personnel, ship officers, and Nigerian Ports Authority staff; groups selected because they possess direct operational knowledge of navigational equipment availability, radar and communication functionality, GPS/ECDIS use, maintenance of aids to navigation, staff competence, and safety outcomes. Purposive sampling ensures respondents have relevant expertise, while stratification by role (port control, pilots, safety, operations, maintenance) guarantees representation across critical functional groups. Apapa was chosen through convenience for access and relevance; within the complex the researcher administered roughly 40 questionnaires per stakeholder category to achieve balanced subgroup coverage and improve the study internal validity. Data collection combines primary and secondary sources. Primary data was gathered via a researcher- administered structured questionnaire, both on paper and electronically (Google Forms) in Apapa Port Complex. The instrument is divided into Section A (demographics: gender, age, education, department, rank, years of experience) and Section B (measures of independent variables: navigational equipment availability, radar/communication functionality, GPS/ECDIS use, navigational-aid maintenance, staff competence; and dependent variables: accident prevention, and compliance with safety regulations). Responses were in a five-point Likert scale (5 = Strongly Agree to 1 = Strongly Disagree). Secondary data was drawn from textbooks, peer-reviewed articles, port safety reports, and relevant grey literature to contextualise findings and inform instrument design. Participation was voluntary, confidential, and preceded by a clear explanation of objectives; completed questionnaires were collected immediately where possible or retrieved at agreed times to maximise response rate and data completeness. Data from the administered questionnaires were coded, entered, cleaned, and analysed using SPSS version 27. The analysis combined descriptive and inferential techniques. Descriptive statistics (frequencies, percentages, means, and standard deviations) was use to summarise respondents' demographics and their item-level responses, providing an empirical profile of navigational-equipment availability, radar/communication functionality, GPS/ECDIS usage, maintenance practices, and staff competence. Graphs and cross-tabulations were used where appropriate to highlight patterns and subgroup differences across respondent categories (pilots, VTS operators, port control, maintenance, etc.). Inferential analysis was adopted to test the study hypotheses and quantify the influence of the independent variables on safety outcomes. The research examined the simultaneous effect of multiple predictors on each outcome, multiple linear regression was the principal modelling approach. The general model specification is:

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \varepsilon$$

where Y denotes a dependent safety outcome (Accident Prevention, "*ACIDPRE*"; Compliance with Port Safety Regulations, "*COMPOREG*"); X_1 = availability of navigational equipment, *"AVANAEQ"*; X_2 = functionality of radar and communication systems, *"FURACOSYS"*; X_3 = use of GPS and electronic chart systems, *"GPSECSYS"*; X_4 = maintenance of navigational aids *"MAINAVIG"*; X_5 = staff competence *"STAFCOMPE"*; β_0 is the intercept; β_1–β_5 are coefficients to be estimated; and ε is the error term. Separate regression models were fitted for each dependent variable:

Model 1 (H_{01}: Accident Prevention, "*ACIDPRE*"):

$$ACIDPRE = \beta_a + \beta_{1,1}AVANAEQ + \beta_{1,2}FURACOSYS + \beta_{1,3}GPSECSYS + \beta_{1,4}MAINAVIG + \beta_{1,5}STAFCOMPE + \varepsilon$$

Model 2 (H_{02}: Compliance with Port Safety Regulations, "*COMPOREG*"):

$$COMPOREG = \beta_b + \beta_{2,1}AVANAEQ + \beta_{2,2}FURACOSYS + \beta_{2,3}GPSECSYS + \beta_{2,4}MAINAVIG + \beta_{2,5}STAFCOMPE + \varepsilon$$

All hypotheses were tested at the 5% significance level ($\alpha = 0.05$); the decision rule is to reject the null hypothesis when the p-value < 0.05. Effect sizes (standardised coefficients), R-squared, adjusted R-squared, and confidence intervals were reported to communicate the statistical significance of findings.

Results and Discussion of Findings

Figure 4.1 illustrates respondents' gender distribution: 59.7% male and 40.3% female. Men therefore make up the majority of the sample, indicating a male-skewed respondent profile; however, the substantial female share ensures that women's perspectives are meaningfully represented in the analysis.

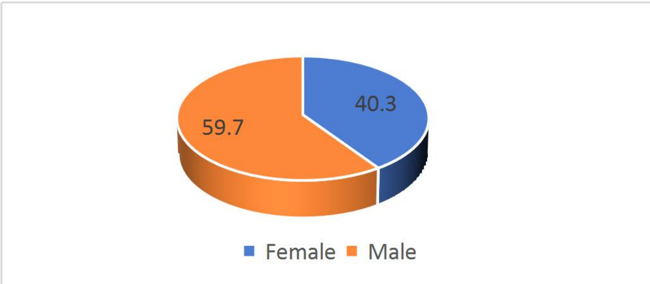

Figure 4.1: Gender of the respondents
Sources: Field survey, (2026)

Figure 4.2 shows respondents' age distribution. The largest share is 25-34 years (40.3%), followed by 35-44 years (26.2%) and 45-54 years (23.1%), indicating that most participants are in their prime working years. Respondents over 55 years make up 7.9%, while those under 25 are 2.4%. This pattern reflects a workforce concentrated in early- to mid-career stages, with limited entry-level and a smaller older cohort, consistent with operational staffing profiles in maritime and port settings.

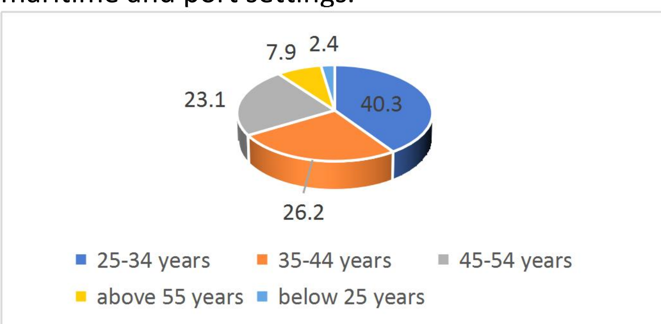

Figure 4.2: Age of the respondents
Sources: Field survey, (2026)

Figure 4.3 shows respondents' educational attainment. The largest group holds a Bachelor's degree or Higher National Diploma (37.2%), followed by NCE/ND holders (29.0%). Postgraduate certificate holders account for 17.6%, while WAEC/SSCE qualifications are the smallest group at 16.2%. therefore, most respondents have tertiary education, indicating a workforce with solid academic and professional preparation for managing port operations and navigational systems.

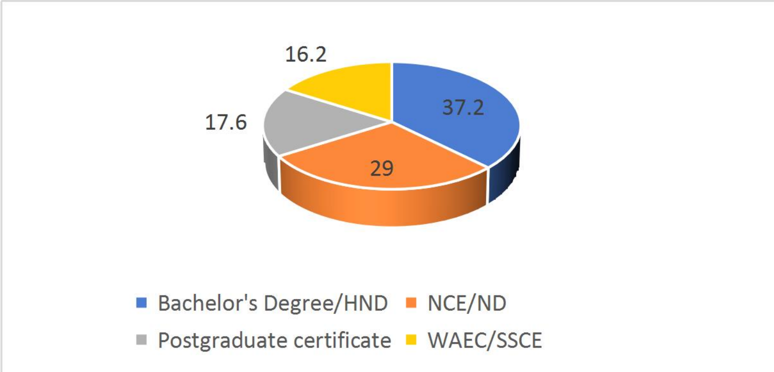

Figure 4.3: Educational distribution of the respondents
Sources: Field Survey, (2026)

Table 4.1 summarises respondents' departmental distribution across port functions. The Operations Department is largest (17.9%), reflecting its central role in coordinating vessel movements and overall port activity. Marine/Harbour (16.9%) and Engineering/Maintenance (15.5%) follow, underscoring their importance for navigational-equipment functionality and infrastructure upkeep. Port Control/Vessel Traffic Unit contributes 14.8%, highlighting its role in radar monitoring, communications, and traffic management, while Safety accounts for 13.5%, indicating an institutional focus on regulatory compliance and accident prevention. Pilotage (10.9%) and Shipping/Terminal Operations (10.5%) provide smaller but essential representation given their direct involvement in manoeuvring and cargo handling.

Table 4.1: Respondents' distribution of department/area of operation

S/N	Measurement criterion	Frequency	Percentage
1	Marine/harbor	49	16.9
2	Port control/vessel traffic unit	43	14.8
3	Safety Department	39	13.5
4	Engineering/Maintenance Department	45	15.5
5	Operations Department	52	17.9
6	Shipping/Terminal Operations	30	10.5
7	Pilotage	32	10.9
	Total	290	100.0

Sources: Field Survey (2026)

Analysis of the influence of navigational aid systems and safety standards on maritime accident prevention

Table 4.2 summarises respondents' perceptions of how navigational aid systems and safety standards influence maritime accident prevention at Apapa Port Complex. Using a decision threshold of 2.50, every item scored above the benchmark, indicating broad agreement that navigational aids and related safety measures materially reduce accident risk. The highest-rated item "Navigational equipment helps prevent marine accidents" (Mean = 3.24, SD = 1.281), signals a strong belief that the availability and use of core equipment are central to safe vessel operations. Equally notable are the mean scores for "Radar and communication systems help reduce accident risks," "GPS and electronic chart systems help prevent navigational errors," and "Regular maintenance of navigational aids contributes to accident prevention" (each Mean = 3.13, SDs = 1.277, 1.251, and 1.251 respectively), which reflect clear recognition that reliable surveillance/communication, accurate positioning/charting, and proactive maintenance are critical components of navigational safety. Respondents also affirmed the human dimension, with "Competent staff is important for preventing vessel accidents" recording a mean of 3.10 (SD = 1.271), showing that personnel competence is considered essential even if it scored slightly lower than the technical items. The overall average mean across the five measures is approximately 3.15, reinforcing a consistent, positive assessment that equipment availability, system functionality, technology use, maintenance practices, and staff competence collectively contribute to accident prevention.

These findings validate the study's multi- factor framework and suggest that safety interventions at Apapa should address both technical systems and human capabilities to achieve meaningful reductions in grounding, collisions, and related port incidents.

Table 4.2: Influence of navigational aid systems and safety stands on maritime accident prevention

S/N	Items measured	N-Statistics	Mean	Std dev.
1	Navigational equipment helps prevent marine accidents	290	3.24	1.281
2	Radar and communication systems help reduce accident risks	290	3.13	1.277
3	GPS and electronic chart systems help prevent navigational errors	290	3.13	1.251
4	Regular maintenance of navigational aids contributes to accident prevention.	290	3.13	1.251
5	Competent staff are important for preventing vessel accidents	290	3.10	1.271
	Valid N (listwise)	290		

Sources: Field Survey (2026)

Analysis of the influence of Navigational aid systems and safety standards on Compliance with Port Safety Regulations

Table 4.3 reports respondents' perceptions of how navigational aid systems and safety standards influence compliance with port safety regulations at Apapa Port Complex. Using a decision benchmark of 2.50, all items exceeded the threshold, indicating that respondents view navigational systems as supportive of regulatory adherence. The highest- rated item was "Radar and communication systems improve compliance with vessel movement procedures" (Mean = 3.16, SD = 1.208), reflecting a strong belief that reliable surveillance and communications are central to ensuring vessel operators and port personnel follow established procedures. "Navigational equipment availability" also scored highly (Mean = 3.07, SD = 1.271), signalling that having adequate, functional equipment enables better conformity with safety rules. Respondents similarly rated human and maintenance factors as important for compliance:

"Staff competence improves adherence to port safety regulations" (Mean = 3.06, SD = 1.264), while "GPS and electronic chart systems help personnel comply with approved routes and procedures" and "Maintenance of navigational aids supports compliance" both recorded means of 3.05 (SDs = 1.280 and 1.263).

Collectively, the cluster mean (≈ 3.08) demonstrates consistent agreement that technical systems, upkeep of aids, and competent personnel jointly promote regulatory compliance and safer operational practices at Apapa Port Complex.

Table 4.3: influence of Navigational aid systems and safety standards on Compliance with Port Safety Regulations

S/N	Item measured	N-Statistic	Mean	Std dev.
1	Navigational equipment availability supports compliance with port safety regulations.	290	3.07	1.271
2	radar and communication systems improve compliance with vessel movement procedures.	290	3.16	1.208
3	GPS and electronic chart systems help personnel comply with approved navigation routes and safety procedures	290	3.05	1.280
4	Maintenance of navigational aids supports compliance with maritime safety standards.	290	3.05	1.263
5	Staff competence improves adherence to port safety regulations.	290	3.06	1.264
	Valid N (listwise)	290		

Sources: Field Survey (2026)

***H_{01}:** There is no significant influence of the availability of navigational equipment, functionality of radar and communication systems, use of GPS and electronic chart systems, maintenance of navigational aids, and staff competence on accident prevention in Apapa Port Complex.*

Table 4.7: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.864[a]	.746496	.717	.45238

a. Predictors: (Constant), *AVANAEQ, FURACOSYS, GPSECSYS, MAINAVIG, STAFCOMPE*

Sources: Field Survey (2026)

Table 4.7 shows that the model explaining accident prevention (ACIDPRE) using the five predictors; availability of navigational equipment (AVANAEQ), functionality of radar and communication systems (FURACOSYS), use of GPS and electronic chart systems (GPSECSYS), maintenance of navigational aids (MAINAVIG), and staff competence (STAFCOMPE), has a very strong overall fit, with a multiple correlation coefficient R=0.864. VThe R Square value of 0.746 indicates that approximately 74.6% of the variance in accident prevention is explained jointly by these navigational system variables, while the Adjusted R Square of 0.717 (which corrects for the number of predictors and sample size) confirms that the model remains robust and not overly inflated by multiple predictors. This infers that navigational equipment availability, system functionality, technology use, maintenance, and staff competence collectively provide a strong statistical explanation of accident prevention outcomes at the port.

Table 4.8: ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	8.862	5	1.772	8.660	.000[b]
	Residual	58.121	284	.205		
	Total	66.983	289			

a. Predictors: (Constant), *AVANAEQ, FURACOSYS, GPSECSYS, MAINAVIG, STAFCOMPE*
b. Dependent Variable: *ACIDPRE*

Table 4.8 indicates that the regresion model relating availability of navigational equipment (AVANAEQ), functionality of radar and communication systems (FURACOSYS), use of GPS and electronic chart systems (GPSECSYS), maintenance of navigational aids (MAINAVIG), and staff competence (STAFCOMPE) to accident prevention (ACIDPRE) is statistically significant. The regression sum of squares (8.862) relative to the residual sum of squares (58.121) shows that a meaningful portion of the variation in accident prevention is explained by the predictors, and the F-statistic of 8.660 with a corresponding significance value of 0.000 ($p < 0.05$) confirms that the model is significant. This implies that, the navigational system variables have a significant effect on accident prevention and that the null hypothesis is rejected.

Table 4.9: Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	1.981	.203		9.750	.000
	AVANAEQ	.025	.059	.030	.424	.005
	FURACOSYS	.030	.063	.038	.480	.002
	GPSECSYS	.095	.040	.151	2.361	.019
	MAINAVIG	.190	.046	.271	4.109	.000
	STAFCOMPE	.159	.039	.264	4.052	.000

a. Predictors: (Constant), *AVANAEQ, FURACOSYS, GPSECSYS, MAINAVIG, STAFCOMPE*
b. Dependent Variable: *ACIDPRE*

Table 4.9 shows that all five predictors have positive relationships with accident prevention (ACIDPRE), meaning higher levels of each variable are associated with improved accident-prevention outcomes. The unstandardized coefficients indicate that, holding other factors constant, a one-unit increase in GPS/electronic chart use (GPSECSYS) increases accident prevention by 0.095 units ($p = 0.019$), maintenance of navigational aids (MAINAVIG) by 0.190 units ($p = 0.000$), and staff competence (STAFCOMPE) by 0.159 units ($p = 0.000$), with MAINAVIG ($\beta = 0.271$) and STAFCOMPE ($\beta = 0.264$) emerging as the strongest standardized predictors. Availability of navigational equipment (AVANAEQ) and functionality of radar/communication systems (FURACOSYS) have smaller standardized effects ($\beta = 0.030$ and β

= 0.038) but still show statistically significant contributions at the reported p-values, suggesting that while equipment presence and system functionality matter, their impact on accident prevention is mediated or amplified when combined with effective maintenance, active use of GPS/ECDIS, and competent personnel.

***H_{02}*: *There is no significant effect of the availability of navigational equipment, functionality of radar and communication systems, use of GPS and electronic chart systems, maintenance of navigational aids, and staff competence on compliance with port safety regulations in Apapa Port Complex*.

Table 4.10: Model Summary[b]

Model	R	R Square	Adjusted R-Square	Std. Error of the Estimate
1	.706[a]	498436	.3480	1.10733

a. Predictors: (Constant), *AVANAEQ, FURACOSYS, GPSECSYS, MAINAVIG, STAFCOMPE*

Table 4.10 shows that the model explaining compliance with port safety regulations using the five predictors; availability of navigational equipment (AVANAEQ), functionality of radar and communication systems (FURACOSYS), use of GPS/electronic chart systems (GPSECSYS), maintenance of navigational aids (MAINAVIG), and staff competence (STAFCOMPE), has a moderate overall fit, with a multiple correlation coefficient R=0.706. The R Square value of approximately 0.498 indicates that about 49.8% of the variance in the dependent variable is jointly explained by these navigational-system variables, while the adjusted R Square of about 0.348 suggests that, after adjusting for the number of predictors and sample size, roughly 34.8% of the variance remains robustly accounted for by the model.

Table 4.11: ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	28.733	5	5.747	4.687	.000[b]
	Residual	348.236	284	1.226		
	Total	376.969	289			

a. Predictors: (Constant), *AVANAEQ, FURACOSYS, GPSECSYS, MAINAVIG, STAFCOMPE*
b. Dependent Variable: *COMPOREG*

Table 4.11 shows that the regression model connecting the five predictors; availability of navigational equipment (AVANAEQ), functionality of radar and communication systems (FURACOSYS), use of GPS/electronic chart systems (GPSECSYS), maintenance of navigational aids (MAINAVIG), and staff competence (STAFCOMPE) to compliance with port safety regulations (COMPOREG) is statistically significant. The regression sum of squares (28.733) compared with the residual sum of squares (348.236) indicates that a non-trivial portion of the total variation in compliance is explained by the model, and the F-statistic of 4.687 with a corresponding p- value of 0.000 ($p < 0.05$) confirms that the set of predictors, taken together, provides a significantly better fit. In other words, at least one of the navigational-system variables contributes significantly to explaining differences in compliance with port safety regulations, so the null hypothesis that they have no joint effect on COMPOREG is rejected.

Table 4.12: Coefficient

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	T	Sig.
1	(Constant)	3.944	.497		7.928	.000
	AVANAEQ	.277	.145	.141	1.909	.017
	FURACOSYS	.073	.155	.039	.472	.037
	GPSECSYS	.234	.099	.156	2.365	.019
	MAINAVIG	.250	.113	.150	2.206	.028
	STAFCOMPE	.097	.096	.068	1.012	.012

a. Predictors: (Constant), *AVANAEQ, FURACOSYS, GPSECSYS, MAINAVIG, STAFCOMPE*
b. Dependent Variable: *COMPOREG*

Table 4.12 indicates that all five predictors have positive effect on compliance with port safety regulations (COMPOREG), meaning that higher levels of each factor are associated with better regulatory adherence. The unstandardized coefficients show that, holding other variables constant, a one-unit increase in the availability of navigational equipment (AVANAEQ) raises compliance by 0.277 units ($t = 1.909$, $p = 0.017$), while GPS/electronic chart use (GPSECSYS) and maintenance of navigational aids (MAINAVIG) increase compliance by 0.234 ($t = 2.365$, $p = 0.019$) and 0.250 units ($t = 2.206$, $p = 0.028$), respectively, making these three variables the strongest contributors in both raw and standardized terms ($\beta = 0.141–0.156$). Staff competence (STAFCOMPE) has a smaller but still positive and statistically significant coefficient ($B = 0.097$, $\beta = 0.068$, $p = 0.012$), suggesting that more competent personnel modestly enhance compliance levels, while functionality of radar/communication systems (FURACOSYS) shows a weaker but still significant effect ($B = 0.073$, $\beta = 0.039$, $p = 0.037$). Generally, the pattern of coefficients implies that improving equipment availability, ensuring active use of GPS/ECDIS, maintaining aids to navigation, and strengthening staff skills all contribute meaningfully to higher compliance with port safety regulations, with the constant term (3.944, $p < 0.001$) indicating a relatively high baseline level of compliance even before accounting for these predictors.

Discussion of Findings

The results provide strong empirical evidence to reject H_{01} and to conclude that marine navigational systems and staff competence have a statistically significant and practically important influence on accident prevention in Apapa Port Complex. The model fit indices show that the combined effect of the five predictors availability of navigational equipment, functionality of radar and communication systems, use of GPS/electronic chart systems, maintenance of navigational aids, and staff competence explains about 74.6% of the variance in accident prevention, with an adjusted R^2 of 0.717 indicating a robust model that is not simply an artefact of overfitting. This high explanatory power is consistent with wider evidence that modern navigation systems, when effectively deployed, substantially reduce collisions, groundings, and other incidents in high- traffic waterways by improving positional accuracy, situational awareness, and decision support for mariners and port operators. The ANOVA result ($F = 8.660$, $p < 0.001$) confirms that the regression model as a whole is highly significant, meaning the set of navigational-system variables jointly provides a significantly better prediction of accident prevention than a model with no predictors, in line with studies showing that electronic navigational charts, real-time oceanographic information, and integrated electronic systems have a measurable, statistically significant impact on reducing allisions, collisions, and groundings in port areas. The coefficient estimates further clarify the relative importance of each factor. All five predictors have positive coefficients, indicating that improvements in each variable are associated with higher levels of accident prevention.

However, maintenance of navigational aids (MAINAVIG) and staff competence (STAFCOMPE) emerge as the most influential predictors in standardized terms ($\beta = 0.271$ and $\beta = 0.264$, respectively), with highly significant p-values ($p < 0.001$). This suggests that well-maintained buoys, beacons, and other aids, combined with competent, well-trained personnel, are the strongest drivers of safer vessel operations a finding that aligns with international research emphasising the critical role of reliable aids to navigation and human factors in preventing marine casualties. The use of GPS and electronic chart systems (GPSECSYS) also has a significant positive effect ($\beta = 0.151$, $p = 0.019$), reinforcing evidence that electronic navigational charts and satellite-based positioning systems substantially reduce accident rates when integrated into bridge and port-control practices. Although the availability of navigational equipment and the functionality of radar/communication systems show smaller standardized coefficients, their statistically significant contributions indicate that simply having equipment present and operational remains a necessary foundation upon which maintenance, active use, and human competence build. Taken together, these results contradict the null hypothesis: they demonstrate that navigational equipment availability, radar/communication functionality, GPS/ECDIS use, maintenance of aids, and staff competence exert a significant, positive influence on accident prevention in Apapa Port Complex, echoing broader findings that modern navigation systems and trained operators are central to enhancing maritime safety in port environments. The evidence from Tables 4.10, 4.11, and 4.12 clearly contradicts H_{02} and demonstrates that marine navigational system variables exert a significant effect on compliance with port safety regulations in Apapa Port Complex. The model summary ($R = 0.706$; $R^2 \approx 0.498$; adjusted $R^2 \approx 0.348$) shows that, even after adjusting for the number of predictors, roughly one-third of the variance in compliance is robustly explained by the combined influence of equipment availability, system functionality, technology use, maintenance, and staff competence an effect size that is non-trivial for a behavioural/operational outcome. The ANOVA result ($F = 4.687$, $p = 0.000$) confirms that the regression model is statistically significant

overall, meaning that the set of predictors as a group provides a significantly better explanation of compliance with port safety regulations than a model with no predictors. In practical terms, this implies that navigational infrastructure and human factors jointly shape how well port users conform to established safety rules and procedures, consistent with broader empirical findings that link the quality and management of aids to navigation, electronic systems, and human performance to maritime safety and regulatory adherence. The coefficient estimates in Table 4.12 further show that all five predictors have positive and statistically significant effects on compliance, reinforcing the decision to reject H_{02}. Availability of navigational equipment ($B = 0.277$, $p = 0.017$) indicates that better-provisioned navigational infrastructure is associated with higher compliance levels, likely because properly equipped environments make it easier for operators to follow prescribed procedures. GPS/electronic chart use ($B = 0.234$, $p = 0.019$) and maintenance of navigational aids ($B = 0.250$, $p = 0.028$)

emerge as particularly important, suggesting that active utilisation of digital navigation tools and reliable, well-maintained buoys and beacons materially support adherence to approved routes, separation schemes, and other regulatory requirements. Staff competence (B = 0.097, p = 0.012) and functional radar/communication systems (B = 0.073, p = 0.037), though smaller in magnitude, still contribute significantly, reflecting the role of skilled personnel and effective surveillance/communication in implementing and enforcing safety regulations in day-to-day operations. Taken together, these results show that H_{02} cannot be sustained: compliance with port safety regulations in Apapa Port Complex is significantly influenced by the availability and functional use of navigational equipment, the maintenance of navigational aids, and the competence of personnel, implying that policy interventions aimed at upgrading equipment, improving maintenance regimes, and strengthening training and competence frameworks are likely to yield measurable improvements in regulatory compliance.

Conclusion

This study concludes that marine navigational infrastructure and human competence are decisive factors in improving safety outcomes at Nigerian seaports, particularly at Apapa Port Complex. The findings show that the availability of navigational equipment, the functionality of radar and communication systems, the use of GPS and electronic chart systems, the maintenance of navigational aids, and staff competence jointly have a strong and significant influence on accident prevention and compliance with port safety regulations. The results further demonstrate that maintenance of navigational aids and staff competence are the strongest drivers of accident prevention, while equipment availability, GPS/electronic chart use, and aid maintenance are especially important for regulatory compliance. The study also establishes that port safety cannot be achieved through equipment provision alone. Rather, effective safety performance depends on the combined interaction of functional technology, regular maintenance, and competent personnel who can interpret and apply navigational information correctly.

Therefore, the evidence rejects both null hypotheses and confirms that marine navigational systems and staff competence play a statistically significant role in reducing accidents and strengthening adherence to safety standards in Nigerian seaports.

Recommendations

Port authorities and maritime regulators should provide and upgrade navigational equipment, communication systems, GPS, and electronic chart systems across Nigerian seaports to improve safe vessel movement and accident prevention. A strict preventive maintenance and staff development programme should be implemented to ensure that aids to navigation remain functional and that pilots, VTS operators, and port control personnel are regularly trained and certified. The Nigerian Ports Authority and related agencies should strengthen monitoring and enforcement of port safety regulations, with equal attention to technology, maintenance, and human competence in all seaports.

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