The Nigerian Institution of Marine Engineers and Naval Architects

(NIMENA)

A Division of the Nigerian Society of Engineers

(NSE)

12th Annual National Conference

NIBECON 2023 TECHNICAL PAPERS

Theme: Harnessing the Nigerian Blue

Economy (Creating our Future through the Ocean-based Resources)

Held at Heliconia Hotel, Eastern By-Pass, Port Harcourt, Rivers State, Nigeria

This 8th December, 2023

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i. Paper I – Assessing the Roles of Maritime Engineering in Sustainable Blue Economy Development in Nigeria

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Theme: Harnessing the Nigerian Blue

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Paper I:
Assessing the Roles of Maritime Engineering in Sustainable Blue Economy Development in Nigeria

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Abstract

The blue economy presents significant opportunities for sustainable growth in Nigeria given the country's extensive maritime resources. However, harnessing the full potential of the blue economy requires building local capacity in key areas like maritime engineering. This paper examines the status of maritime engineering in Nigeria and assesses priority areas to develop capabilities to grow the blue economy sector. After analyzing gaps in skills, infrastructure, technology and policies, the study proposes recommendations focused on investments in technical training, research and development, adoption of emerging technologies, infrastructure upgrades and strategic partnerships. Finally, it concludes that developing homegrown expertise in maritime engineering is fundamental to Nigeria's quest for responsible and sustainable blue economy.

Key words: Maritime Engineering; Blue Economy; Maritime Development; Ocean resources

1. Introduction

The "blue economy" concept recognizes the ocean's vast potential for sustainable economic development through diverse activities like offshore energy production, seabed mining, marine biotechnology, tourism, transportation, and fisheries (Silver et al, 2015). With a coastline spanning over 850 km and maritime area encompassing over 200 nautical miles, Nigeria is endowed with substantial ocean resources that can drive blue economic growth. The country has prioritized developing its blue economy as part of long-term development plans to harness the potential of its marine and maritime sectors, as indicated in Figure 1 (Chidi, 2022).

Figure 1: Oil and gas platforms in the Gulf of Guinea

Engineering capabilities play a pivotal role in unlocking the promise of ocean-based economies by enabling utilization of marine resources and development of offshore infrastructure and technologies. Maritime engineering, which focuses on the ocean environment, is particularly critical for blue economy activities ranging from offshore oil and gas to marine renewable energy and deep-sea mining (Bazari & Longva, 2022). As Nigeria aims to transition towards a sustainable blue economy model, building local expertise in maritime engineering should be an urgent strategic priority.

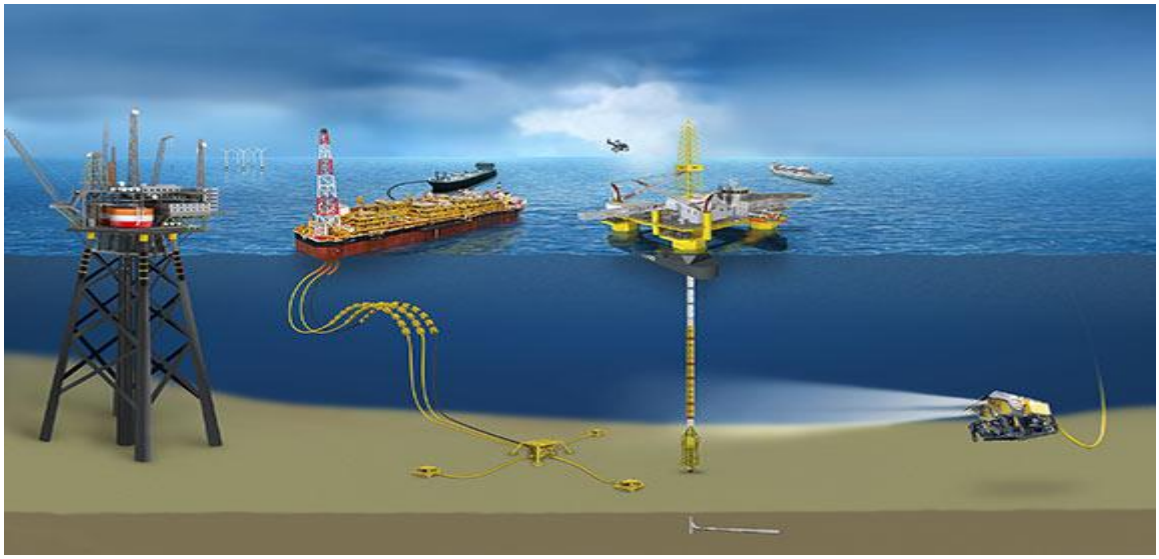

Figure 2: Subsea development of Nigeria offshore oil and gas

1.1 Objective and Scope

This paper investigates Nigeria's maritime engineering landscape and examines priority areas that require strengthening to support diverse blue economy industries. The analysis focuses on identifying critical gaps in skills, infrastructure, technologies and national policies related to maritime engineering. Key sectors that require engineering innovations to foster productivity, efficiency, safety and sustainability are highlighted. Finally, recommendations are proposed for developing a vibrant maritime engineering ecosystem in Nigeria through education, research, investments, technological capabilities and enabling policies.

1.2 Scope of Research

The paper presents an overview of maritime engineering as a field. It considers prospects of expanding Nigeria's maritime engineering capacity citing the country's blue growth potential. Priority engineering focus areas for different blue economy sectors are critically analysed. At the end, it proposes policy recommendations to build maritime engineering expertise and innovation in Nigeria against all the prevalent debilitating factors.

2. An Overview of Maritime Engineering

Maritime engineering is a field that deals with the design, construction, installation and operation of technological systems and infrastructure in the marine environment (Sharma, 2022). It encompasses various aspects like ocean structures, maritime vehicles and transportation, resource extraction, coastal and offshore construction, marine environmental management, and ocean energy systems. Maritime engineering integrates knowledge across disciplines like naval architecture, nautical science, ocean engineering, marine engineering, offshore and subsea engineering and marine surveying. It requires an understanding of the mechanical, electronic, electrical, and civil engineering aspects tailored to maritime transport, infrastructure, and its allied activities. It also intersects with marine science covering oceanography, marine biology, and environmental studies to ensure minimal environmental impacts.

2.1 Major Areas of Interest

Some major focus areas of maritime engineering include:

(i) **Port and Harbour Infrastructure**: Maritime engineers handle activities like planning, design and construction of docks, wharfs, jetties, terminals, and harbours. This also includes dredging to create and maintain navigational channels.

(ii) **Offshore Platforms and Structures**: Designing, building, and installing offshore drilling rigs and platforms for oil and gas, wind turbines and ocean energy systems. Ensuring structural integrity under challenging ocean conditions.

(iii) **Marine Vehicles and Transportation**: Ship and boat design including hull forms, powering, control systems, stability, and manoeuvrability. Modifying and maintaining vessels. Developing marine propulsion technology.

(iv) **Ocean Resource Extraction**: Designing equipment for activities like offshore oil and gas production, fishing, seabed mining, marine biotechnology, and desalination.

(v) **Coastal Engineering**: Beach nourishment, erosion control, designing ports, harbours, jetties, and other coastal infrastructure. Environmental impact assessment.

(vi) **Underwater Technology**: Technologies for underwater exploration, deep-sea mining, underwater detection, and communication systems. Remotely operated underwater vehicles.

(vii) **Marine Pollution Control**: Developing solutions for prevention, mitigation, and control of marine pollution like oil spills, marine debris, industrial effluence, etc. The establishment of proper waste management systems.

(viii) **Maritime Logistics, Operations, and Security**: Improving efficiency, safety and security of maritime operations and logistics using technology. This includes ships and ports safety and security.

2.2 Maritime Engineering Landscape in Nigeria

Nigeria has over 35 registered maritime engineering consulting firms and shipyards for ship repairs (NIMASA, 2022). Maritime education is offered at 8 major universities and polytechnics. Nigeria also has merchant navy institutes and training schools for seafaring careers. However, there remains a shortage of highly skilled maritime engineers and operators within the country while local shipbuilding and maintenance capabilities are limited. Most large marine vessels and platforms operating in Nigerian waters are imported with minimal local contents. The gaps in maritime engineering capacity act as a barrier for Nigeria in harnessing its blue economy potential which the next section examines.

3. Developing Maritime Engineering Capacity in Nigeria

Maritime engineering capacity enhancement requires both human capacity building and infrastructural development. It involves training and retraining of personnel in contemporary technologies, use of expert system, and their working relationships. Figure3 shows engineers on oil rig.

Figure 3: Maritime engineers at work on oil/gas rig

3.1 Nigeria's Blue Economy Potential

Nigeria's blue economy has significant room for growth across diverse sectors:

(i) Offshore oil and gas: Nigeria has around 200 offshore platforms accounting for 70% of total production, which is projected to rise further with more deepwater developments (Okonuju et al, 2019).

(ii) Shipping and ports: Nigeria has seaports in Lagos, Port Harcourt, Calabar and Delta states and these ports either need upgrades, maintenance and additional manpower to improve efficiency and capacity. Coastal shipping provides over 70% of freight cargo volumes (Mfon et al, 2018). However, Nigerian seaports are inefficient and ineffective because of high port costs, archaic clearing process, and lack of automation. These factors have made Nigerian Ports unattractive to importers who divert their cargoes to more efficient seaports in neighbouring countries. These goods are later smuggled through the country's porous borders, thereby making Nigeria lose several billions of naira in revenue yearly.

Figure 4: displays containers at Lagos seaport.

(iii) Fisheries and aquaculture: With waters containing over 200 fish species, Nigeria aims to increase its 2.2 million tons of fish production to 5 million tons by 2025 (Federal Ministry of Agriculture & Rural Development, 2022). Figure 5 presents both the inefficient local fishing technique and the efficient mechanised method.

(a) (b)

Figure 5: Fishing in the Gulf of Guinea: (a) Local fishing gear and (b) Motorised trawler

(iv) Shipbuilding and ship repair: Nigeria has a goal to reduce reliance on imported vessels by building in-country capacity for construction, maintenance and retrofitting of ships. What is lacking is the presence of a competitive repair yard.

Figure 6: Nigerian Navy Dockyard in Lagos

(v) Offshore renewable energy: Nigeria has set a target for renewable energy to reach 30% of its energy mix by 2030, with prospects for offshore wind and ocean energies (Federal Ministry of Power, 2022).

Figure 7: Nigerian wind energy project in the Gulf of Guinea

(vi) Hydrocarbon industry: In addition to offshore oil and gas, Nigeria has untapped potential for seabed and methane gas extraction. The hydrocarbon industry is yet to leverage on the opportunities maritime engineering provides to grow Nigeria's local economy.

(vii) Marine biotechnology: Nigeria's biodiverse ocean ecosystems are a rich source for pharmaceutical, biofuel and chemical development.

Figure 8: Offshore hydrocarbon refinery in the Gulf of Guinea

3.2 Maritime Engineering Challenges

However, Nigeria faces considerable hurdles in maritime engineering capability, infrastructure and enabling policies which have slowed blue economy progress. Some key challenges include:

(i) **Talent Gap**: Acute shortage of trained maritime engineers, naval architects, surveyors, captains, and technical specialists for both private sector and public agencies. Heavy reliance on expatriates.

(ii) **Weak Shipbuilding Industry**: Lack of local capacity for marine and offshore vessel construction, maintenance, conversion, and retrofitting.

(iii) **Port Infrastructure Deficit**: Nigerian ports suffer from aged facilities, productivity and efficiency issues, poor cargo handling capacity and frequent congestion.

(iv) **Technology Gap**: Most marine technologies and engineering systems used in sectors like offshore oil and gas, dredging, and Naval operations are imported. There are limited domestic manufacturing and R&D capabilities.

(v) **Policy and Regulation**: Outdated policies, excessive red tape and weak enforcement hamper development of new marine industries and adoption of modern engineering systems.

(vi) **Access to Financing**: Limited access to investment capital and high borrowing costs impede maritime infrastructure projects and adoption of advanced marine technologies.

(vii) **Maritime Safety**: None adherence to safety rules and failure of maritime administrations to enforce safety regulations.

(viii) **Security**: There are incessant attacks from sea pirates, terrorists, and armed robbers. Also, the sea routes are heavily silted, clogged, and non-navigable.

3.3 Benefits of Expanding Local Maritime Engineering Expertise

Developing Nigerian expertise in maritime engineering is crucial to address the gaps hindering the progress of the country's blue economy. Some key benefits include:

(i) **Efficient Utilization of Marine Resources**: Advanced engineering enhances productivity, safety, and cost-effectiveness of offshore oil/gas, fishing, ocean renewable energy, mining etc.

(ii) **Technology Indigenization and Self-reliance**: Localizing marine engineering, construction and maintenance reduces dependence on foreign firms and creates jobs.

(iii) **Sustainable Use of Ocean Resources**: Marine engineering innovations can ensure minimal impacts on fragile ocean ecosystems.

(iv) **Operational Resilience**: Indigenous engineering skills ensure optimal uptime, maintenance and performance of maritime infrastructure and assets.

(v) **Reduced Capital Flight**: Lower reliance on imported vessels and technologies improves balance of payments.

(vi) **National Security**: Capacity for marine defense technologies reduces risks for offshore oil, ports, and maritime activities.

(vii) **Competitiveness**: Strong engineering foundation positions Nigeria as an attractive location for global marine companies.

4. Essential Areas for Maritime Engineering Development

Based on the gaps and opportunities, here are some priority maritime engineering areas for Nigeria:

4.1 Port Infrastructure and Dredging

(i) Extending ports and building additional deep seaports to enhance cargo handling capacity.

(ii) Port engineering systems like piers, breakwaters, quay walls, lighthouses, terminal infrastructure.

(iii) Channel dredging and land reclamation technologies to create draught for larger vessels.

(iv) Automating port operations using robotics, internet of things, maritime cloud solutions.

4.2 Offshore Oil/Gas Platform and Drilling Engineering

(i) Designing fixed and floating offshore oil/gas platforms suited for Nigeria's coastal conditions.

(ii) Localizing fabrication and integration of topside production modules and jackets.

(iii) Advanced drilling equipment tailored for offshore deepwater reserves.

(iv) Subsea engineering systems, underwater equipment installations and control.

4.3 Marine Vessel Design, Construction and Maintenance

(i) Indigenous design skills for offshore support vessels, cargo ships, fishing boats, ferries, and navy vessels.

(ii) Infrastructure and systems for in-country vessel construction, maintenance, and retrofitting.

(iii) Dry-docking facilities for ship and rig repair, conversion and scraping.

(iv) Technology and infrastructure for vessel fuel conversion, emission control and automation.

4.4 Fishing and Aquaculture Technology

(i) Advanced offshore aquaculture systems, fish cages and hatcheries.

(ii) Fishing vessel, gear, and equipment innovations to boost efficiency and sustainability.

(iii) Onboard handling, processing, packaging, and cold storage technologies.

(iv) Fish finding and fish behaviour analysis systems.

4.5 Ocean Renewable Energy

(i) Evaluating feasibility and design of offshore wind, wave, and tidal energy systems.

(ii) Floating offshore wind turbine foundation engineering tailored for Nigeria's coast.

(iii) Power electronics, subsea cables, and offshore grid integration for ocean renewables.

(iv) Developing hybrid platforms integrating offshore wind, oil/gas, and ocean energy systems.

4.6 Marine Pollution Control and Biotechnology

(i) Modelling software, sensors, and aerial systems to monitor oil spills, wastes and pollution.

(ii) Engineering bioremediation solutions using microbes, biosurfactants, biopolymers etc.

(iii) Marine biotech R&D for pharmaceuticals, biofuels, industrial enzymes, and chemicals.

(iv) Engineering processing systems for marine biotechnology applications.

4.7 Ocean Mining and Seabed Mineral Extraction

(i) Technology for mapping, accessing, and extracting Nigeria's deep sea mineral reserves.

(ii) Vertical underwater mining shaft systems, seafloor crawlers, pumps and lifting systems.

(iii) Support vessels, platforms, and onshore infrastructure to transport and process seabed ores.

(iv) Environmental impact assessment and developing sustainable mining practices.

4.8 Coastal Protection and Port Infrastructure Resilience

(i) Solutions to mitigate rising sea levels, coastal erosion, floods, and storms.

(ii) Protecting coastal settlements, ports, and maritime infrastructure from climate risks.

(iii) Engineering climate resilient marine structures and buildings.

4.9 Maritime ICT, Automation and Digitalization

(i) Automated cargo handling systems, cranes, and robotics at ports and on vessels.

(ii) Maritime cloud platforms, sensors, IoT, big data analytics, AI, and digital twin simulations.

(iii) Remote monitoring, predictive maintenance, logistic optimization, using digitalization.

(iv) Electronic navigation, dynamic positioning, enhanced communications, and automation systems for vessels.

4.10 4.11 R&D, Manufacturing and Strategic Partnerships

(i) Joint R&D projects between industry, government agencies and universities.

(ii) Aerospace and defence partnerships to adapt maritime applications.

(iii) Partnerships with universities abroad to exchange maritime engineering knowledge.

(iv) Building local manufacturing capabilities through joint ventures.

(v) Collaboration platforms and clusters linking stakeholders.

4.11 Ocean Resource Mapping and Planning

(i) Advanced surveys and technologies like sonar, LIDAR, GIS, radars to map ocean topography, resources, habitats, and infrastructure.

(ii) Spatial data analysis using geospatial information systems (GIS) and geospatial marine cloud platforms.

(iii) Maritime spatial planning models balancing conservation, sustainability, and economic/industrial demands.

5. Recommendations for Strengthening Maritime Engineering in Nigeria

5.1 Increase Public and Private Investments

Substantially higher investments are vital for developing maritime infrastructure, education and R&D. Government funds should support universities, vocational institutes, and R&D centers focused on marine engineering. Tax breaks and low interest loans can incentivize private companies to invest in infrastructure, technologies and skills training. Diaspora remittance funds could also be utilized to advance sustainable blue economy.

5.2 Incentives for Adopting Advanced Marine Technologies

Providing tax breaks, subsidies, and preferential loans for adopting cutting-edge marine technologies related to construction vessels, port infrastructure, renewable energy, aquaculture,

biotech etc. can accelerate technology indigenization. Fiscal incentives for joint R&D between industry and academia should also be introduced.

5.3 Partnerships with Leading Maritime Firms

Strategic partnerships with leading international maritime companies can enable knowledge transfer to Nigerian firms through training programs, onsite assignments, and joint projects. Partnerships in areas like offshore platforms, marine biotech, ocean mining, marine surveying and port infrastructure development must be prioritized.

5.4 Technical and Vocational Education

(i) Scholarships for students to pursue maritime engineering and naval architecture degrees abroad.

(ii) Curriculum reforms at polytechnics and technical institutes to meet industry demands.

(iii) Workforce training programs in partnership with maritime companies.

(iv) Sponsoring student competitions for designing ships, ROVs, AUVs, and ocean technologies.

5.5 Building Multidisciplinary Ocean Research and Engineering Centres

Establishing state-of-the-art research centres at universities for translational research across ocean engineering, marine sciences, data analytics and environmental management. They can serve as hubs linking academia, industry and government.

5.6 Supporting Maritime Start-ups and Innovation Ecosystems

Providing business incubation, grants and mentorship to Nigerian startups working on maritime technologies through dedicated programs. Collaboration with international accelerators and innovation hubs should be facilitated. Access to risk capital needs to be improved substantially.

5.7 Localization of Marine Manufacturing Capabilities

Policy initiatives and joint ventures with foreign firms are required for phased indigenous manufacturing of vessels, port equipment, cranes, offshore platforms, and other marine technology components. This will build vital self-reliance.

5.8 Attracting Maritime Talent from Nigeria's Diaspora

Leveraging networks of prominent Nigerian engineers and technicians working with leading international maritime firms by providing incentives for them to return and contribute their expertise. Their global experience can catalyze capability development.

6. New Inventions by Our Local Maritime Engineers

6.1 Design, Development and Production of AirBoat

Inventors – Engr. Dr. Tamunodukobipi Daniel, Engr. Prof. (Comr.) E.A. Ogbonnaya, Engr. F. Keribo

Airboat is propelled by aerial propeller and steered by a pair of vertical aerial rudders which direct a stream of forced air towards starboard or portside as required for maneuvering. Both propeller and rudders are mounted in a protective cage to prevent damage resulting from flying objects or overhanging tree branches. Airboat carriage capacity depends on buoyancy, mission, and nature of route. Some airboats have buoyancy sufficient for carrying more than 10 passengers, and may be unsinkable because of built-in floaters. In the absence of floaters, a flooded airboat sinks very quickly (8-15seconds). On some, passengers are sheltered from the harsh environment using a fixed or retractable canopy. Airboat can readily climb in and out of water having a bank inclined as much as 45°. Typically, airboats do not have brakes and reverse motion. Stopping and reversing are dependent on the operator's maneuvering competence. Their characteristic Teflon-coated flat-bottom in conjunction with the absence of protrusions below the waterline enables them to safely glide over delicate vegetation, marauding animals, craggy river canals, grassland, and frozen lakes.

Figure 9: Airboat prototype

Source: (Tamunodukobipi et al, 2017)

6.2 The Real-Time Floating Surveillance Unit (RFSU)

Inventors – Engr. Azubuike John Chuku

The Real-time Floating Surveillance Unit (RFSU) concept consists of a floating structure that can be anchored in strategic locations in the gulf of Guinea and equipped with Radar and Auto Identification System in order to scan the surrounding area. The data recorded by the Radar and the AIS will be transmitted live, through a satellite antenna to a control station. The data from all the RFSUs when processed will be applied to keep a constant surveillance over the gulf. The power required for the operation of the Radar will be supplied by Solar panels, installed on the RFSU, through batteries to support the operation all the time (Chuku et al, 2017).

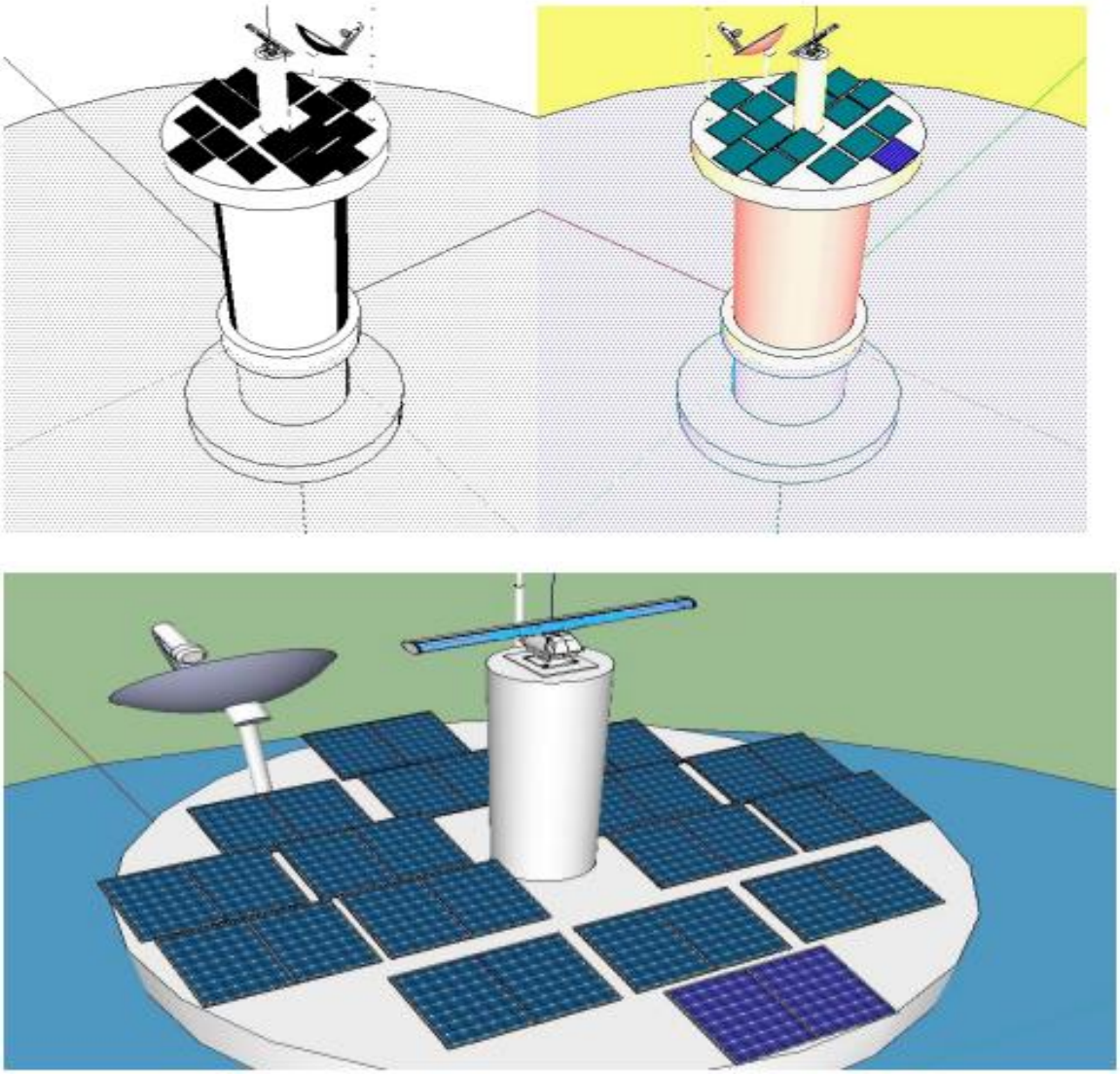

Figure 10: The RSFU and Equipment mounted on the top.

Source: (Chuku et al, 2017)

Conclusion

In conclusion, maritime engineering serves as a lynchpin for unlocking Nigeria's immense blue economy potential across sectors like offshore oil and gas, fisheries, transportation, and renewable energy. Developing local expertise and knowledge in this arena through targeted investments, training programs, research centers, strategic partnerships, infrastructure development and progressive policies is therefore of vital economic and strategic importance for the country's future.

Sustained commitment and collaboration between government, industry and academia is essential to build a vibrant maritime engineering ecosystem over the next decade. This can significantly advance Nigeria's journey towards becoming a globally competitive blue economy.

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Paper II:
Combating Marine Debris to Enhance Blue Economy in the Niger Delta

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Abstract
Marine debris poses a major threat to realizing the potential of the blue economy in the Niger Delta region of Nigeria. This study examined the sources, composition and impacts of plastic pollution along the Port Harcourt-Okrika waterfronts. A total of 20 marine debris types were collected and identified at the three selected stations along the Port Harcourt-Okrika waterfronts. These were Marine Base waterfront (Station 1); Okrika Mainland waterfront (Station 2); and Okrika Island waterfront (Station 3). Marine Base waterfront (Station 1) was the most affected by marine debris with 241.52 kg (44.31%) of the debris. This was followed by Station 3, Okrika Island waterfront, with 213.63 kg (39.19%) of the debris. While Station 2 had 89.90 kg (16.49%) of the marine debris. The types of debris found include plastic bottles, fibres, Styrofoam, fishing nets, glass bottles and plant materials. Collected wastes after sorting and classification were given to scavengers for recycling, while the remnants were disposed of at Government approved dumpsites. The participants were sensitized to be part of the solution/ winning team and were taught how to imbibe the culture of Waste to Wealth advocacy. Findings underscore the urgent need for concerted action to curb plastics influx into the ocean to support sustainable maritime sectors, protect livelihoods, and foster a circular economic system. Tackling this ecological crisis necessitates collaborative strategies aligned with the blue economy vision.

Key words: Marine Pollution; Marine Debris; Pollution Prevention and Control; Enhancing Blue economy; Environmental Degradation.

1. Introduction
The world's oceans, seas and marine resources present tremendous opportunities for socioeconomic development and environmental sustainability, encapsulated as the 'blue economy' concept (Ekegren, 2018). However, the growing menace of marine debris, especially plastics,

threatens to undermine the promise of this new development paradigm. Figure 1 shows the degradation of the coastline by marine debris. Marine debris is human induced contamination and degradation of the marine ecosystem by directly or indirectly introducing noxious solid substances into the marine environment causing deleterious effects on living resources, hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of sea water, reduction of amenities and navigation. Combating plastic pollution is thus critical for ocean health and the expansion of sustainable maritime sectors (Beaumont et al., 2019). This paper discusses research conducted on assessing and mitigating marine debris along the Niger Delta coastline and examines the implications for transitioning Nigeria towards a sustainable blue economy. The Niger Delta is home to vibrant coastal communities that rely on the rivers and seas for food, jobs, and transport. Nevertheless, plastics from municipal solid waste, oil industry activities, fishing, and maritime transport are increasingly clogging up these waterways.

Fig 1: Marine debris at Marine Base waterfront

The rapid industrialisation and other anthropogenic activities result in massive waste influx into the oceans, forests and landfills, harming ecosystems, and human health (Kirchherr et al., 2017). Plastics accumulate in sediments, wash up on beaches, entangle or are ingested by organisms, and hamper navigation and operations (Ajao et al., 2022). Figure 2 indicates the harmful impacts of marine debris on sea animals. The ubiquitous presence of plastic bottles, bags, containers, nets,

and tires along the coastline pose a persistent threat to the productivity and health of marine ecosystems, with detrimental impacts on local populations (Ajah & Abam, 2019).

Figure 2: Death of aquatic animals: (a) Turtle entangled in abandoned net and (b) Whale ingested plastic debris

The research aims to quantify the abundance, diversity, and sources of marine debris along the Port Harcourt-Okrika waterfronts as a first step towards achieving marine environmental solutions. Engaging local populations in the assessment and cleanup is also vital for awareness and ownership (Hartley et al., 2018). Transitioning to a regenerative circular system is imperative, where waste is transformed into valuable resources (Geissdoerfer et al., 2017). However, changing the status quo requires evidence-based policymaking and multi-stakeholder partnerships (Oyake Ombis et al., 2018). Unassumingly, the outcomes of this research can guide interventions by government, private sector, and civil-society stakeholders to beat plastic pollution and optimize the vast promise of growth in the nation's blue economy.

1.1 Statement of Problem

The proliferation of non-biodegradable plastics has disrupted fragile marine ecosystems and impacted downstream economic activities, threatening the sustainability and equity goals of the blue economy (Mulia et al., 2020). These debris emanate from anthropogenic activities such as shipping, Port operations, fishing, offshore installations or dumping of refuse at sea (Mira et al.,

2016). Most marine solid pollutants or debris are unsightly, detrimental to fisheries and tourism, kill and injure a wide range of marine life, have the capacity to transport potentially harmful chemicals and invasive species, and constitute a significant threat to marine transportation and human health. Figure 3 shows the massive environmental degradation of a waterfront in the Niger Delta. According to a report by the United Nations, the number of marine debris in the world's oceans is increasing at an alarming rate, and if no action is taken, there will be more plastic in the oceans than fish by 2050 (Kershaw, 2016). Therefore, this menace, if not curbed, will have severe consequences on marine operations, wildlife, habitats, and ultimately, human health.

(a) (b)

Figure 3: Environmental degradation and hazard to marine operations

1.2 Significance of Study

Stemming the tide of plastic pollution is integral to harnessing the blue economy potential of the Niger Delta in a sustainable manner. Keeping coastal and marine ecosystems healthy will promote productivity in fisheries, maritime trade, tourism, aquaculture, and offshore oil and gas (Pawar et al., 2018). Implementing the recommendations of the study will prevent plastics from degrading the marine ecosystems: thus, ensuring food security, jobs creation, biodiversity, preservation of marine infrastructure, and enhancement of revenues that power socioeconomic development along the coast (Jambeck et al., 2015). The research outcomes can inform policies and innovation to advance circular models that eliminate plastic waste flooding the marine ecosystem while creating value from recovered plastics (Kirchherr et al., 2017).

1.3 Literature Review

The life cycle of plastics begins with extraction of raw materials; design, and production of item; packaging and distribution; use and maintenance; and reuse, recycling, recovery, or final disposal (Borrelle et al., 2020). The used plastics are disposed through several different routes. Some are gathered, sorted, classified, and recycled through formal or informal waste management schemes and turned into plastic pellets or flakes, and re-enter the production and use phase. However, most are incinerated, disposed in the river, or used as landfills/dumpsites. Plastics ingested by fish and shellfish pose risks to food safety and human health when consumed (Smith et al., 2018). Entanglement in derelict nets and debris can impair productivity and catch rates for artisanal fishers, threatening nutrition, incomes, and wellbeing. The visual impact of shoreline littering reduces the aesthetic appeal for recreation (Wyles et al., 2016). Microplastics can also enter and bio accumulate in marine food chains with potential long-term consequences (Barboza et al., 2020). On this premise, (Sari et al. (2022) examines the generation, composition, and recycling potential of marine debris in the area. Their research reveals a high daily generation of 230 m3 or 303.6 tons, with a composition including various materials such as plastics, biodegradable waste, and metals. The recycling potential is 67.86%, focusing on composting biodegradable waste and recycling PET plastic. These findings can inform government decision-making and guide marine debris management worldwide. (Sebille et al. (2020) addresses the distribution and transport of marine plastic debris, highlighting the need for better understanding and mapping. Their study emphasizes the importance of quantifying the global inventory of marine plastics to develop effective mitigation strategies. (Marin et al. (2021) explores the use of machine learning and deep learning techniques to automate the cleanup of marine debris. Six deep convolutional neural networks (CNNs) are evaluated for their effectiveness in identifying and classifying underwater marine debris. The best performing model is achieved by fine-tuning the Inception-ResNetV2 feature extractor, with an accuracy of 91.40% and F1-score of 92.08%. As a follow up, Valdenegro-Toro (2019) focuses on the problem of marine debris in coastal areas and its impact on marine life and human health. The study evaluates the use of deep neural networks (DNNs) for detecting marine debris in underwater images: hence, promoting the use of Autonomous Underwater Vehicles for surveying and collecting marine debris in underwater environments. Agamuthu et al. (2019) consider marine debris as a global concern, with plastics being the major component. Millions of metric tonnes of plastics enter the oceans annually, causing significant

harm to marine organisms, the environment, human health, and the economies off nations. Figure 4 displays the prevalence of marine debris around Onne port. Marine mammals mistakenly ingest debris which results in fatality. Plastics can convey harmful chemicals and invasive species to upset the delicate ecological diversity of the Gulf of Guinea. Humans are exposed to microplastics through seafood consumption. As revealed by Sari et al. (2021) plastic pollution contributes to greenhouse gas emissions and threatens the ocean's ecosystem. Therefore, sustainable production and consumption of plastics is imperative, and community engagement creates awareness on responsible waste disposal behaviours (Xanthos & Walker, 2017).

(a) (b)

Figure 4: Marine debris: (a) Onne Port debris collection and (b) Reclamation of coastal land at Ogu community waterfront

The research strategy of building stakeholder partnerships, improving infrastructure and services, employing technologies, and monitoring progress is emphasized as a veritable means of eliminating plastics pollution (Oyinlola et al., 2021). Combating marine plastic debris now will safeguard livelihoods, public health, and the integrity of interconnected marine ecosystems for current and future generations (Newman et al., 2015). This will involve integrated approaches engaging all stakeholders across the plastic lifecycle, from extraction and production to recycling, recovery and reintegration (Borrelle et al., 2020). Nigeria can harness the blue economy to create jobs, promote circular resource flows, and achieve the Sustainable Development Goals (SDGs). However, the realization of this vision depends on proactive efforts to mitigate plastic pollution

through a combination of behavioural changes, technological advances, infrastructural investment, and collaborative governance (Oluwatosin et al., 2020).

2. Materials and Methods

The marine debris assessment was conducted along three stations – Marine Base waterfront, Okrika Mainland waterfront and Okrika Island waterfront in Rivers State. These locations were purposively selected based on preliminary surveys indicating high debris accumulation. The fieldwork was carried out over two days with active participation of community members. The tools employed for the cleaning of the Okrika Island waterfront were: 5 rakes, 4 shovels, 10 refuse baskets, 24 waste disposal bags, 3 wheelbarrows, 1 Spring balance of 120kg, hand gloves, hard hats, nose masks, hard boots, reflector vests, life jackets, 1 dragnet of 2m by 12m, and 3 boats with 10 paddles. Figure 4 displays the marine debris combat team equipped with relevant PPE and sanitary gears while Figures 5 and 6 display the Team combatting marine debris both at the beach and midstream using dragnet, respectively.

Figure 5: Ready to combat marine debris at Okrika Island Waterfront

Figure 6: Cleanup of marine debris at Okrika Island Waterfront

The authors, who were facilitators, organized a demonstration of the trawling process to the participants, utilizing two hired speed boats. The collected waste was then properly disposed of on land at government-approved dumpsites. This exercise brought about a sense of excitement and optimism among the participants, as they expressed their gratitude to NIMASA's efforts in safeguarding their vital natural resource, the river water, from the destructive impact of waste.

Figure 7: Cleanup of marine debris midstream using dragnet at Okrika Island Waterfron

The debris cleanup procedure entailed gathering all visible waste material along the shoreline and adjoining areas. Rakes and shovels aided collection into bags and baskets. Full bags were transported to the sorting area using wheelbarrows. There, the debris was manually segregated into categories and weighed using the spring scale, with quantities recorded. Signage, demonstrations, and oversight ensured proper waste separation. Finally, the bagged debris was loaded for transportation to designated disposal sites after completion as shown in Figure 8

Figure 8: Cleanup of marine debris: (a) Segregation process; (b) Transportation; and (c) Disposal at approved landfill

3. Results and Discussion

From the MDCP activity, the following findings were made. The Table 1 shows the different types of marine debris collected at the various stations along the shoreline of the Okrika-Marine Base waterway, Nigeria during the 2023 Marine Debris Combat program. Whereas Figure 9 displays percentage by mass debris from the various stations.

Table 1: The different types of marine debris collected at the stations

SN	Types of Marine Debris	Station 1		Station 2		Station 3	
		Kg	Kg%	Kg	Kg%	Kg	Kg%
1.	Plastic bottles/ sachets	23.35	9.67	16.34	18.20	10.11	4.73
2.	Plastic drums/ containers	85.67	35.47	28.16	31.36	67.93	31.80
3.	Plastic shoes	-	-	1.78	1.98	3.21	1.50
4.	Plastic bags	15.12	6.26	3.00	3.34	8.11	3.80
	% Plastic contents		**51.4**		**54.88**		**41.86**
5.	Old clothes	3.52	1.46	16.00	17.82	10.27	4.81
6.	Electrical appliances	21.49	8.90	16.00	17.82	9.15	4.28
7.	Netting Materials	1.71	0.71	2.38	2.65	15.14	7.09
8.	Broken Car headlamp	4.29	1.78	-	-	-	-
9.	Old sack Bags	1.25	0.52	0.50	0.56	2.05	0.96
10.	Car tyres	54.20	22.44	-	-	43.22	20.23
11.	Empty Paint tins	-	-	-	-	2.01	0.94
12.	Glass Bottles (whole)	7.52	3.11	-	-	3.89	1.82
13.	Empty cement Bags	-	-	-	-	1.50	0.70
14.	floater/cork Materials	0.37	0.15	1.56	1.74	-	-
15.	Broken glasses/ bottles	-	-	-	-	6.74	3.15
16.	Old cotton (door blind material)	0.20	0.08	-	-	4.00	1.87
17.	Taplin Material	6.77	2.80	-	-	8.14	3.81
18.	Organic waste	7.14	2.96	-	-	6.81	3.19
19.	seaweed	2.73	1.13	3.41	3.80	4.02	1.88
20.	Metal cans/ tins	6.19	2.56	0.67	0.75	7.33	3.43
Total Debris Abundance		**241.52**	**100.0**	**89.90**	**100.0**	**213.63**	**100.0**

The total debris collected over two days of fieldwork was 545.05 kg. Marine Base had the highest levels at 241.52 kg (44.31%), followed by Okrika Island at 213.63 kg (39.19%) and Okrika Mainland at 89.9 kg (16.49%). These findings reveal hotspots of high waste accumulation for priority remedial action (Hartley et al., 2015). Marine Base and Okrika Island waterfronts were heavily littered because of several land reclamation sites and waterfront dumpsites. In contrast, the marine debris from Okrika Mainland Waterfront was the least because of the urban lifestyle of the

people and the absence of waterfront landfills. While some marine debris were site-specific (e.g., netting materials), others were prevalent across all stations (e.g., plastic bottles), highlighting common usage and disposal practices.

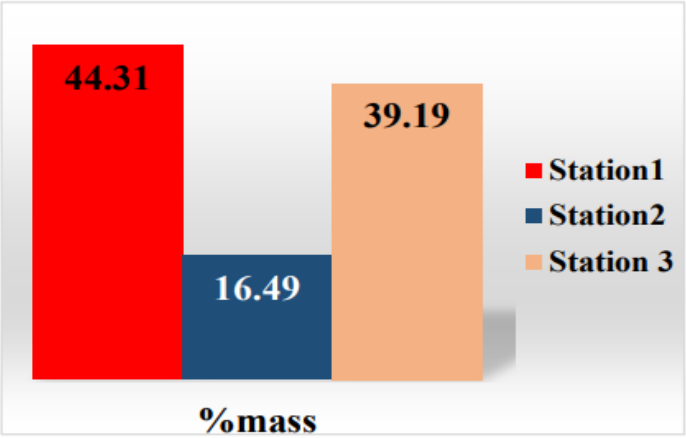
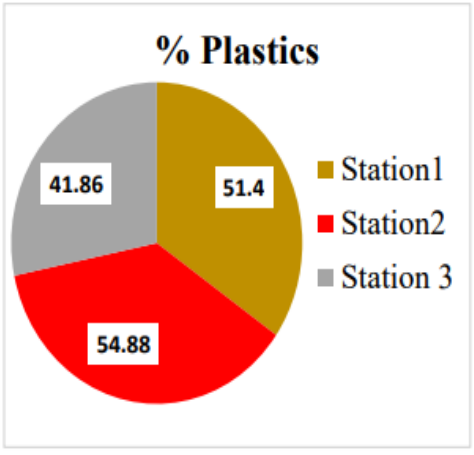


Figure 9: Percent by mass of marine debris from the various stations

The composition analysis shows plastics constituted a high proportion across all three stations ranging from 41-55% by weight, as indicated in Figure 10. Dominant plastic debris types were bottles, containers, bags, shoes, fishing nets and straps. Worn out tires were also a major component. Other waste included appliances, textiles, metals, glass, organics, and foam.



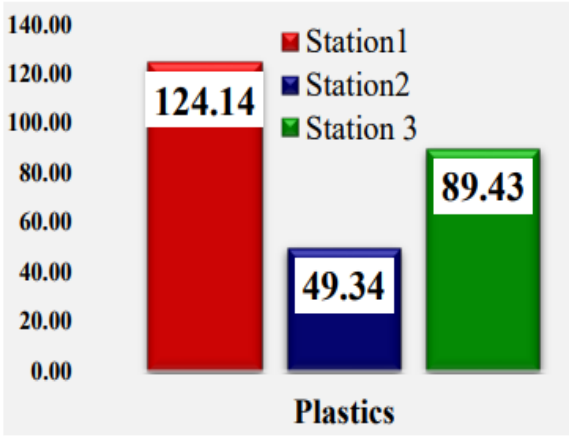


Figure 10: Plastic contents by mass of marine debris for the various stations

4. Recommendations for the Blue Economy

The following 10 measures are recommended to combat marine plastic pollution in the Niger Delta based on the research findings:

(i) Support circular systems to extract value from waste plastics through community-based collection, sorting, and recycling. Provide logistics and financial incentives to optimize recovery (Borrelle et al., 2020).

(ii) Invest in reprocessing technologies to transform recycled plastic into raw materials for manufacturing industries. This helps build a circular economy (Kirchherr et al., 2017).

(iii) Promote product and business model innovations to redesign plastic goods and services to minimize waste generation at source (Mulia et al., 2020).

(iv) Develop infrastructure for integrated and sustainable waste management encompassing transport, sorting, recycling, treatment, and disposal (Ajah & Abam, 2019).

(v) Implement community engagement and awareness campaigns tailored to context to change attitudes and behaviours around plastics (Hartley et al., 2018).

(vi) Strengthen policy and regulatory frameworks to drive systemic shifts in plastic production and usage towards circular models. Incorporate extended producer responsibility (Borrelle et al., 2020).

(vii) Build technical and institutional capacities on plastic waste audits, environmental impact monitoring, and resource recovery solutions (Beaumont et al., 2019).

(viii) Adopt biodegradable or easily recyclable alternatives to conventional plastics to reduce ecological threats from careless waste disposal practices (Xanthos & Walker, 2017).

(ix) Establish robust monitoring mechanisms to periodically evaluate progress on curbing marine plastic pollution using key indicators (Kershaw et al., 2022).

(x) Foster multi-stakeholder collaborations between government agencies, businesses, academia, civil society, and communities for a coordinated strategy against marine plastic debris (Oyinlola et al., 2021). Advancing the blue economy in the Niger Delta entails keeping coastal and marine ecosystems healthy by beating plastic pollution through a combination of policies, technologies, infrastructure, and behavioural changes.

5. Conclusion

This study highlights the significant, yet surmountable challenge posed by marine plastic debris to Nigeria's aspirations for a thriving blue economy centered on its vast ocean resources. Keeping coastal and marine ecosystems healthy by mitigating pollution is crucial for expanding productive maritime sectors sustainably. The solutions lie in creating an enabling policy environment, enhancing technical capabilities and infrastructure, harnessing Indigenous knowledge, employing appropriate technologies, and fostering innovative business models. With informed decisions, strategic investments and collective action, Nigeria can secure the natural capital and productivity of its waters to generate economic growth, decent employment, and long-term prosperity across coastal communities. The proliferation of plastic waste is antithetical to the blue economy vision and must be addressed urgently. The time to act is now by joining hands to combat marine plastics, protect our oceans, and build a sustainable, just, and equitable blue economy. This will require hard choices and compromises by powerful interests vested in the linear plastic economy status quo. However, the gravity of the global plastics pollution crisis calls for ambitious strategies to safeguard the world's oceans for generations to come. Nigeria has a vital leadership role to play in the region and globally by demonstrating replicable models to overcome this challenge through innovation, partnerships, and localized solutions.

Acknowledgement

The authors appreciate the organizers and sponsors of the 2023 Marine Debris Combat Programme (MDCP) which include the Director General, Nigerian Maritime, and Safety Agency (NIMASA) and Verteville Energy, Lagos.

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The Nigerian Institution of Marine Engineers and Naval Architects
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A Division of the Nigerian Society of Engineers (NSE)

12th Annual National Conference

NIBECON 2023 TECHNICAL PAPERS

Theme: Harnessing the Nigerian Blue

Economy (Creating our Future through the Ocean-based

Paper III:
The Roles of Marine Professionals in Achieving a Veritable Maritime and Blue Economy

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Abstract

We are like islands in the sea separate on the surface but connected on the deep. The Ocean's role as the engine of all life on planet is threatened by the consistent depletion in terrestrial resources and as a result the need for a significant economic gain has created an upsurge in the quest to attain a "blue economy". Nigerian however, has not been left out in this quest, being a country that has one of the largest wetlands in the world with its coastal and marine ecosystem covering a total of 70,000 square kilometer, thus making the development of a Nigerian Blue Economy a necessity for the country's benefit. Although, the struggle to attain the blue economy transcends the domestic shores of our coastlines, the Marine Professionals play a crucial role in the development of a sustainable blue economy. Giving the country's blue economy potential, the Africa Blue Economy Alliance, using data from NIMASA projects the value of Nigeria's untapped blue economy potential at a stunning $296bn. The DG/CEO (Nigerian Maritime Administration and Safety Agency) NIMASA hinted that "the massive underutilized blue economy in Nigeria presents enormous prospects for growth and development". Both the Public and private Marine Stakeholders play significant roles in achieving the Blue economy's objectives. The article will discuss their contributions and how it cut across various sectors including renewable energy, fisheries, maritime law enforcement and more. We must synergize to reap the maximal maritime benefits.

1. Introduction

Definition of the Blue Economy: The sustainable use of ocean resources for economic growth, improved livelihoods, and preservation of the ocean ecosystem. Importance of the Blue Economy: The oceans cover 70% of the Earth's surface and are vital for global food security, climate regulation, and overall well-being. Marine professionals play key roles in implementing sustainable practices

KEY PILLARS OF THE BLUE ECONOMY

1. Sustainable Fisheries:
    i. Responsible fishing practices to maintain fish stocks.
    ii. Aquaculture for increased seafood production.

2. Renewable Energy:
    i. Harnessing tidal and wave energy.
    ii. Offshore wind energy projects.
3. Maritime Transport:
    i. Eco-friendly shipping practices.
    ii. Improving port infrastructure and efficiency.
4. Tourism and Recreation:
    i. Responsible coastal and marine tourism.
    ii. Preservation of marine ecosystems for recreational activities.

1.1 Aim and Objectives

Aim: To generate an economic value from the maritime industry for a government

Objectives**:**

i. To use water resources avenue to generate income for the country's economy
ii. To improvise a better way of generating an internal revenue for the country
iii. To boost the economy of our nation using coastal, creek, river, ocean, mineral resources and ecofriendly system

1.2 Scope of Research

The paper present an overview of maritime field activities and immediate environment in consideration to pollution in the maritime industries at large for the siting example for the country blue economy growth potential. I prioritize my focus on the economy advantage that are critically neglected through the attitude of men around the water either trading or doing sailing activities as debating factor.

2. An overview of the Marine Professionals

Marine professionals are those who base their livelihood on sea and water around them (Sharma,

2022). This encompasses various aspect of maritime activities, ocean structure, maritime vehicles, transportation, resort, extraction on and offshore construction, marine environmental management and renewable energy system. There is an interaction of knowledge and discipline such inclusive of naval architecture, nautical science, oceanographers, marine engineering, offshore and oil rig activities and electrical civil engineering aspect that tailor around the transportation and infrastructure and highlight activities such as freight forwarders which are more interested in making their businesses at the marine environment and minimize the environmental impact implications.

2.1 Major areas of Interest

A. Oceanography research

B. Coastal Engineers

C. Transportation and ferry

D. Offshore platform structures

E. Port and Harbor Infrastructural

F. Coastal Maritime Traders

2.2 Marine Professional Landscape

Nigeria has over 35 register maritime shipping line and shipyards repairs (NIMASA, 2022). Marine education is offered at 8 major universities and polytechnic. Nigeria also has merchant navy institutions and Training School for seafarers to build their career yet there are remaining shortage highlight in maritime industry within the country while the local ship building and maintenance capacity are within the country. Most large and marine platform coming from foreign country was so skeptical of entering Nigeria waters or territorial waters because of lack of maintenance of our water territory. The Nigeria

2.3 The Blue Economy

The blue economy concept recognizes the ocean as development spaces that must be sustainably tapped for economic prosperity (Mulazzani & Malorgio, 2020). Blue economy covers traditional ocean industries like fisheries, maritime transport, and coastal tourism as well as emerging industries like offshore renewable energy, aquaculture, seabed extractive activities, marine

biotechnology, and submarine cables (Schutter & Hicks, 2019).

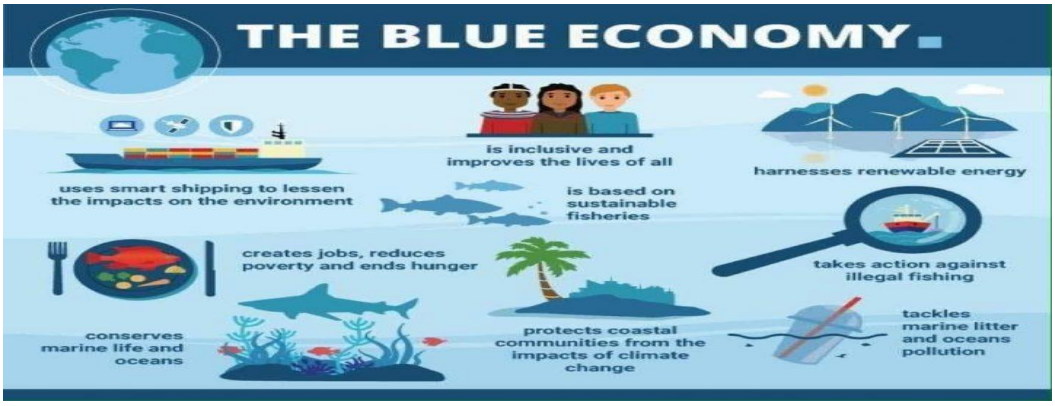


Figure 1: Maritime Blue Economy Ecosystem

The World Bank (2017) estimates that the global blue economy is worth over US$1.5 trillion per year and anticipates growth to over US$3 trillion by 2030. Hence coastal countries like Nigeria with vast maritime domains stand to gain tremendously by strategically harnessing the potentials of blue economy sectors. However, as noted by Silver et al. (2015) suitable infrastructure is imperative for stimulating key maritime industries, facilitating trade flows, easing logistics connectivity, and providing the platform for blue economy enrichment.

2.4 Sustainable Fisheries

One Importance of sustainable practices is to prevent overfishing and preserve marine biodiversity. Implementation of technology for responsible fishing, such as GPS tracking and fishery management systems. Promotion of aquaculture as an alternative to wild-caught fisheries. Marine professionals play significant roles in the above mentioned by conducting research on fish stocks and eco-systems ,applying expertise to promote aquaculture ensuring it aligns with environmental sustainability such that is taken at Nigeria Institute for Oceanography and Marine Research (NIOMR).

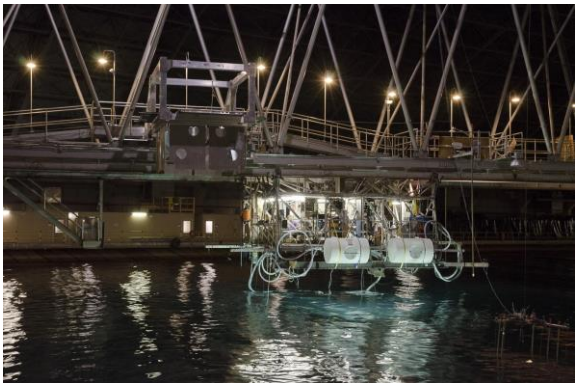
Small Island Governments have made decent work and social protection their highest policy

priority, aiming to link them to the so called blue economy sectors such as fisheries. The development of small-scale commercial fishing is primarily driven by transnational fisheries trade and depend on the dive fisher labor force facing issues with deficits in decent work, health and safety, and safety at sea provisions.

2.5 Renewable Energy

Overview of harnessing energy from ocean tides and waves.

Advantages of consistent and predictable energy sources. Utilizing wind farms in open sea areas to generate energy for wind turbine system. Reducing dependence on fossil fuels and mitigating climate change such as ozone depletion and greenhouse effect. Marine professionals are instruments in sparking marine energy entrepreneurship and engaging an emerging, diverse workforce to achieve ambitious renewable energy goals. Marine professionals should utilize advanced technology for harnessing tidal, waves and offshore wind energy, contribute to the design and implementation of marine energy projects, develop and implement eco-friendly shipping technologies and lastly enhance port infrastructure for sustainability and efficiency. By so doing they serve as a complementary technology to boost the viability of other renewable energy technologies and hybrid systems.



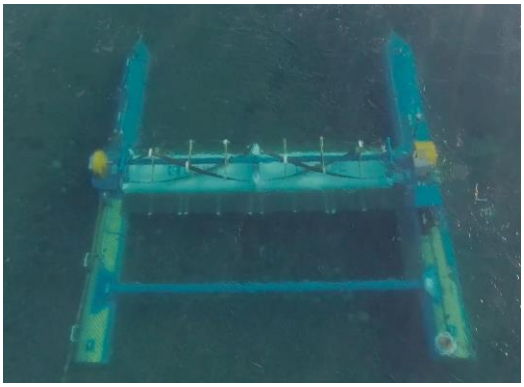


Figure 2: Overview of harnessing energy from ocean tides and waves.

2.6 Tourism and Recreation Management

Balancing economic benefits with environmental preservation. Community involvement in tourism planning. Strategies for protecting coral reefs, mangroves, and other sensitive habitats.

Regulations to prevent over-exploitation of marine resources. Marine professionals play important roles by participating in the planning and management of marine protected areas, advising on sustainable tourism practices, conducting research on marine ecosystems and biodiversity. Marine professionals can as well channel resources into developing marine tourism in Nigeria. The urgent need for the country to adopt the blue economy initiative has paved a smooth path for marine stakeholders to invest in marine tourism by collaborating with local communities to ensure that tourism benefits are shared equitably. This involves creating opportunities for local businesses, preserving cultural heritage, and involving communities in decision-making processes. Advising on the construction and maintenance of facilities such as jetties, viewing platforms, and visitor centers to ensure minimal impact on marine environments.

Figure 3: Tourists vessels

While we want to harness the opportunities that comes with utilizing the ocean in terms of tourism, marine professionals do well to minimize the impact of tourist activities on marine life. This may involve setting rules for approaching wildlife, protecting nesting areas, and managing interactions with marine animals.

2.7 Marine Law Enforcement

Marine professionals can also play potential vital roles in maritime law enforcement, and can act as the eye and the ears of maritime security agencies, for instance, in addressing fishery crimes. Marine professionals work to establish and implement safety management systems on ships and maritime facilities. They conduct safety drills, provide training, and monitor compliance with

safety standards. Monitoring and regulating activities that may have environmental impacts, such as oil spills, waste disposal, and emissions. Taking legal action against violators to prevent and mitigate environmental damage.

2.8 Skill and Career Development

A competitive, resilient, and socially fair blue economy needs highly qualified and skilled professionals. Yet today, many blue economy sectors undergo difficulties finding the right people, which hampers their growth. The European Commission however is supporting actions to solve this mismatch.

The Nigerian Maritime Administration and Safety Agency (NIMASA) have taken fruitful measures to equip aspiring Nigerian youths with requisite skills, thus tackling one of the challenges of the blue economy, thereby improving productivity and employment. NIMASA Management is empowering youths through skills acquisition at the centers located at the six geo-political zones across the country. The programs are also to instill a sense of purpose and self-worth, promoting social integration within maritime host communities such as in the Port city of Apapa.

The vision is"tackling unemployment with a long-term goal of enhancing maritime security".

Figure 4: Photo of the NIMASA Skill Acquisition Centre, in Apapa Lagos.

R-L: Permanent Secretary, Federal Ministry of Marine and Blue Economy/Transportation, Dr. Magdalene Ajani, Honourable Minister, Federal Ministry of Marine and Blue Economy, Adegboyega Oyetola, CON and Director General, Nigerian Maritime Administration and Safety Agency (NIMASA) Dr. Bashir Jamoh, OFR (left) during the visit of the Minister to the NIMASA Skill Acquisition Centre, in Apapa Lagos.

3. Nigeria's Ports and Maritime Sector

This sector serves as a critical backbone for external trade and economic prosperity accounting for over 95 percent of exports and imports (Buhari, 2019). Prior to the 2006 port reforms, the sector was plagued by acute infrastructure decay, monumental port congestion, chaotic administrative bottlenecks from multiplicity of agencies, and poor service quality that eroded competitiveness (Mfon, 2013). These factors constrained maritime sector contribution to national GDP compared to more strategic roles played by the sector globally in powering blue economy for other coastal states. However, the 2006 concession programme granting port terminal leases to private operators helped transform infrastructure, improve efficiency, and achieve record cargo milestones over recent years as presented in Figure 1 showing cargo throughput over 16 years.

3.1 Requirements to Develop Maritime Infrastructures

Nigeria urgently requires significant investments in maritime infrastructure to eliminate current capacity shortages, facilitate trade flows and capitalize on blue economic activities across the coastal regions.

3.2 Local and International Seaport Infrastructure Development

Nigeria currently lacks deep seaport infrastructure to accommodate Very Large Container Carriers (VLCCs) and Ultra Large Crude Carriers (ULCCs) which now dominate global shipping and oil transportation (Nwanosike & Tipi, 2021). Figure 5 displays this category of ships requiring a large draught. With just three meters depth, Nigeria's premier Lagos ports remain shallow, unable to allow large capacity new generation vessels. Larger container vessels also divert to neighboring countries. The impacts constrain shipping, undermine transshipment hub prospects, increase costs, and impede wider maritime productivity essential for blue economy optimization as identified by (Okeke, 2014).

(a)

(b)

Figure 5: Cargo ships requiring a large draught: (a) VLCC and (b) ULCC

Though Nigeria recently completed the Lekki Deep Seaport to support 90,000 tonnes DWT ships, other ports need similar engineering interventions. Proposed Badagry Deep Seaport is also underway but further deep seaport projects are vital at Onne, Calabar, Warri, and Port Harcourt to expand capacity. Deep seaports allow efficient consolidation of export cargo from agricultural, solid mineral and oil sectors into VLCC loads attracting more shipping traffic and revenues. Hence engineering deep seaport projects remains an urgent maritime infrastructure priority.

Figure 6: VLCC loading at the Lekki deep seaport

3.3 Floating and Dry Ports Infrastructure Development

Nigeria's dry port infrastructure is also grossly inadequate. The few inland container depots (ICDs) including Isiala Ngwa, Jos and Funtua are small facilities unable to alleviate landside bottlenecks and seaport congestion. Dry ports when fully developed promote intermodal transport, provide platforms for cargo consolidation, shipment of imports to inland areas, and exports from production zones to seaports.

Figure 7: Dry cargo port solution to decongesting port terminals

Hence engineering more dry ports close to major cities using PPP models is crucial for shipping cost reduction, inventory savings, decongestion and toll-revenue generation, as dry port usage expands in consonance with cargo throughput growth.

3.4 Channel Dredging Lines

Expanding dredging and maintaining adequate depths along vital shipping channels on Nigeria's coastal shelf, rivers, and port basin locations will allow seafarers passage for bigger vessels and prevent ship groundings as a results of debris and wastes dumps carried by the waters around the countries of the world. This will facilitate movement of containers through inland waterways, spurring maritime connectivity with inland locations for a free access and port free hazards.

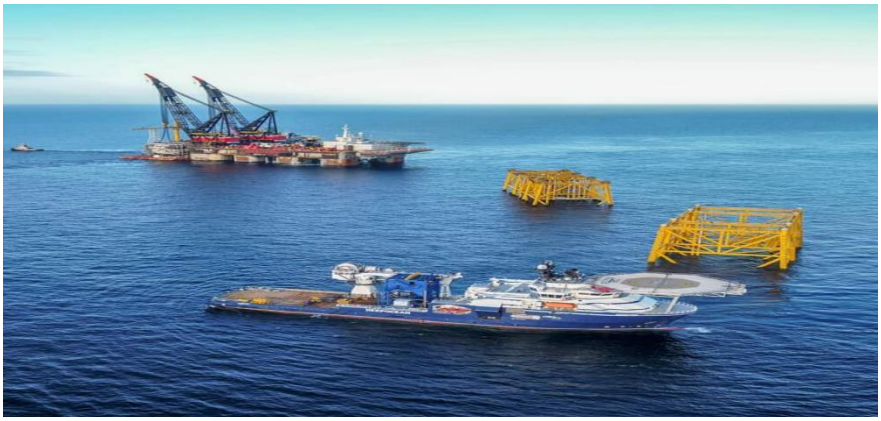


Figure 8: Dredging and widening of water channels for easy maneuverability

Currently, heavy lugs on channels frequently hampers ship and boat maneuverability. Attaining over 13 meters depth and 200 meters width dimensions for the channels ensures they align

suitably with engineered deep seaport requirements and if there is accumulated obstructions, it may become a dangerous hazard. The dredging and channel engineering must also capture inland water channels, especially along Rivers Niger and Benue, to support IVTM catalyzed for more dry ports and boat services.

3.5 Inadequate Seaport Equipment Capacity

Current cargo volumes already exceed handling capacity at major ports often resulting in long vessel queuing, waiting times and gridlocks (Mfon et al, 2018). It underscores the urgent need for expanding port infrastructure to keep pace with Nigeria's growing maritime trade and support emerging sectors. Key aspects include:

(i) **Electronic Call-up System:** Adoption of digital truck call-up platforms with RFID technology integration can optimize cargo evacuation, decongest port access roads, and enhance supply chain visibility when theres a cleared access road for easy transportation.

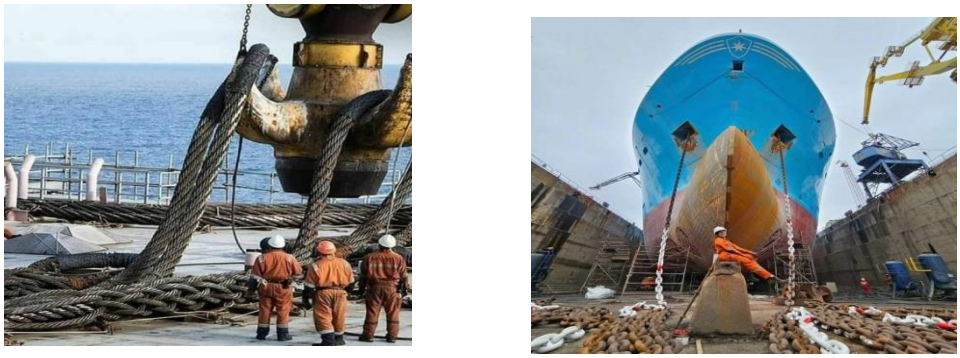


Figure 9: Nigerian seaport congestion due to inadequate seaport equipment.

(ii) **Rail & Road Networks:** Interconnecting seaports to key inland trade hubs through modern rail and road linkages will ease congestion, facilitate inland container transports, and support multi-modal cargo distribution when the access areas are free from dirt and miscreants.

(iii) **Truck Transit Parks:** Establishing trailer parks and holding bays fitted with required amenities will address haphazard truck parking and congestion around ports arising from delays. Also not allow the hooligans loitering around

(iv) **Inland Container Depots:** Building dry ports and container freight stations linked with seaports by rail will ease congestion through port decentralization and extend inland access to maritime trade with waste control mechanisms strategically placed at a

conspicuous locations.

3.6 Challenges That Could Be Faced By Marine Professionals

Marine professionals face several challenges in their efforts to achieve a sustainable Blue Economy. Here are some common challenges and potential solutions:

Overfishing:
Challenge: Depletion of fish stocks due to overfishing.

Solution: Implement and enforce sustainable fishing practices, including fishing quotas, gear restrictions, and marine protected areas. Promote responsible aquaculture as an alternative.

1. Climate Change Impact:

Challenge: Rising sea temperatures, ocean acidification, and extreme weather events.

Solution: Develop and implement climate-resilient strategies. This includes researching and adopting technologies that can mitigate climate impacts and adjusting marine practices to changing conditions.

2. Pollution:

Challenge: Marine pollution from plastic, oil spills, and other contaminants.

Solution: Enforce strict regulations on waste disposal, promote recycling, and invest in clean technologies. Implement comprehensive oil spill response plans and raise public awareness to reduce plastic usage.

3. Lack of International Cooperation:

Challenge: Limited collaboration among nations in managing shared marine resources.

Solution: Foster international cooperation through treaties, agreements, and joint initiatives. Encourage the sharing of data, knowledge, and best practices to address global challenges collectively.

Conclusion

MARINE PROFESSIONALS play a pivotal role in the development of a veritable blue

economy. Their contributions are vast and varies, spanning from renewable energy to fisheries, maritime law enforcement, and skills and career development. It is also important to note that achieving this initiative is a collective responsibility of the marine community. As the world continues to recognize the importance of the blue economy the role of marine professionals will only become critical.

"THE IMPORTANCE OF THE WORLD'S OCEAN FOR OUR COLLECTIVE FUTURE IS UNDENIABLE" KITACK LIM"

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Theme: Harnessing the Nigerian Blue

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Paper V
The Place of Security in the Development of the Maritime Sector in Nigeria

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Abstract

Nigeria's extensive maritime domain and strategic location have enabled it to command over 70% of shipping and commerce in West Africa. However, escalating security threats from piracy, kidnapping, oil theft, and cyber hacking are incurring major economic losses and reputational damage. This research analyses the importance of maritime trade for Nigeria's development ambitions and role as the foremost regional maritime power. Assessment of current security dynamics spotlights economic and strategic impacts across ports, shipping, and offshore oil infrastructure. The naval, coast guard, and maritime agency protection capacities require urgent modernization to stabilize the maritime environment. Board interagency coordination alongside international partnerships and ship security protocols offer vital complements toward rebuilding maritime security.

Key words: Maritime security and safety; Blue economy; Ships and Ports Security; Combating Maritime Crime

1. Introduction

The seas have long served as catalysts for human civilization and prosperity, underpinning exploration, migration, and global trading systems that transpire predominantly via maritime channels. Today, seaborne commerce transports approximately 90% of all world cargo and remains indispensable for development in coastal countries like Nigeria (Crist, 2003). Nigeria possesses extensive maritime endowments, including over 853 nautical miles of coastline and a network of ports and inland waterways that provide vital access to international shipping (Atakpa, 2023). The African Atlantic Countries include Nigeria, Morocco, Mauritania, Senegal, Gambia, Cape Verde, Guinea, Guinea Bissau, Sierra Leone, Liberia, Côte d'Ivoire, Ghana, Togo, Benin, and Cameroon.

Blessed with a robust coastline spanning about 853 nautical miles (from Badagry in the Southwest to Calabar in the Southeastern fringes) and a labyrinth of navigable Inland Waterways stretching for about 3,000 kilometres all emptying into the vast Atlantic Ocean. Nigeria commands about 70% of trade and commerce in the sub region as shown in Figure 1, a position that also bequeaths her with enormous responsibilities in the realm of maritime security in the Gulf of Guinea (GoG). Located at the heart of the GoG which stretches from Senegal to Angola in the Southern part of Africa, Nigeria, among the maritime nations in the region, has had her fair share of challenges in the quest to create an enabling environment for her maritime trade to thrive. Cardinal among these is the issue of insecurity across her channels and water ways.

Figure 1: Map showing countries making up GoG

However, despite the tremendous wealth generation enabled by maritime assets, Nigeria's coastal waters and adjoining GoG now face intensifying threats from piracy, hijacking, kidnapping, and oil theft which incur major economic losses alongside reputational damage (Ogbonnaya & Igwe, 2019). The GoG is known to be rich in abundant fisheries, cobalt and other minerals and crude oil. Explorers from far and wide have toured the GoG in search of these resources hence the reason for several maritime related crimes bedeviling the GoG as indicated in Figure 2. This phenomenon has equally given rise to an upsurge in terrorism, piracy, smuggling, human trafficking, trade in narcotics and dangerous arms and ammunitions, poaching even in maritime protected areas and armed robbery attacks on vessels and their crew, etc. All of these have posed monumental challenges to the development of the global maritime industry. This article analyses the escalating maritime security challenges Nigeria faces and their deepening impacts on national development ambitions. Assessment spotlights economic repercussions across ports, shipping fleets, and offshore oil infrastructure as maritime crimes escalate.

Figure 2: Maritime Piracy Attacks

Strategic analysis further examines the naval and coast guard protection roles and coordination with the maritime safety agency alongside international partnerships within the region. Collectively, findings underscore the imperative of upgrading naval capacity and law enforcement operations, strengthening inter-agency coordination, and employing comprehensive ship security protocols as vital to stabilizing Nigeria's maritime sector and restoring an environment conducive to sustainable prosperity.

Figure 3: Naval gunboat stops a Pirate Attack in the GoG

2 The Economic Importance of Nigeria's Maritime Sector

2.1 Nigeria's Advantageous Coastal Geography

Nigeria possesses a highly favourable maritime geography marked by direct access to the Atlantic Ocean and a concentration of regional trade flows in the GoG were Nigeria spearheads economic activity. By virtue of its coastal location and steadily developed port infrastructure, Nigeria now commands dominance over regional shipping, handling an estimated 70% of all maritime commerce in West Africa (Atakpa, 2023). In total, Nigeria controls over 315,950 square kilometres of territorial waters and exclusive maritime economic zones rich in fish stocks, aquatic life, and offshore hydrocarbons (Ogbonnaya & Igwe, 2019).

2.2 Infrastructure Foundation

The current maritime infrastructure foundation traces back over a century, beginning with the pioneering Port Harcourt facility built in 1912 and the Apapa Port in Lagos in 1921 (Ogbonnaya et al., 2019). Deep seaports, oil export terminals, and navigational jetties have extensively expanded since the 1960s, with the recent Lekki Deep Sea Port commissioned in 2023 set to reinforce shipping capacity (Ogbonnaya et al., 2023). This entrenched port, terminal, and inland waterways ecosystem now catalyses and sustains vibrant international trade.

2.3 Revenue and Trade Catalyst

In total, Nigeria's maritime assets and activities facilitate tremendous economic value for domestic prosperity and global commercial exchange. Ports operations and inland barging generate substantial employment and incomes while petroleum exports clearly form the major source of national revenue since the 1970s (Igwe & Ogbonnaya, 2019). Services support for offshore oil/gas activity also contributes significantly to GDP. The strategic location enables Nigeria to mediate a higher proportion of regional trade flows, thus, benefiting from demands for importer and exporter services. However, despite the immense potential maritime assets confer, their productivity and income generation remain hampered by increasing insecurity from seaborne criminals and insurgents.

Figure 4; Oil pipeline vandalism and stealing

2.4 Rising Tide of Maritime Insecurity

Myriad security threats have increasingly afflicted vital global sea lanes and now severely undermine stability closer to Nigerian shores (Mejia Jr., 2003). Key contemporary risks centered on piracy, hijacking, kidnapping, oil theft, and cyber hacking targeting commercial ships, port infrastructure and offshore platforms (Ogbonnaya & Nwaorgu, 2019). Costs from maritime crime worldwide now exceed billions of dollars annually and the forecast trends point higher without interventions to reverse the tide. As indicated in Figure 5, the military fierce intervention of using kinetics and bombing of illegal refineries have grossly polluted the environment with noxious liquids and gases, damaged marine habitats and vegetation, and killed aquatic lives. This adversely affects the prospects of harnessing a sustainable blue economy.

Figure 5: The hazards of bombing illegal refineries and incessant oil spills on marine lives and habitats

2.5 Piracy and Terrorism Menace

Each year numerous attacks afflict commercial ships globally, despite preventive efforts by vessel crews and maritime security forces. More than 80% of world piracy acts occur in African waters, notably the GoG, Strait of Malacca, and Horn of Africa basins (Efanga, 2016). Sophisticated cyber hacking has been especially problematic recently, including events where ransomware viruses temporarily disabled major port terminals in Barcelona and San Diego alongside a breach costing Maersk shipping lines $200 million (Ogbonnaya & Igwe, 2019). Environmental terrorism groups like Sea Shepherd also interdict ships and offshore oil platforms as political protest.

Gulf of Guinea Epicentre

The GoG has become an epicentre of intensifying international piracy alongside Niger Delta militancy affecting onshore energy infrastructure. In 2020 alone the region recorded 84 attacks and 135 crew kidnappings for ransom - exceeding the combined global total elsewhere (Atakpa, 2023). And signs in 2023 show further spikes as foreign gangs and local insurgents capitalize on turmoil amid limited deterrence. Figure 6 displays maritime criminals operating in the GoG.

Figure 6: Maritime criminals robbing and kidnapping commuters at sea

3. Impacts on Nigeria's Maritime Sector

Threats of piracy and kidnapping for ransom have made ship owners more reluctant to operate in Nigerian waters, instead diverting journeys towards perceived safer routes often farther from shore (Ogbonnaya et al., 2019). Nigerian ports outside Lagos report reductions in shipping traffic and revenue since owners view southern hydrocarbon terminals as higher risk. The costs and consequences of stolen cargoes, delayed shipments, and securing the release of kidnapped sailors also take heavy financial toll on shipping firms and oil companies (Crist, 2003).

3.1 Reputational Damage

In addition to direct economic costs, perceptions that Nigeria's coastal security is rapidly deteriorating also tarnish its standing within the global maritime industry (Igwe & Ogbonnaya, 2019). International stakeholders urge Nigeria to elevate protections more forcefully if it hopes to sustain smooth operations. However, low progress, further reprisals by foreign partners have severely restricted maritime trade flows.

3.2 Implications for Development

Ultimately maritime insecurity severely undercuts Nigeria's development ambitions, imposing barriers against trade while shrinking income from what should be a burgeoning arena of economic

growth cantered on its extensive coastal resources and ecosystems (Ogbonnaya & Igwe, 2019). Until tangible headway curtails risks from seaborne crime, kidnap and oil theft, Nigeria's aspirations towards industrialization and sustainable prosperity in the blue economy will remain deeply constrained. Rebuilding maritime security is thus an urgent national priority.

4 Maritime Security Concerns to Nigerian Blue Economy

The international market is replete with the massive movement of cargo by sea. This phenomenon has equally given rise to an upsurge in terrorism, piracy, smuggling, human trafficking, trade in narcotics and dangerous arms and ammunitions, poaching even in maritime protected areas and armed robbery attacks on vessels and their crew, etc. All of these have posed monumental challenges to the development of Nigerian blue economy.

4.1 Maritime cybercrime and the Blue Economy

Of greatest concern to global maritime security is the issue of maritime cybercrime in which the criminals have perfected the art of breaching maritime cyber security systems to enable them gain access into the strongholds of classified and sensitive data and information to perform their nefarious activities. This, they do in collaboration with hackers who are adept at compromising even very sophisticated digital systems. These crimes are committed across all facets of the industry including during port operations, port paperwork, at voyage times, and information transmission from ports of departure to destination ports, etc. Systems that could be rendered vulnerable by the maritime cyber criminals include Bridge systems, Cargo handling and management systems, Propulsion and machinery management and power control systems and access control systems. Others are passenger servicing, administrative systems, crew welfare systems, and communication systems. This hampers maritime businesses and the blue economy.

4.2 Kidnapping and Piracy at Sea

According to the International Maritime Bureau, the GoG in the year 2020 alone, witnessed 84 attacks on ships, with 135 seafarers kidnapped for ransom. The GoG experienced a nearly 50 % increase in kidnapping for ransom between 2018 and 2019, and around 10 % increase between 2019 and 2020. However, the GoG region where Nigeria plays a critical role in maritime trade witnessed a lull in criminal activities, especially piracy, between year 2020 and late 2022. This

was sequel to signing into law, of the Suppression of Piracy and other Maritime Offences (SPOMO) Act by President Muhammadu Buhari in June 2019. Beginning from January 2023 however, maritime insecurity in the region has spiked once again, thus making the GoG to account for about 95 % of all kidnappings for ransom at sea globally. By this, the region has overtaken the Gulf of Aden between Somalia and Yemen and the Strait of Malacca between Malaysia and Indonesia as the hotbeds of maritime insecurity on a global scale. This is indicative of the fact that the Nigerian military has a lot of work to do in ensuring safer waters for the nation's maritime industry and by extension, the Nigerian blue economy.

4.3 Disuse of some Seaports in Nigeria

Being the main maritime powerhouse in the West and Central African sub-region and the GoG in general, the Nigerian waterways have in recent times experienced untold incidences of criminal attacks on vessels and unwholesome activities ranging from kidnappings, piracy, crude oil theft, poaching, smuggling and trade in narcotics and illegal arms. All of these have served to undermine the security architecture of the nation's maritime environment and by extension, the development of a pluralistic blue economy. Ugly scenarios such as these have continued to send negative signals to the international shipping community whereby ship-owners have become weary and very reluctant to send their vessels to ports, especially in the Niger Delta region. Thus, Ports such as Warri, Koko, Port Harcourt and Calabar in the central and southeastern areas of Nigeria have experienced unmitigated doldrums in their operations in recent years. This constitutes a monumental threat to sustainable blue economy.

5 Strategic Institutional Roles & Capabilities

Multiple domestic and international institutions retain strategic roles and capabilities to help tackle maritime threats and reinforce stability along Nigeria's expansive 853-kilometer coastline and web of adjoining waterways which constitute its lifeblood. However, operational scale and technologies require upgrades to counter intensifying risks.

5.1 Role of the Military in Tackling Insecurity on Nigerian Waters.

Nigeria is one of the signatories to the Gulf of Guinea Commission (GoGC), a treaty signed at Libreville, Gabon, on the 3rd of July 2001 with the objective of establishing mutual confidence, peace, and security across the region. Other signatories include Angola, Congo, Gabon, Equatorial Guinea, Sao Tome and Principe, Cote d'Ivoire, Ghana, Guinea, Liberia, Togo, and Sierra Leone.

Consequently, Nigerian military provides a sophisticated technology driven intelligence and military fire power to ensure safer waters for the sustenance of her fledgling maritime trade. The Navy maintains a specialized Maritime Guard Command co-located with local facilities run by the Nigerian Maritime Administration and Safety Agency (NIMASA) to promote close interagency coordination on patrols and rapid response contingencies (Atakpa, 2023). In addition, the Federal Government through the NIMASA, recently launched the Integrated National Security and Waterways Protection Infrastructure project also known as the 'Deep Blue Project' on the 10th of June 2021. It is headquartered at the NIMASA Maritime Resource Centre in Kirikiri, Lagos. Better known as the C4 (Command, Control, Coordination and Computer) Centre, the Deep Blue Project is equipped with very sophisticated digital gadgets and other infrastructure capable of monitoring the movement of vessels in and around Nigeria's territorial waters. These include Interceptor Boats, Special Mission Vessels, Helicopters, Special Mission Aircrafts, Maritime Intelligence Systems, Armoured Vehicles for ground operation and an Intervention Unit which includes trained personnel for swift action purposes (DefenceWeb, 2023). Figure 7 shows NN Offshore Patrol Vessel (OPV) escorting a cargo ship.

Figure 7: NN Offshore Patrol Vessel (OPV) in action at sea

Armed with the Suppression of Piracy and other Offences Act of July 2019 and working in conjunction with the NN, NIMASA acted swiftly in foiling a pirate's attack on a Chinese fishing

vessel off the Nigerian coast in June 2020 using an NN - OPV. Ten of the pirates were arrested, tried by a Federal High Court, and sentenced to 48 years imprisonment each, to serve as deterrent to other maritime criminals. In a similar incident, a Chinese fishing vessel, MARINE 707 with 51 crew members which included 48 Ghanaians and 3 South Koreans was interdicted by the NN on the 18th of May 2021, operating illegally in the GoG. The vessel and her crew members were promptly arrested and handed over to the Ghanaian and South Korean Authorities for further investigation and action. Tranquility on our waterways is sine qua non to the growth and development of the nation's blue economy.

5.2 Role of Nigerian Institution of Marine Engineers and Naval Architects (NIMENA)

NIMENA being the foremost maritime engineering society in Nigeria, should:

(i) ensure the training of seafarers in line with the Standards of Training, Certification and Watchkeeping (STCW)'95 Protocol.

(ii) establish code and standards for maritime professionals. It should inculcate timeless values of discipline, ethics, and professionalism to its members.

(iii) play a crucial role in enhancing maritime security and safety of ships and ports in Nigeria by contributing significantly to the development and implementation of policies that ensure the strict implementation of IMO regulations and rules.

(iv) facilitate the exchange of knowledge and expertise among its members, through conferences, seminars, and workshops. The institution should promote continuous learning and skill development, enabling marine engineers and naval architects to stay abreast of the latest security technologies and strategies.

(v) collaborate with relevant stakeholders to develop and enforce standards that enhance the resilience of maritime infrastructure against security threats.

(vi) conduct research to identify emerging security issues in the maritime industry, providing valuable insights for policymakers and security agencies.

(vii) raise awareness about the importance of maritime security among industry stakeholders, policymakers, and the general public.

(viii) serve as a knowledge hub, disseminating information on best practices and innovative approaches to enhance security; and

(ix) through its code of ethics and professional standards, encourage a high level of integrity and accountability within the marine engineering and naval architecture professions, contributing to the overall trustworthiness of individuals working in the maritime sector.

Conclusion

In conclusion, Nigeria's extensive 853-kilometer coastline and concentration of regional shipping in proximate waters have conferred tremendous advantages in harnessing maritime assets to generate national prosperity from ports, fishing, and offshore oil. However, intensifying predation from pirates, kidnappers, and Niger Delta militants are now incurring major losses for maritime commercial activity while tarnishing Nigeria's international standing as a reliable economic partner. The Nigerian Institution of Marine Engineers and Naval Architects should play a multifaceted role in promoting and enhancing maritime security in Nigeria, encompassing advocacy, education, research, and collaboration with various stakeholders. Curtailing risks by expanding naval capacities, coordinating enhanced coastal surveillance and interdiction operations with modern agencies like NIMASA, and fast-tracking implementation of the comprehensive international ship and port security protocols are vital first steps toward stabilizing Nigeria's maritime operating environment to restore confidence essential for sustainable development of its maritime sector.

Recommendations

Finally, the recommendations are as follows:

i. being a littoral state, Nigeria should adopt all aspects of IMO especially on SOLAS;
ii. there should be more OPVs provided for Nigerian maritime patrol;
iii. the digital system on the forward operational bases should be well equipped;
iv. piracy and illegal activities onboard in the ocean should be controlled accordingly; and
v. the relationship between NIMASA, NN and NIMENA should be strengthened

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The Nigerian Institution of Marine Engineers and Naval Architects
(NIMENA)
A Division of the Nigerian Society of Engineers
(NSE)

12th Annual National Conference
NIBECON 2023 TECHNICAL PAPERS

Theme: Harnessing the Nigerian Blue

Economy (Creating our Future through the Ocean-based

Paper VI

Engineering Infrastructure Needs for Blue Economy Growth in Nigeria's Port and Maritime Sector

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Abstract

Nigeria's ports and maritime sector have great potential to drive blue economy growth and contribute more significantly to national development. However, the sector faces infrastructure gaps that constrain its performance. This paper examines the engineering infrastructure needs of Nigeria's ports and maritime sector to support blue economy growth. Analysis of cargo traffic trends, port performance metrics, and infrastructure quality indices over 15 years reveals significant infrastructure deficits. Key recommendations include deep seaport construction, dry port development, dredging of water channels, rail and road connectivity upgrades, and technology modernization. Targeted infrastructure engineering interventions can strengthen maritime operations, stimulate trade, improve competitiveness, and harness the blue economy prospects in fisheries, shipping, offshore oil and gas, maritime transport, and coastal tourism. A strategic blueprint for infrastructure engineering is proposed to unlock the immense potential of Nigeria's ports and maritime sector. Key words: Maritime Infrastructural Development; Blue economy; Multimodal Transportation; Ports and Harbour Development; and Maintenance of Maritime Infrastructure.

Key words: Maritime Infrastructural Development; Blue economy; Multimodal Transportation; Ports and Harbour Development; and Maintenance of Maritime Infrastructure.

1. Introduction

As a coastal state on the Gulf of Guinea endowed with an extensive coastline and strategically located within West Africa, Nigeria possesses tremendous maritime potentials which if well harnessed can substantially advance blue economy growth and national development (Ifere & Bassey, 2020). Its 853km coastline, inland waterways spanning over 10,000km, as well as ports and harbors provide opportunities for fishing, aquaculture, maritime transport, shipbuilding, tourism, offshore oil and gas, and other economic activities . Its oceans economy has immense

potential to catalyse economic diversification, job creation, food security, and improved socio economic wellbeing while advancing ocean sustainability. The ports and maritime sector occupy a strategic position as the gateway for Nigeria's international trade and economic links vital for The Nigerian Institution of Marine Engineers and Naval Architects (NIMENA) NIBECON 2023 TECHNICAL PAPERS, Theme: Harnessing the Nigerian Blue Economy (Creating our Future through the Ocean-based Resources) blue economy advancement (Parambi et al., 2021). However, the country currently harnesses only a fragment of its blue economy potential valued at over $1.2 trillion annually. Nevertheless, persistent gaps in maritime infrastructure constrain efforts to improve the productivity and competitiveness of the nation's ports and fully utilize the rich marine resources for optimal blue economy progression (Okeke, 2014). Note that the sector accounts for over 95 percent of the country's international trade by volume and about 60 percent by value. However, Okon (2018) highlights that deficient port infrastructure often causes delays, congestion, bottlenecks and increased costs for maritime operations and trade flows. Consequently, engineering infrastructure improvements in Nigeria's ports and maritime domain represents a crucial imperative for stimulating blue economy sectors, facilitating external trade, attracting shipping traffic, easing supply chain costs, and driving wider national growth prospects. This paper examines the key engineering infrastructure needs of Nigeria's ports and maritime sector that must be addressed to support accelerated blue economy growth and harness inherent potentials within the domains of shipping, fisheries, coastal tourism, offshore oil and gas, and maritime transport. Analysis of major infrastructure gaps is conducted drawing on cargo traffic statistics, performance indicators, and infrastructure quality metrics over a 15-year period. Key recommendations and a strategic blueprint are proposed for vital engineering infrastructure interventions in Nigeria's ports and maritime architecture.

1.1 The Blue Economy

The blue economy concept recognizes the ocean as development spaces that must be sustainably tapped for economic prosperity (Mulazzani & Malorgio, 2020). Blue economy covers traditional ocean industries like fisheries, maritime transport, and coastal tourism as well as emerging industries like offshore renewable energy, aquaculture, seabed extractive activities, marine biotechnology, and submarine cables (Schutter & Hicks, 2019). The World Bank (2017) estimates that the global blue economy is worth over US$1.5 trillion per year and anticipates growth to over

US$3 trillion by 2030. Hence coastal countries like Nigeria with vast maritime domains stand to gain tremendously by strategically harnessing the potentials of blue economy sectors. However, as noted by Silver et al. (2015) suitable infrastructure is imperative for stimulating key maritime industries, facilitating trade flows, easing logistics connectivity, and providing the platform for blue economy enrichment.

2 Nigeria's Ports and Maritime Sector

This sector serves as a critical backbone for external trade and economic prosperity accounting for over 95 percent of exports and imports (Buhari, 2019). Prior to the 2006 port reforms, the sector was plagued by acute infrastructure decay, monumental port congestion, chaotic administrative bottlenecks from multiplicity of agencies, and poor service quality that eroded competitiveness (Mfon, 2013). These factors constrained maritime sector contribution to national GDP compared to more strategic roles played by the sector globally in powering blue economy for other coastal states. However, the 2006 concession programme granting port terminal leases to private operators helped transform infrastructure, improve efficiency, and achieve record cargo milestones over recent years as presented in Figure 1 showing cargo throughput over 16 years.

Table 1: Cargo throughput in metric tonnes at Nigerian ports for 16 years (1995 - 2011)

YEAR	IMPORT	EXPORT	THROUGHPUT	TURN-AROUND (DAYS)
1995	9,289,971	3,983,082	13,273,053	6.17
1996	10,224,300	5,251,001	15,475,301	6.34
1997	11,213,624	5,369,181	16,582,805	6.71
1998	14,286,864	5,038,854	19,325,718	7.31
1999	15,751,331	6,481,605	22,232,936	6.31
2000	19,230,496	9,702,384	28,932,880	7.01
2001	24,668,791	11,271,901	35,940,692	7.91
2002	25,206,380	11,780,861	36,987,241	11.34
2003	27,839,293	11,926,652	39,765,945	7.89
2004	26,907,075	13,909,872	40,816,947	6.44
2005	29,254,766	15,697,312	44,952,078	7.40
2006	29,089,268	17,061,250	46,150,518	5.31
2007	35,544,965	21,928,385	57,473,350	3.75
2008	41,195,616	22,787,133	63,982,749	4.59
2009	45,757,149	20,018,360	65,775,509	6.55
2010	46,928,848	29,815,879	76,744,727	5.38
2011	52,010,440	31,439,592	83,450,032	5.48

Source: Nigerian Ports Authority

The cargo traffic analysis shows rising imports dominating total throughput, indicating the import dependent nature of the economy. As further depicted in Figure 2, while exports remained under 40 percent, total cargo volumes increased markedly post-concession reaching a peak of 84 million metric tonnes in 2011. The peak coincided with surging oil prices which expanded government spending and boosted imports for infrastructure projects (Akinwale, 2012).

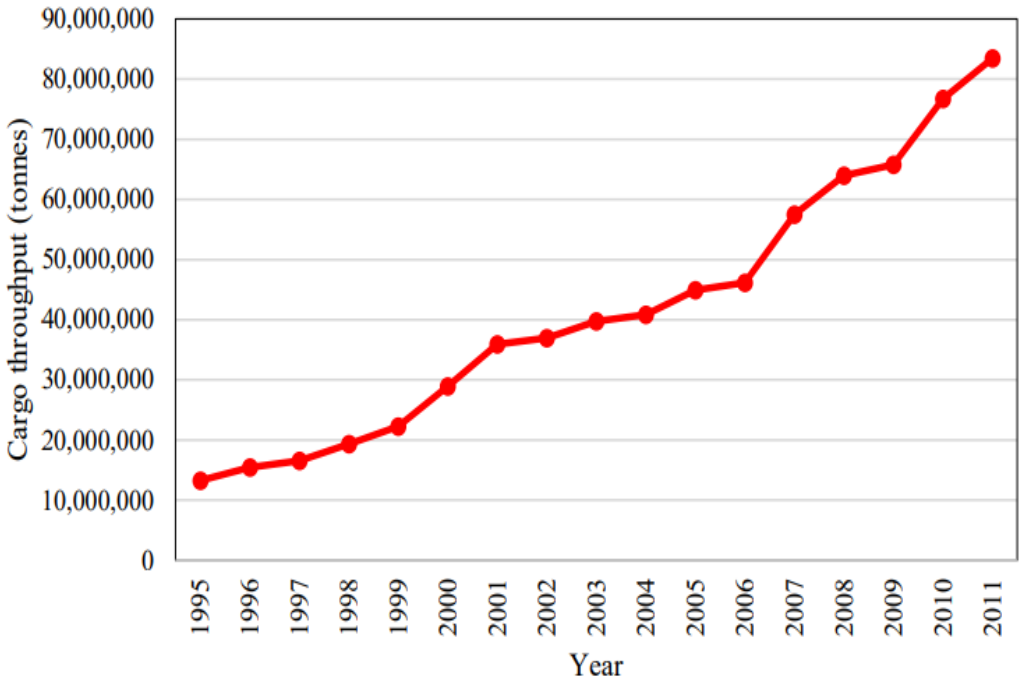

Figure 1: Rise of Cargo Throughput at Nigerian Ports (1995 – 2011) [Source: NPA Statistics]

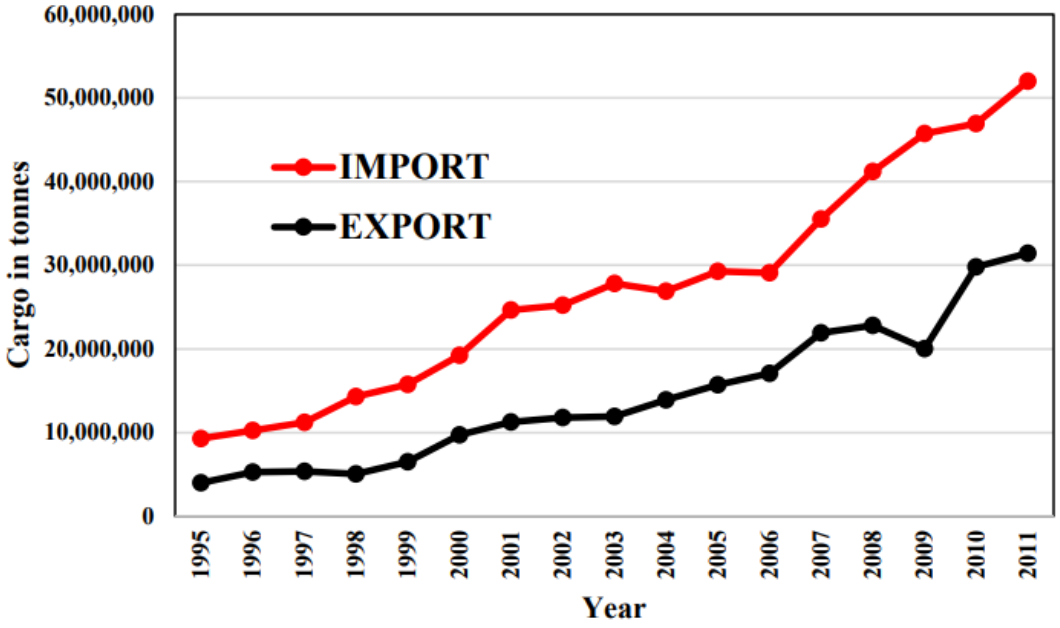

Figure 2: Cargo trade showing import and export for 1995 – 2011 [Source: NPA Statistics]

Figure 3 shows the disparity between import and export in percentages. The chart clearly displays the country's over dependency on import. However, several underlying constraints still inhabit efforts to attain higher efficiency thresholds and fully catalyse the maritime sector for optimal blue

economy impact.

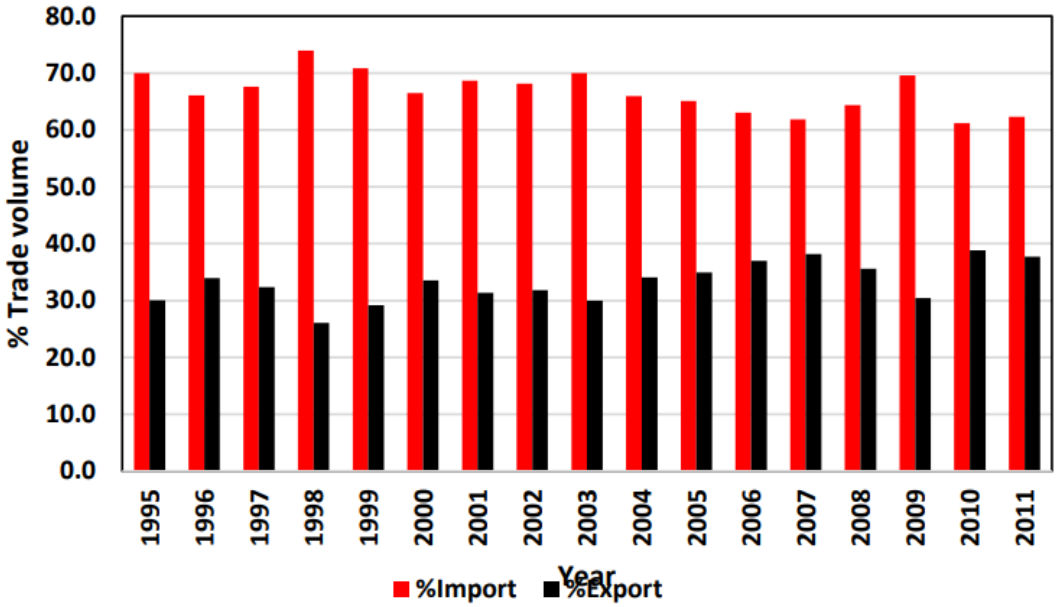

Figure 3: Percentage import and export of cargo through Nigerian ports for 1995 – 2011

The absence of modern cargo handling equipment, the use of obsolete port terminal infrastructure and inefficient cargo clearing process have extended the turnaround time for maximum two days (48hrs) to has high as 12 days as indicated in Figure 4.

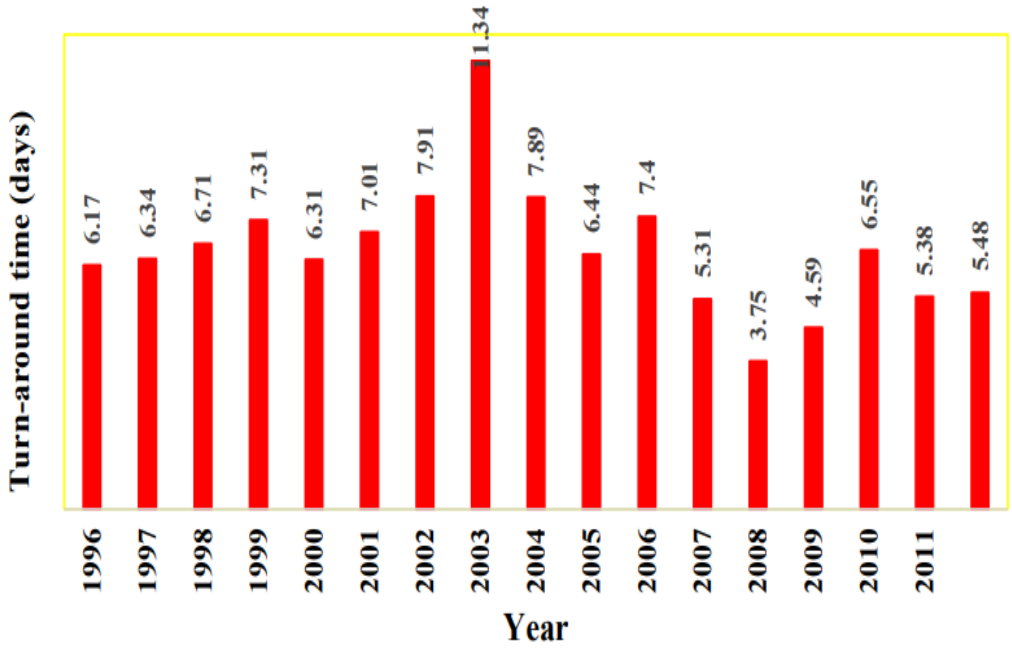

Figure 4: Cargo vessel turnaround time at Nigerian ports for 1995 – 2011

3 Critical Maritime Infrastructure Needs

Nigeria urgently requires significant investments in maritime infrastructure to eliminate current capacity shortages, facilitate trade flows and catalyse blue economic activities across coastal regions. Key engineering infrastructure projects that require priority implementation include:

3.1 Seaport Infrastructure Nigeria currently lacks deep seaport infrastructure to accommodate

Very Large Container Carriers (VLCCs) and Ultra Large Crude Carriers (ULCCs) which now dominate global shipping and oil transportation (Nwanosike & Tipi, 2021). Figure 5 displays this category of ships requiring a large draught. With just three meters depth, Nigeria's premier Lagos ports remain shallow, unable to allow large capacity new generation vessels. Larger container vessels also divert to neighbouring countries. The impacts constrain shipping, undermine transshipment hub prospects, increase costs, and impede wider maritime productivity essential for blue economy optimization as identified by (Okeke, 2014).

(a) (b)

Figure 5: Cargo ships requiring a large draught: (a) VLCC and (b) ULCC

Though Nigeria recently completed the Lekki Deep Seaport to support 90,000 tonnes DWT ships, other ports need similar engineering interventions. Proposed Badagry Deep Seaport is also underway but further deep seaport projects are vital at Onne, Calabar, Warri, and Port Harcourt to expand capacity. Deep seaports allow efficient consolidation of export cargo from agricultural, solid mineral and oil sectors into VLCC loads attracting more shipping traffic and revenues. Hence engineering deep seaport projects remains an urgent maritime infrastructure priority.

3.2 Dry Port Infrastructure Nigeria's dry port infrastructure is also grossly inadequate.

The few inland container depots (ICDs) including Isiala Ngwa, Jos and Funtua are small facilities unable to alleviate landside bottlenecks and seaport congestion. Dry ports when fully developed promote intermodal transport, provide platforms for cargo consolidation, shipment of imports to inland areas, and exports from production zones to seaports. Hence engineering more dry ports close to major cities using PPP models is crucial for shipping cost reduction, inventory savings, decongestion and toll-revenue generation, as dry port usage expands in consonance with cargo throughput growth.

Figure 6: Dry cargo port solution to decongesting port terminals

Expanding dredging and maintaining adequate depths along vital shipping channels on Nigeria's coastal shelf, rivers, estuaries, and port locations will allow safer passage for bigger vessels and prevent ship groundings. This will facilitate movement of containers through inland waterways,

spurring maritime connectivity with inland locations.

Figure 7: Dredging and widening of water channels for navigation

Currently, heavy siltation of channels frequently hampers navigation. Attaining over 13 meters depth and 200 meters width dimensions for the channels ensures they align suitably with engineered deep seaport requirements. The dredging and channel engineering must also capture inland water channels, especially along Rivers Niger and Benue, to support IVTM catalysed by more dry ports.

3.4 Inefficient Seaport Infrastructure and Systems

Current cargo volumes already exceed handling capacity at major ports often resulting in long vessel queuing, waiting times and gridlocks as shown in Figure 8 (Mfon et al, 2018). It underscores the urgent need for expanding port infrastructure to keep pace with Nigeria's growing maritime trade and support emerging sectors. Key aspects include:

i. **Electronic Call-up System:** Adoption of digital truck call-up platforms with RFID technology integration can optimize cargo evacuation, decongest port access roads, and enhance supply chain visibility.

Figure 8: Nigerian seaport congestion due to inefficient seaport facilities and systems

ii. **Rail & Road Networks:** Interconnecting seaports to key inland trade hubs through modern rail and road linkages will ease congestion, facilitate inland container transports, and support multi-modal cargo distribution.

iii. **Truck Transit Parks:** Establishing trailer parks and holding bays fitted with required amenities will address haphazard truck parking and congestion around ports arising from delays.

iv. **Inland Container Depots:** Building dry ports and container freight stations linked with seaports by rail will ease congestion through port decentralization and extend inland access to maritime trade.

3.5 Multimodal Transportation and Roads Network

As (Adekanbi, 2021) highpoints, developing intermodal transport infrastructure is pivotal for efficient freight distribution from ports inland. Nonetheless, Nigeria's ports have remained seaside enclaves with huge landside disconnect partly accounting for bottlenecks and rising haulage costs. Rail infrastructure is a key imperative allowing bulk freight transfers over long distances complementing trucks for intra-city distribution. Hence a coordinated port-rail interconnection engineering agenda involving channelization of dedicated freight rail-lines into key seaports is profoundly important to support dry port operations as shown in Figure 9.

Figure 9: Multimodal transport solution for enhanced maritime operation.

Furthermore, specialized engineering works to expand and upgrade maritime access roads into seaports, strengthen pavement capacity and construct functional truck parks for articulated vehicles used in haulage operations is vital for seamless freight flows. (Ogunsanwo, 2021) stresses investing about N80 billion in roads upgrades serves as key infrastructure priority for boosting port productivity. Hence integrative rail and road engineering interventions remain utmost imperatives.

3.6 Cargo Handling Infrastructure

As earlier highlighted, gaps in handling equipment and terminal infrastructure often undermine operational efficiency, service quality and overall productivity. Hence engineering aspects must prioritize procuring large capacity quay cranes, extending berth space, constructing stacking areas along with installing automated cargo handling systems essential for fast turnaround of vessels, as indicated in Figure 10. Nigeria can adapt leading global ports operational efficiency by deploying engineering innovations in automated guided vehicles, smart logistic technologies, truck call up apps and AI powered analytics for cargo forecasting and traffic scheduling as (Kumar & Haq, 2021) propose.

Figure 10: Cargo handling equipment at port

3.7 Ship Building & Repair Yards

New shipyards provisioned with modern slipways, fabrication workshops and equipment will foster domestic vessel construction and maintenance capacity to tap into demands for offshore oil/gas, fishing trawlers etc. as shown in Figure 11.

Figure 11: Shipyard for ship building and repairs

Engineering designs, technical studies, environmental impact assessments and commercial feasibility analysis need to be urgently undertaken on these infrastructure initiatives to determine costs, site locations and project timelines for successful implementation and profitability.

3.8 Infrastructure for Ships and Ports Security and Safety

As indicated in Figure 12, maritime security remains indispensable for business continuity, vessels, and cargo safety. Hence engineering aspects must encompass perimeter fencing, CCTV systems, sensors, scanners, patrol boats, channel marking and vessel traffic systems (Adewumi, 2015). Robust engineering interventions in security infrastructure foster confidence, attracts more shipping traffic and stimulates spin-off for ancillary maritime services.

Figure 12: Ships and ports security and safety

4 Recommendations for Advancing Port and Maritime Infrastructure

A concerted strategy encompassing planning, engineering, financing, reforms, and capacity building is essential:

4.1 Infrastructure Masterplan

Detailed infrastructure development plans focused on augmenting port capacity synchronized with maritime connectivity expansion needs to be formulated considering forecasted blue economy growth across sectors.

4.2 Public-Private Partnerships

The immense costs needed make private sector participation critical through PPP models for accelerated infrastructure delivery across Greenfield deep seaports, terminals, dredging, digital

systems, and intermodal links. Viability gap funding can potentially offset initial risks.

4.3 Customs, Regulations and Policy Reform

Streamlining excessive red tape, taxes, and paperwork to expedite clearances while reforming tariff structures through greater regional harmonization. Fiscal incentives also need to promote sustainability focused engineering infrastructure adoption.

4.4 Local Content Requirements and Capacity Building

Mandating joint ventures and local sourcing stipulations in projects can enable skills development in areas like port engineering design, construction, mechanization, equipment fabrication, digital technologies, and environmental management. Table 2 summarizes the major engineering infrastructure needs highlighted based on gaps analysis that must be urgently bridged to boost productivity.

Conclusion

As coastal countries globally prioritize marine resources more consciously for economic diversification, Nigeria must equally harness inherent maritime potentials optimally towards expanding the frontiers of domestic blue economy agenda for sustainable growth. However, substantial engineering interventions focused on bridging infrastructure gaps represent a critical success factor. Thus, implementing the proposed strategic blueprint for maritime infrastructure upgrading serves as a vital avenue for supporting the engineering revamp considered indispensable towards bolstering the productivity, efficiency, global competitiveness and blue economy prospects of Nigeria's ports and maritime sector.

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