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Dry-Docking Technologies: Assessment and Perspective in the Nigeria Maritime Sector

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Abstract

The study presents a detailed review of dry-docking practices in Nigeria and some selected maritime countries. Dry-docking is a critical operation for the inspection, maintenance, and repair of ships, ensuring seaworthiness and compliance with international safety standards. Across Nigeria, the sector faces numerous obstacles including inadequate infrastructure, limited capacity of existing docks, high operational costs, and heavy reliance on foreign facilities. In the study, various maritime standards, recommended practices, and insights from academic and industry literature were systematically reviewed, focusing on current practices within Nigeria's maritime industry and beyond. This study aimed to develop a sustainable framework for vessel docking maintenance that is economically accessible to vessel owners, thereby promoting adherence to best practices and ensuring sustainable ship maintenance in Nigeria. Findings reveal that docking practices in the country are also selective, and existing policies and frameworks are largely unsustainable given the national maritime sector's ambitions. A novel docking technology is proposed to support sustainable framework in addressing prevalent tendencies of cost-cutting and profit-driven compromises, hence, fostering responsible maintenance practices in the shipping sector.

Keywords: Dry Docking, Nigeria, Ship Repair, Maritime Industry, Challenges, Floating Dock, Infrastructure

1.0. INTRODUCTION

Dry-docking is a fundamental process in the maritime industry. It is the process of removing or lifting a ship out of water for the underwater part of the hull to be accessed for inspection, maintenance, repair, and ensuring the seaworthiness of ships (Morra, 2011). Globally, it serves as a preventive measure to uphold vessel safety, prolong operational lifespan, and maintain compliance with international maritime standards. In Nigeria, dry-docking is especially crucial given the country's dependence on maritime trade, oil and gas transportation, and growing domestic shipping activities.

Despite its importance, the dry-docking sector in Nigeria faces numerous challenges. Existing facilities are limited in number and capacity, often leading to congestion and long waiting periods for vessels. Infrastructure deficiencies, such as aging docks and insufficient supporting equipment, hinder efficient operations. High operational costs, coupled with a reliance on foreign dry-docking services, further strain the local shipping industry and lead to capital flight. Moreover, meteorological and oceanographic conditions, such as high tidal variations and

seasonal storms, pose operational risks, particularly for floating dock systems, which are more sensitive to environmental fluctuations.

Technical expertise is another critical constraint. Skilled personnel in ship repair, maintenance planning, and dock operation are in short supply, often necessitating the engagement of foreign specialists. This limits the ability of Nigerian facilities to handle complex repairs or large vessels, reducing competitiveness in the regional maritime industry. Furthermore, gaps in modern dock technology, lack of standardization, and insufficient regulatory enforcement exacerbate operational inefficiencies.

These challenges highlight the urgent need for investment, technological innovation, and policy support to strengthen Nigeria's dry-docking capacity. Addressing these limitations is essential not only for improving the maintenance and repair of vessels but also for fostering a sustainable maritime industry, reducing dependency on foreign facilities, and enhancing national ship repair capabilities.

The study reviews the current dry-docking practices across Nigeria, evaluates the challenges faced by local operators, and examines opportunities for modernization and expansion of the sector by making inferences from some selected maritime countries. the study aims to inform strategies that can enhance the efficiency, safety, and sustainability of Nigeria's dry-docking industry. A dry-docking perspective is sought after in this work for ship owners, marine companies and the maritime sector generally with a capability of carrying and maintaining small and mid-size ship. A perspective dry-dock system is expected to be cheap, fast in operation, easily accessible and can also transit from one location at sea to another to perform its operations at various locations. It will serve as another novel facility used in dry-docking of marine vessels at marginal expense and at higher speed.

1.1. Systematic Review of Methodology

A systematic review approach was applied to assess dry-docking practices, challenges, and regulatory frameworks across Nigeria, China, Rotterdam, and Singapore. The review focused on two main sources: various maritime standards and academic and industry literature.

1.2. Scope of Maritime Standards

The various maritime standards in this study refer to internationally recognized regulations governing ship maintenance and dry-docking operations. These include the International Maritime Organization (IMO) conventions, Safety of Life at Sea (SOLAS) and the International Convention for the Prevention of Marine Pollution (MARPOL) requirements, the International Safety Management (ISM) Code, and classification society rules such as China Classification Society (CCS), Det Norske Veritas (DNV), and Lloyd's Register. National regulatory documents

and port guidelines from the selected countries were also reviewed to enable cross-country comparison.

1.3. Selection of Academic and Industry Literature

The materials used in this study were entirely secondary data obtained from published conference papers, journal articles, technical reports, and relevant documents from maritime agencies in the respective countries. These sources included policy literatures, practice literatures, and research literatures relating to dry-docking operations and maritime infrastructure.

A systematic qualitative review was employed to examine these materials. The process involved identifying relevant maritime standards, screening academic and industry publications, and critically analyzing their content to draw technical inferences. This approach enabled the study to synthesize existing knowledge and develop a new perspective on dry-docking concepts suitable for the Nigerian maritime environment.

2.0 MATERIALS AND METHODS

The materials used in the work were secondary data from published conference, journal and technical papers as well leading relevant information from maritime agencies of the respective countries. These include policy literatures, practice literatures and research literatures. The method employed was primarily critical qualitative reviews of literatures and drawing inferences and shaping a new perspective in dry-docking concept.

2.1 Types of Dry-Dock

Dry Docks as hydro technical naval buildings serve to keep ships in a given position without the participation of liquid in which they could be submerged. Different types of dry docks are used for repairing and maintaining of ships. According to Otter, (2003), the most common ones are:

i. Graven dock
ii. Floating dock
iii. Marine Rail Dock
iv. Shiplift
v. Marine mobile lifts

Among these, the marine mobile lifts and ship lifts are mainly used for small vessels such as recreational yachts, tugs, pilot boats, etc. Generally speaking, there are mainly two types of dry-dock systems in Nigeria for seagoing vessels. They are Graven and Floating docks (Otter, 2003).

i. Graven Dry-Dock

A graven dock is a permanent, land-based structure constructed from reinforced concrete, with supporting blocks, retaining walls, and a gated entrance. Vessels are floated into the dock and positioned on keel and bilge blocks. Once the vessel is correctly aligned, the dock gates are

sealed, and water is pumped out, exposing the hull for inspection, maintenance, and repair. Modern graven docks use steel and concrete gates, which may be hydraulically operated or mounted on rollers for smooth operation (Ramli & Sobri, 2018).

ii. Floating Dry- Dock

A floating dry dock is a U-shaped, buoyant structure that can lift vessels out of water for maintenance, repair, or salvage. Vessels are positioned as the dock submerges through ballasting, and then raised by de-ballasting to rest on keel blocks. Floating docks are constructed from steel with integrated ballast tanks and are usually deployed in sheltered harbors to minimize the impact of waves and tides. They are classified into Caisson-type, where the bottom and wings are continuous, and Pontoon-type, where the bottom consists of individual pontoons connected to the dock wings (Sadeghi et al., 2018).

2.2 Dry docking in Nigeria

According to the Nigerian Maritime Administration and Safety Agency (COSCO Shipping Repair, 2022) 35% of marine vessels were serviced using Graven docks in Nigeria while 65% relied on floating docks between 2014 and 2023, as demonstrated in the chart shown in Figure 1

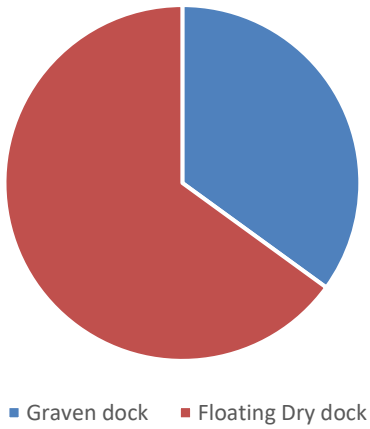


Figure 1: Comparison of Graven Dock and Floating Dock Utilization in Nigeria (2014–2023)

This reflects the growing preference for floating docks in Nigeria, largely due to their flexibility, ease of installation in coastal areas, and lower construction and maintenance costs compared to traditional Graven docks, which require permanent excavation and heavy civil works. Graven docks, though durable and capable of handling large vessels, are fewer in number and face challenges such as high capital investment and limited expansion capacity. In contrast, floating docks like those operating in Lagos, Warri, and Onne have become more practical solutions for servicing offshore support vessels and commercial ships.

Details of the Comparison of Floating and Graven Docks are presented in Table 1.0.

Table 1.0: Comparison of Floating Docks and Graven Docks

S/N	Parameter	Floating Dock	Graven Dock
1	Construction Cost	Relatively lower (steel, modular, relocatable).	Very high (requires excavation, concrete, heavy infrastructure).
2	Installation	Flexible – can be sited in coastal waters with minimal civil works.	Fixed – permanent installation; cannot be relocated once built.
3	Capacity (Vessel Size)	Suitable for medium to large vessels, limited by pontoon design.	Accommodates very large vessels, including naval ships and supertankers.
4	Maintenance of Dock	Requires regular upkeep (ballast tanks, pumps, corrosion control).	Lower frequent maintenance (concrete structure), but pumping systems still need care.
5	Repair Operations	Efficient for short-term or routine repairs; widely used for offshore support.	Best for heavy, complex, or long-term repairs requiring a stable environment.
6	Operational Cost	Lower running cost, scalable with demand.	Higher operational cost, energy-intensive dewatering.
7	Durability / Lifespan	25–40 years (steel maintenance critical).	50+ years (robust, permanent structure).
8	Accessibility	Can be placed near offshore bases and ports (Onne, Warri, Lagos).	Limited to existing locations (Apapa Graven Dock, Naval Dockyard Lagos).
9	Flexibility of Use	Highly flexible – can be expanded, relocated, or modified.	Inflexible once built; modifications are costly.

2.3. Docking Systems in Selected Maritime Nations

To better understand Nigeria's dry-docking landscape and the operational inefficiencies affecting its ship repair industry, it is important to examine how similar systems function in other maritime nations with more established infrastructures. This section explores the docking systems in China, Rotterdam (Netherlands) and Singapore, three global leaders in ship repairs and maritime engineering, highlighting their operational methods, regulatory frameworks, and challenges.

2.4. Dry-Docking in China

China's maritime industry operates thousands of docking and repair facilities distributed across coastal cities such as Shanghai, Dalian, Guangzhou, and Qingdao. The country's docks accommodate a wide range of vessels ranging from bulk carriers and tankers to container ships and naval vessels, using both the graven and floating dock systems.

2.4.1. China Maritime Regulatory and Oversight Framework

China's docking and ship repair industry operates under a layered regulatory structure designed to maintain safety, technical quality, and compliance with international maritime standards (COSCO Shipping Repair, 2022). Oversight responsibilities are divided among several key agencies:



Figure 2.0 China Maritime Regulatory Framework

i. Ministry of Transport (MOT): Sets national maritime infrastructure policy and technical standards for shipyards, including those handling large commercial and naval vessels. The MOT ensures national alignment with international frameworks such as IMO and SOLAS while promoting modernization across China's major docking hubs.

ii. Maritime Safety Administration (MSA): Acts as the enforcement body, overseeing compliance with safety, environmental, and operational regulations. The MSA is also responsible for licensing shipyards, auditing docking operations, and investigating incidents related to maintenance failures or pollution during docking.

iii. China Classification Society (CCS): Provides technical inspections, surveys, and certifications for both vessels and shipyards. It ensures structural integrity and operational readiness in accordance with national regulations and international classification standards.

iv. Local Port Authorities: Handle day-to-day regulation of port and docking operations, including coordination of emergency response, pollution control, and waste management during repair or maintenance work.

Collectively, these agencies establish a broad compliance framework aimed at ensuring consistency across China's vast maritime sector. However, enforcement is not always uniform. Differences in regional capacity, funding, and technical expertise lead to gaps between policy and practice, especially in smaller or provincial shipyards. Overlapping administrative functions sometimes slow approval processes, while limited oversight resources contribute to inspection delays (COSCO Shipping Repair, 2022). These systemic inefficiencies can extend vessel downtime and increase operational costs, thus, creating a measurable economic burden for ship-owners who depend on tight turnaround schedules.

2.4.2. Common Docking Methods in China

China's ship repair and maintenance industry relies primarily on graven docks and floating docks, with graven docks remaining the most common and widely utilized method across major coastal shipyards. These include facilities in Shanghai, Dalian, Guangzhou, and Zhoushan, where extensive dry-docking infrastructure accommodates large vessels such as oil tankers, container ships, and naval craft. On the other hand, floating docks, though secondary in usage, have expanded significantly in recent years in China. They provide greater operational flexibility, allowing shipyards to service vessels of varying tonnage without the need for permanent shore-based infrastructure. Floating docks are particularly common in medium-sized provincial ports in China and among private repair firms catering for coastal or offshore service vessels (COSCO Shipping Repair, 2022).

This dual-system approach enables China's shipyards to maintain both high-capacity, fixed dry-docking operations for large ships and mobile, adaptable docking solutions for smaller and medium-tonnage vessels.

2.5. Dry-docking in Rotterdam, Netherlands

Rotterdam, one of the world's busiest and most advanced maritime hubs, has an extensive network of ship repair and dry-docking facilities that support both commercial and naval operations. Strategically located along the North Sea, Rotterdam's port complex stretches over 40 kilometers and hosts major shipyards such as Damen Ship repair Rotterdam, Keppel Verolme, and Rotterdamsche Droogdok Maatschappij (RDM) Rotterdam, each offering comprehensive repair, maintenance, and conversion services.

The city's shipyards accommodate a diverse range of vessels, including Liquefy Natural Gas (LNG) carriers, offshore support vessels, container ships, oil tankers, and cruise liners. Docking operations primarily employ graven docks and floating docks, with advanced automation and environmental management systems ensuring compliance with strict European maritime regulations.

Rotterdam's dry-docking infrastructure has evolved to meet global sustainability goals, emphasizing energy efficiency, digital monitoring, and eco-friendly waste management. The city's position as a global maritime hub ensures that its docking facilities operate at a high technical standard while maintaining alignment with international conventions such as Safety of Life at Sea (SOLAS), the Convention for the prevention of Maritime Pollution (MARPOL), and the International Maritime Organization (IMO) guidelines.

2.5.1. Rotterdam Maritime Regulatory and Oversight Framework

The docking and ship repair industry in the Netherlands functions under a coordinated regulatory framework that ensures environmental compliance, operational safety, and technical integrity. Key oversight bodies include (Port of Rotterdam Authority, 2021):

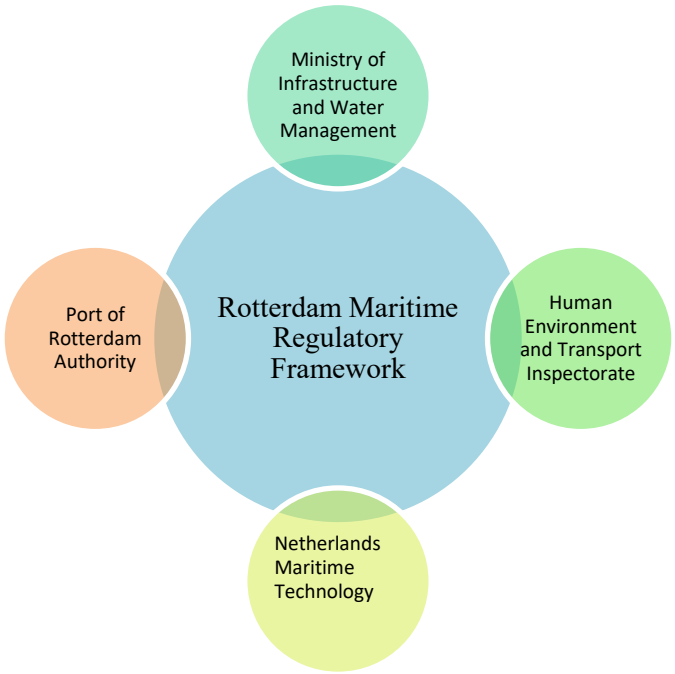


Figure 3.0 Rotterdam Maritime Regulatory Framework

i. Ministry of Infrastructure and Water Management (I&W):

This ministry Oversees the maritime infrastructure policy, environmental standards, and technical compliance across national shipyards. It enforces alignment with European Union maritime directives and international safety codes.

ii. Human Environment and Transport Inspectorate (ILT):
This unit functions as the primary enforcement agency, ensuring ship repair operations meet the European Union (EU) and IMO safety, pollution, and labour standards. ILT also licenses shipyards and investigates incidents involving environmental violations or maintenance-related accidents.

iii. Netherlands Maritime Technology (NMT):

This sector represents the Dutch shipbuilding and repair industry, supporting innovation, sustainability, and collaboration between private shipyards and government agencies.

iv. Port of Rotterdam Authority:

The Port of Rotterdam Authority manages port infrastructure and logistics, coordinating environmental monitoring, waste management, and emergency response during docking and repair operations (Damen Ship Repair Rotterdam, 2023.). Together, these bodies maintain a high standard of regulatory compliance, ensuring that Rotterdam's docking sector remains efficient, environmentally responsible, and globally competitive.

2.5.2. Common Docking Methods in Rotterdam

Rotterdam employs a range of modern docking systems designed for efficiency, versatility, and environmental protection. As stated earlier, the main docking methods are the Graven and Floating dock system.

The graven dock is the primary docking method used in Rotterdam's large industrial shipyards. Facilities such as Damen Ship repair Rotterdam and Keppel Verolme operate massive concrete-lined graven docks capable of handling ultra-large crude carriers (ULCCs), naval vessels, and offshore platforms. The Floating docks, on the other hand, play a complementary role, particularly for medium-tonnage vessels, tugboats, and offshore support units (Damen Verolme Rotterdam, 2023). These docks are designed for rapid service operations and mobility within the port. Many are equipped with automated ballast systems, corrosion-resistant coatings, and waste collection units for environmental safety.

2.6. Docking in Singapore

In Singapore, dry docking is a major maritime service due to the country's strategic location along one of the world's busiest shipping routes. Singapore hosts some of the world's most

advanced and busiest ship repair and dry docking facilities (Maritime and Port Authority of Singapore, 2022).

2.6.1. Singapore Maritime Regulatory and Oversight Framework

Dry docking operations in Singapore are regulated and guided by several maritime authorities and international conventions (Maritime and Port Authority of Singapore, 2024).

i. Maritime and Port Authority of Singapore (MPA):
This is the main regulator overseeing maritime safety, ship registration, and port operations.
ii. Singapore Registry of Ships (SRS):
The Singapore Registry of Ships ensures compliance with flag state requirements.
iii. Workplace Safety and Health Council (WSHC):
This unit regulates shipyard safety standards.
iv. National Environment Agency (NEA):

The National Environment Agency regulates pollution and waste management from shipyard activities.
These bodies apply standards of IMO Conventions, SOLAS, MARPOL, the International Safety Management (ISM) code and Classification Society Rules in carrying out their operations. They maintain a high standard of regulatory compliance, ensuring that Singapore's docking sector remains efficient, environmentally responsible, and globally competitive.

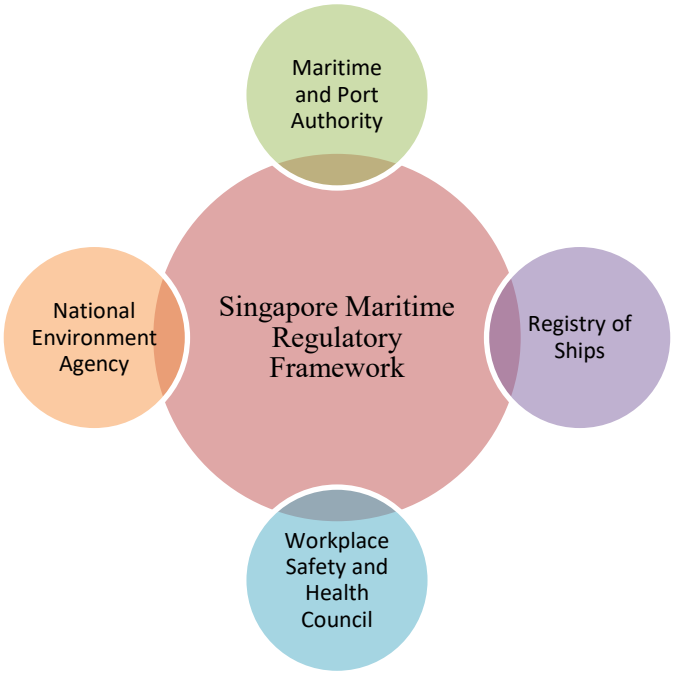


Figure 4.0 Singapore Maritime Regulatory Framework

The common methods of dry docking in Singapore are the Graven Dock, Floating Dock and the Syncrolift / Shiplift System. The Syncrolift / Shiplift System make use of a platform that can be lowered into the water, the vessel is positioned, and the platform is lifted vertically using synchronized hoists. The vessel is then transferred on rails to a dry working berth, where the maintenance is carried out (Alhaouli, 2023). This system is common for smaller ships such as tugs, offshore support vessels etc.

2.7. Challenges of Dry Docking in Singapore, China and Rotterdam

Despite advanced technologies and strong regulatory frameworks, the docking systems in these countries face several technical, financial, environmental, logistical and operational challenges. These issues are common to these countries under study, and by extension, to other maritime countries. The challenges of dry-docking systems influence sustainability across the nations' ship repair industries. Figure 5.0 presents a summary of the challenges.

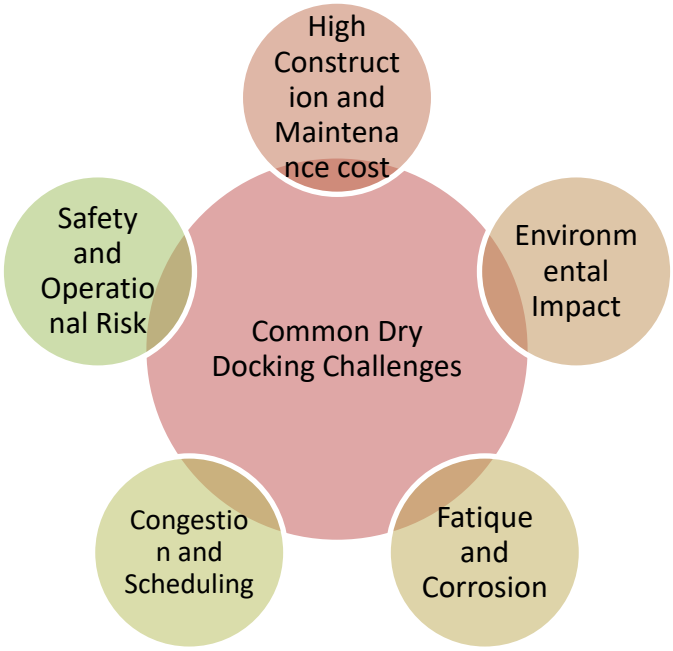


Figure 5.0 Common Challenges of Dry Docking in Singapore, China and Rotterdam

i. High Cost of Construction and Maintenance

Graven docks require extensive excavation, reinforced concrete, and complex pumping systems. The cost of constructing a single large graven dock can run into hundreds of millions of dollars, making them economically viable only for major state-owned or heavily subsidized shipyards. The long-term maintenance of these facilities, especially those built in the 1980s and 1990s demands continuous investment in drainage systems, corrosion protection, and gate machinery.

Furthermore, operating graven docks requires substantial energy for water pumping, heating, and lighting. As energy prices in Europe continue to rise, operational or maintenance costs for large dry docks have increased significantly, reducing profitability for independent shipyards.

ii. Congestion and Scheduling Constraints

Often times, due to high demand, dock spaces, vessels are booked months in advance. Once a vessel occupies a graven dock, no other vessel can be serviced until the repair cycle is completed. This single-occupancy limitation often creates scheduling bottlenecks, particularly in major ports leading to longer turnaround times and revenue loss for shipyards, and vessel operations and charter commitments for ship owners.

iii. Environmental Impact:

The process of draining, cleaning, and repainting vessels within dry docks generates pollutant runoff and chemical waste. Proper treatment of these materials is costly, and non-compliance with environmental regulations can lead to penalties, adding to the financial strain on operators.

iv. Structural Fatigue and Corrosion:

With respect to floating docks, repeated cycles of submersion and refloating expose them to severe metal fatigue, hull deformation, and corrosion. These conditions increase maintenance frequency and cost, especially in saltwater environments.

v. Safety and Operational Risks:

Floating docks are vulnerable to external environmental factors such as wind, waves, and tidal currents. Improper ballast management or uneven weight distribution can cause instability during lifting, posing safety risks to personnel' and vessels.

2.8. Types of Dry Docks Facilities in Nigeria

Nigeria's maritime industry is supported by a diverse range of dry-docking facilities, each tailored to accommodate various vessel types and sizes. These facilities play a crucial role in maintaining the operational readiness of the national fleet and ensuring compliance with international maritime standards. Listed below are the various types of dry-docking facilities in existence in Nigeria.

i. **Niger dock Shipyard**

The Niger Dock Shipyard is located in Snake Island Integrated free zone, Lagos State. Basically, it has a Graven Dock of 25,000 Dead Weight Tons (DWT) capacity, and a Floating Dock of

5,000 DWT capacity. The graven Dock accommodates vessels up to 200 meters in length and 33 meters in beam.

The Shipyard specializes in shipbuilding, repair, maintenance, and refurbishment. Notably, over 700 vessels have been dry-docked in the past decade, including complex projects such as rig refurbishments and large vessel constructions (NIMASA, 2019).

ii. **Naval Dockyard Limited**

The Naval Dockyard Limited is located in Ahmadu Bello Way, Victoria Island, Lagos State. It has a Graven Dock of 20,000 DWT capacity and accommodates vessels up to 180 meters in length and 10,000 tons in displacement (NIMASA, 2021). The Shipyard Provides comprehensive dry-docking services, including vessel inspection, hull cleaning and painting, propulsion system maintenance, and complete vessel overhauls.

iii.. **Shipside Drydock Limited**

The Shipside Drydock Limited is located in Okirika Creek, in Port Harcourt, Rivers State. It has a floating Dock with Maximum lifting capacity of 5,000 tons. The dimensions of the dock are 110 meters in length; external and internal beams of 32 and 26 meters, respectively (The Guardian, 2025). Shipside Drydock Limited offers a wide range of services, including blasting and painting, maintenance of propulsion systems, engine works, bow thrusters, rudder systems, hatches, piping systems, shaft works, winches, generators, electrical systems, navigational equipment, classification surveys, rig fabrication/revamping, piping work, and water jets replacement.

iv. **West Atlantic Shipyard**

The West Atlantic Shipyard is located in Onne Oil and Gas Free Zone, Federal Ocean Terminal, Onne Port Complex, Rivers State. It has a Floating Dock which accommodates vessels of capacities up to 200 meters in length and 30 meters in beam (AllAfrica, 2025). The West Atlantic Shipyard specializes in ship repair and maintenance services, catering for the oil and gas sector.

2.8.1. Challenges of Dry Dock Systems in Nigeria

Dry-docking remains a vital component of vessel lifecycle management, providing the platform for inspection, maintenance, and repair of hulls, propulsion systems, and underwater fittings. In Nigeria, however, the available dry-docking facilities have not kept pace with the growing demands of the maritime sector, particularly with respect to coastal trade, offshore oil and gas support, and naval operations. The few operational Graven and floating docks in the country are heavily concentrated in Lagos and a handful of coastal centers, leaving large areas underserved.

Moreover, many of these facilities are constrained by operational inefficiencies, environmental vulnerabilities, and high maintenance costs.

As a result, Nigerian shipowners frequently resort to foreign shipyards for essential maintenance, leading to extended downtime, capital flight, and reduced competitiveness of the national fleet. To contextualize the need for innovative solutions, it is important to highlight the prevailing challenges within Nigeria's dry-docking system, which continue to limit efficiency, safety, and accessibility. The challenges of Dry Dock Systems in Nigeria are enumerated in the following points;

i. Geographical Concentration and Limited Accessibility

The distribution of dry-docking facilities in Nigeria is highly uneven, with the majority concentrated within Lagos State. Niger Dock PLC, with a rated capacity of 25,000 tons, and the Nigerian Naval Dockyard, with a capacity of 10,000 tons (Punch Newspapers, 2022), represent the largest and most frequently utilized installations. Outside Lagos, smaller facilities such as Starzs Marine and Engineering in Onne and the West Atlantic Shipyard in Port Harcourt provide limited capacity, while several other yards remain either inactive or underutilized. This concentration of infrastructure creates accessibility challenges for vessels operating in Calabar, Warri, and the inland waterways of the Niger Delta, which must transit considerable distances to access docking services. Such inefficiencies lead to prolonged downtime, increased operational expenditure, and in certain cases compel shipowners to seek foreign docking facilities, thereby exacerbating capital flight from the local maritime sector.

ii.. Stability Limitations of Floating Docks in Adverse Conditions

Floating docks in Nigeria, though offering relative flexibility compared to fixed Graven docks, are inherently constrained by environmental loads. Facilities such as those operated by the West African Dry Docks and Niger Benue Transport Company experience difficulty maintaining station under strong tidal currents, wave actions, and seasonal winds prevalent in Nigeria's coastal and estuarine waters (Punch Newspapers, 2023). These stability issues compromise docking precision, extend operation times, and elevate safety risks for both vessels and personnel. In contrast, graven docks, such as Niger dock, offer superior structural stability but lack geographical adaptability. Thus, the instability of floating docks in exposed environments remains a significant limitation within the Nigerian context.

iii. Inefficiency of Ballasting and De-ballasting Operations

The ballasting systems employed by most Nigerian dry docks are based on conventional pump-driven mechanisms, which, while reliable, are time-intensive. Submergence and refloating cycles often require extended durations, thereby limiting throughput. At facilities such as the Naval

Dockyard in Lagos and Starzs Shipyard in Onne, the docking of medium-sized vessels is frequently delayed due to the slow pace of ballast water transfer operations (Business & Transport, 2018). In a national context where only six out of ten shipyards are functional, such inefficiencies compound congestion and significantly constrain the available docking windows. This limitation is particularly detrimental to support vessels in the oil and gas sector, where operational delays directly translate to financial penalties and lost production time.

iv. High Corrosion Rates and Maintenance Costs

Nigeria's tropical marine environment, characterized by elevated temperatures, humidity, and salinity, accelerates corrosion in both fixed and floating dock structures. Graven docks such as Niger Dock require continual maintenance of gates, pumping systems, and structural culverts to maintain operational reliability (CIOD Nigeria, 2025). Floating docks, by virtue of their constant immersion, face even higher corrosion-related costs, necessitating frequent hull plating renewals and reapplication of protective coatings. For instance, the floating docks at West African Dry Docks have required repeated interventions to counter steel degradation, resulting in prolonged downtime and significant expenditure (Trusted Docks, 2023.). These high lifecycle maintenance costs reduce profitability and act as a disincentive for private investment in new dry-docking infrastructure within Nigeria.

V. Absence of Real-Time Monitoring and Control Systems

A further limitation of Nigerian dry dock facilities is the lack of integrated real-time monitoring and control systems. Vessel alignment, trim, and load distribution are largely managed through manual operations and operator experience rather than automated or sensor-driven processes. Even at relatively advanced facilities such as the Naval Dockyard, ballast control remains conventional, without comprehensive instrumentation for monitoring six degrees of freedom, wave forces, or inclination. Smaller facilities, such as Shipside Dry Docks in Lagos, operate with minimal digital integration (Wikipedia, 2025). This absence of real-time monitoring increases the risk of misalignment on keel blocks, inefficient load transfer, and operational delays, while also precluding predictive maintenance practices that are standard in more advanced ship repair facilities worldwide.

3.0. RESULT AND DISCUSSION

3.1. Proposed Solution: Pneuma-dock Dry-dock System

The challenges identified in Nigeria's dry-docking sector highlight systemic limitations in capacity, stability, corrosion, efficiency, and technological advancement. Addressing these issues

requires solutions that are not only cost-effective but also flexible, resilient, few parts or components exposed to corrosion agents, efficient, and technologically adaptive to Nigeria's unique maritime environment. Conventional Graven docks, though reliable, are capital-intensive and geographically rigid. Floating docks, while more flexible, are prone to instability, corrosion and high maintenance costs, and operational inefficiencies. Given the need to deal with some of these dry-docking challenges, the design and construction of PneumaDock: a novel, mobile dry-docking system powered by pneumatic inflation and stabilized by retractable spud legs is presented. It is designed for small and mid-size vessels to eliminate ballast reliance, reduces structural bulk, and enhances seakeeping performance for regions with limited shore-based facilities, such like Nigeria.

The pneumaDock shown in Figure 6 with exploded view shown in Figure 7 provides a substantial alternative and innovative solution to cost and maintenance challenges, location/site flexibility, time demand and corrosion resilience.

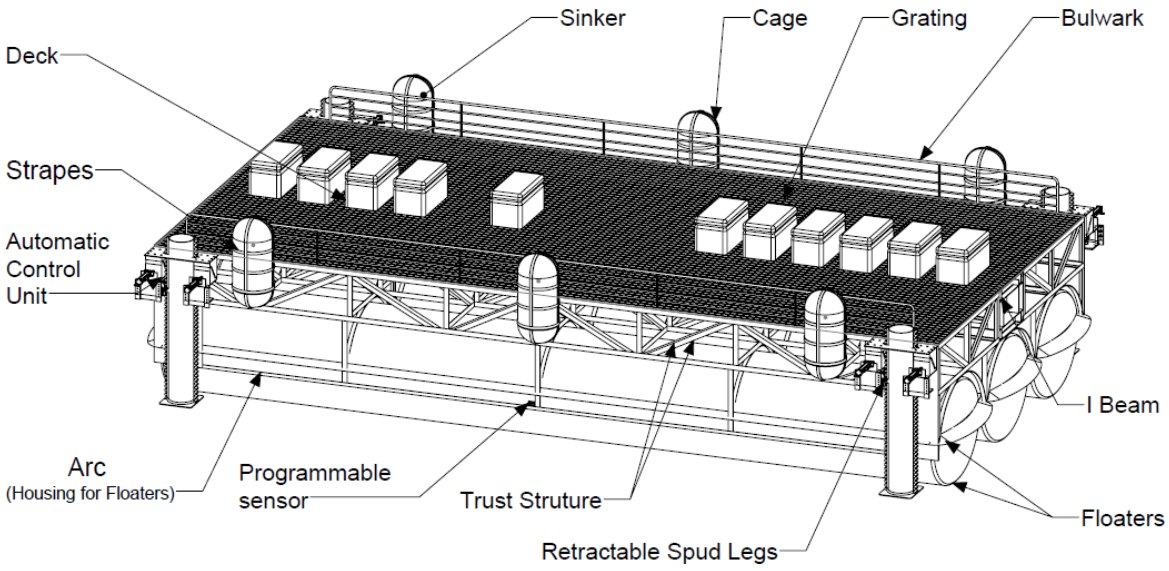


Figure 6.0: Pneuma-Dock Assembly

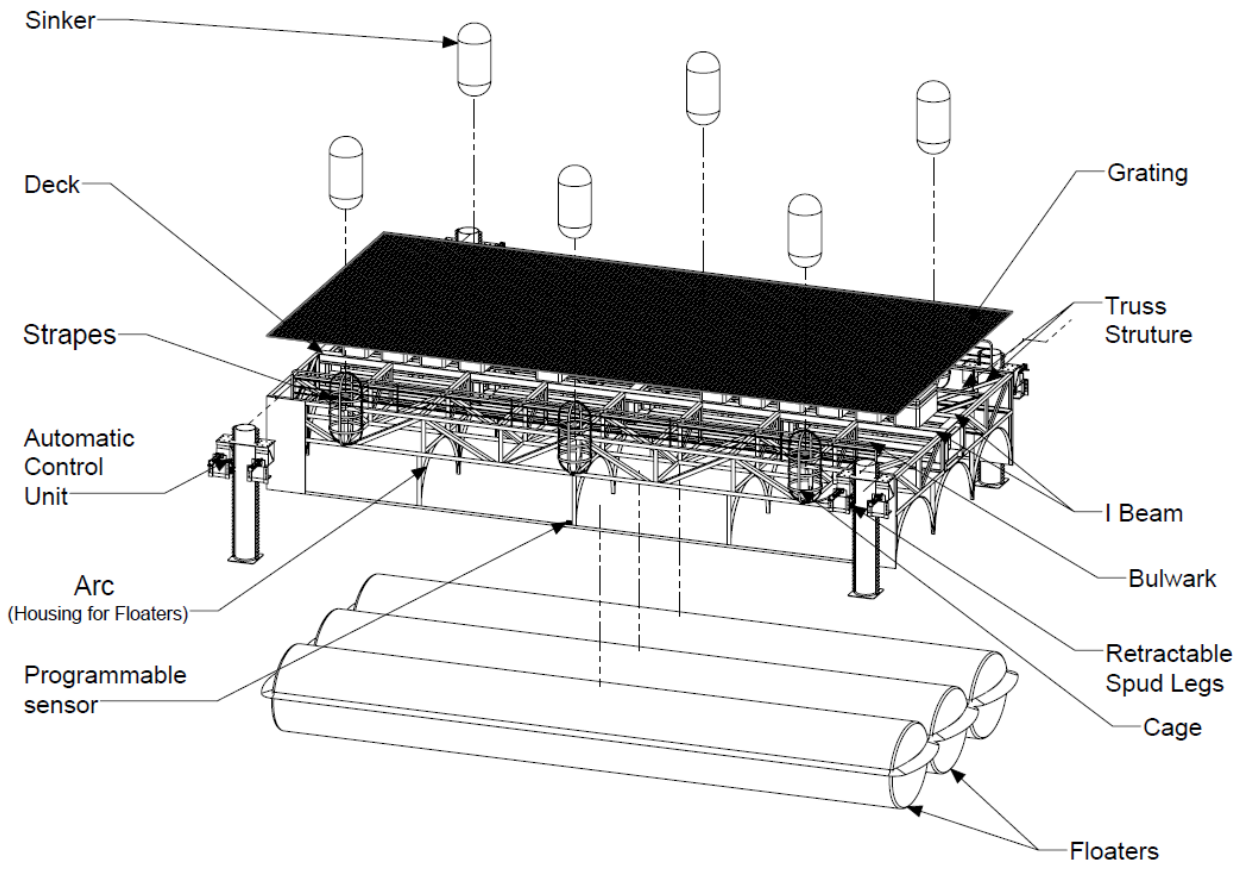


Figure 7.0: Exploded View of Pneuma-Dock

The general arrangement drawing of the Pneumatic mobile dry dock (pneuma-dock) is shown 8.0. Unlike conventional fixed or floating docks, the proposed system combines mobility, pneumatic buoyancy control, seabed anchoring, and advanced monitoring capabilities. By leveraging floaters, sinkers, retractable spud legs, and an integrated automatic control unit. The design offers a versatile and scalable platform for ship maintenance. It is specifically tailored to improve accessibility across underserved regions, enhance stability under environmental loads, reduce turnaround times through efficient pneumatic systems, and lower lifecycle maintenance costs through material optimization.

This innovative concept represents a practical engineering solution that directly addresses the deficiencies of most current dry-docking facilities.

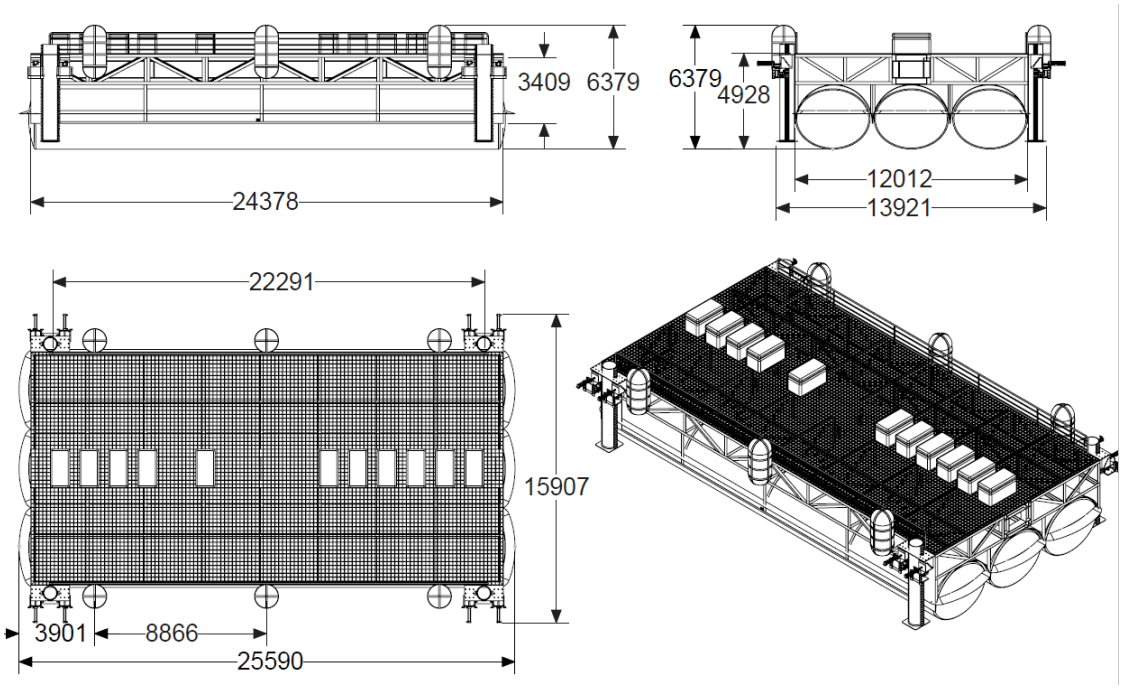


Figure 8.0: Isometric Diagram of the Pneuma-Dock (all dimensions in mm)

3.2. Major Principles Governing the Pneumatic Mobile Dry Dock

The operational concept of the PneumaDock is founded on four core scientific and engineering principles that collectively enable controlled submergence, lifting, stability, and reliable vessel support. These principles ensure that the system remains both technically feasible and operationally effective.

i. Archimedes' Principle of Buoyancy

The fundamental scientific basis of the system is Archimedes' law, which states that a body immersed in fluid experiences an upward force equal to the weight of the displaced fluid (Jahinke, 2007). The PneumaDock applies this principle by inflating and deflating pneumatic floaters to vary the amount of displaced water, thereby controlling its buoyant force. Inflation increases upward buoyancy and raises the dock, while deflation reduces buoyancy and allows controlled submergence beneath the vessel.

ii. Pneumatic Displacement and Air–Water Volume Regulation

The dock uses compressed air as the primary medium for draft control. By altering the internal air volume of the floaters and sinkers, the overall density of the dock is adjusted relative to the surrounding water. Increased air volume results in positive buoyancy, while reduced air volume increases density and enables sinking. This principle allows for rapid, energy-efficient vertical movement without the need for heavy pumping systems as in the case of conventional floating drydocks.

iii. Hydrostatic Stability and Equilibrium Principles

Stability during docking operations is maintained through adherence to hydrostatic relationships between the center of gravity, center of buoyancy, and metacentric height. The structural configuration of I-beams, truss frameworks, and distributed buoyant elements ensures a favorable stability profile. This prevents excessive trim or heel during vessel entry, seating, and lifting, and maintains a stable platform throughout all operational phases.

iv. Seabed Reaction and Structural Fixation (Spud-Leg Principle)

After the vessel is lifted above water level, the dock transits from a floating system to a stabilized platform through the deployment of spud legs onto the seabed. These legs transfer vertical and lateral loads to the seabed, minimizing movement caused by waves or currents. This principle provides the rigidity and steadiness required for hull maintenance, inspection, and repair, ensuring safe and reliable operation.

3.3. Components of the Pneuma docking systems

The PneumaDock is in the form of a pontoon. The main compositions of the pontoon are; I-beam, Truss structure, Floaters, Sinkers, Gratings, RetractableSpud Legs, Automatic Control Unit etc.

i. I-beams:

They are standard structural steel shape widely used as a primary framework in the construction and metal building industry. They are integral to a variety of structures, including bridges, parking garages, skyscrapers, hospitals, and more. Also referred to as H-beams, W-beams, wide-flange beams, universal beams, or rolled joists. I-beams are specifically designed to function as strong support members capable of withstanding diverse types of loads, including heavy weights. In this design, two I-beams were positioned at the center of the deck to serve as the main load-bearing elements for the vessel to be maintained, ensuring structural stability and strength.

The parameters of the I-beam used in the design of the dock are:

Height of beam = 200mm

Web thickness = 27mm

The two I-beams are joined together by other similar I-beams to form the center backbone of the structure and then the other parts of the dock are made using trusses to form the skeletal ribs.

ii. Trusses:

A truss is essentially a triangulated system of usually straight interconnected structural elements; it is sometimes also referred to as an open web girder. The individual elements are connected at nodes; the connections are often assumed to be nominally pinned. Trusses are used because they are very good at carrying vertical loads. There are various types of trusses however the one

chosen for this design is the warren truss. This is because it is an efficient and lightweight structure, often used in applications where weight needs to be minimized while maintaining structural integrity.

The trusses are arranged as follows: 4 longitudinal trusses spaced at equal intervals apart. 17 transverse trusses spaced 1.5m apart. The trusses are made of c-channel having dimensions; 80mm height and 8mm thickness.

iii. Floater:

As stated earlier, the PneumaDock makes use of a pneumatic system for its submergence and emergence in water. Thus for this to be possible, it is provided with air bag-like tube (Floaters), which are inflated and used to keep the dock afloat at all times and are deflated at a controlled rate to enable the dock submerge to lift the ship which needs to be maintained, and finally inflated again to restore the deck afloat. These floaters are three in number and are cylindrical in shape, with diameters of 3 meters each. They are designed using hypalon material. Hypalon is a high temperature, chemical and rupture resistant synthetic rubber material. The floaters are located at the keel or bottom of the dock, positioned in the longitudinal direction.

iv. Sinkers:

The sinkers typically refer to the ballast mechanism used to control the buoyancy of the platform. They are also pneumatically driven. By adjusting the amount of air in the sinkers, the platform's draft and buoyancy are controlled. They are vertically positioned at six points around the dock, with a diameter of 0.4 meter each. They are also designed using hypalon materials.

The sinkers are also designed for submerging and resurfacing of the dry dock, but they operate at the point where the floaters have negative buoyancy. Once at the docking site, sinkers are inflated to control submersion, enabling the structure to sink just below the keel of the target vessel. After the vessel is positioned on the keel blocks, the floaters are reinflated to lift both the dock and the vessel above sea level. The spud legs are then deployed to anchor the system firmly to the seabed before maintenance begins.

v. Grating:

This refers to a framework of parallel or crossed bars or slats, usually made of metal or fiberglass, set at a regular interval to create a mesh-like structure. This arrangement of bars allows for the passage of light, air, liquids, and small objects while providing support and strength. The steel grating serves as the deck plating of the PneumaDock structure. It was adopted for the design due to its less weight and ability to carry loads. The weight of the steel grating measured for the deck is 3tonnes.

vi. Automatic Control Unit

The structure includes an automatic control unit to monitor wave activity, vessel motion, global positioning, and inclination in real time. This unit also governs the spud legs hydraulically, ensuring stable and precise operations under varying marine conditions.

3.4. Operation of the PneumaDock system

The mobile pneumatic dry-docking structure operates through a carefully coordinated sequence that utilizes its floaters, sinkers, spud legs, and automatic control system to safely lift and support vessels for maintenance. Prior to launching, the floaters are partially inflated to provide initial buoyancy, while the spud legs remain retracted. Once deployed into the water, the structure floats and is towed to the docking site by a tugboat, as the dry dock is not self-propelled. The tugboat also transports the compressor used to supply pressurized air for inflating the floaters and sinkers, ensuring the structure itself remains lightweight and stable during transit.

At the maintenance site, the sinkers are inflated to control and regulate the downward submersion of the dock. The floaters are then deflated, allowing the structure to submerge to a depth of approximately one meter below the keel of the vessel to be serviced. The vessel is maneuvered into position and aligned with the docking or keel and bilge blocks located on the dock's working deck. Once the vessel rests securely on these blocks, the floaters are inflated, raising the entire structure and the supported vessel above sea level.

To ensure stability during maintenance, the spud legs are extended until they rest firmly on the seabed, thereby anchoring the structure and eliminating unwanted motion due to waves or currents. This provides a stable and safe environment for inspection, cleaning, or repair activities.

The structure integrates an automatic control unit that monitors and displays critical real-time data, including wave conditions, six degrees of freedom motion, global positioning, and inclination. This system also controls the spud legs and hydraulic power units, enabling precise and automated operation.

Through the combined action of its floaters, sinkers, and spud legs supported by robust material selection such as stainless steel for corrosion resistance and Hypalon for durable floatation elements—the invention offers a flexible, lightweight, and efficient solution for vessel dry-docking in coastal waters.

3.5. How the Pneuma Mobile Dry Dock Addresses the Challenges of most Dry Dock Systems

The comparative review shows that Nigeria's current dry-docking practices face major weaknesses, including limited infrastructure, outdated equipment, weak regulatory enforcement,

and slow operational processes. In contrast, countries such as China, Rotterdam, and Singapore operate advanced, well-regulated dry-docking systems supported by automation, diversified dock types, and real-time monitoring technologies.

These international examples highlight important lessons for Nigeria, particularly the need for improved technological integration, stronger compliance frameworks, greater operational efficiency, and better regional accessibility to docking facilities. The gaps identified demonstrate that Nigeria's existing systems cannot fully support its growing maritime fleet.

These shortcomings justify the development of a new, more flexible and efficient dry-docking framework. The proposed PneumaDock system addresses the identified limitations by offering mobility, enhanced stability, corrosion resistance, faster docking operations, and improved monitoring capabilities positioning it as a viable solution to elevate Nigeria's dry-docking capacity to global standards.

The proposed pneumatic mobile dry dock incorporates several innovative features such as pneumatically operated floaters and sinkers, retractable spud legs, lightweight and corrosion-resistant materials, and an integrated automatic control unit that collectively mitigate the persistent limitations of Nigerian dry-docking facilities. Its operational principle is based on controlled buoyancy and seabed anchoring, while its modular and mobile design enables deployment across diverse maritime locations. The manner in which the system addresses the identified challenges is outlined below.

i. Accessibility and Geographical Concentration

Unlike conventional Graven docks fixed in location, the pneumatic mobile dry dock is designed to be towed by tugboats and deployed at locations where maintenance is required. This mobility decentralizes ship repair infrastructure, extending docking services to regions such as Calabar, Warri, and inland waterways in the Niger Delta. By reducing the need for long transit to Lagos-based facilities, the system minimizes downtime and lowers operational costs, directly improving accessibility for operators of coastal and offshore support vessels.

ii. Enhancing Stability in Adverse Conditions

Floating docks in Nigeria are frequently destabilized by tides, currents, and winds. The pneumatic mobile dry dock counters this limitation through the integration of retractable spud legs that anchor the structure to the seabed during maintenance. Once deployed, the spud legs transfer part of the structural load to the seabed, thereby transforming the dock from a freely floating system to a semi-fixed, stable platform, thereby reducing the most dangerous of the six degrees of freedom motion of a floating structure – Roll motion to zero. This greatly enhances operational safety and reliability under Nigeria's challenging environmental conditions.

iii. Reducing Inefficiency of Ballasting and De ballasting Operations

Conventional pump-driven ballast systems are slow and energy-intensive. In contrast, the proposed design employs pneumatic floaters and sinkers that allow rapid inflation and deflation with compressed air supplied from a tugboat-based compressor. This method shortens the submergence and lifting cycles considerably, reducing docking and undocking time. Faster turnaround enhances the throughput of maintenance operations, which is particularly advantageous in a country where limited dry-docking capacity causes significant congestion.

iv. Mitigating High Corrosion and Maintenance Costs

Corrosion-related degradation is a major cost driver especially in Nigeria's tropical marine environment. The proposed system addresses this through careful material selection: stainless steel is employed in critical load-bearing areas for its durability and weldability, while floaters and sinkers are fabricated from Hypalon material, which offers high resistance to ultraviolet radiation, chemical attack, temperature extremes, and wear. This combination reduces structural degradation, minimizes the frequency of maintenance interventions, and extends service life compared to conventional steel-intensive floating docks.

v. Light Weight Design of the Structure

The Pneuma-Dock structure is designed to have a lighter weight than when compared with other floating dock counterparts. This light weight is achieved by the application of two I-beams as the major structural element which supports the ship to be maintained, and Truss structure surrounding the I-beams. The deck is covered with grating and not plates as commonly used in conventional floating dry docks.

With these structural arrangements, the entire dock does not only have a reduced weight but less components of the dock are exposed to corrosion attack- sea water, as the floater also lifts the structure above still water level during maintenance operation of ships, thereby reducing the rate of corrosion attack on the structure.

Structural analysis on the Pneuma-Dock Structure showed that the dock can support a load of 1.3 times its self-weight. This is an indication of how efficient the pneuma-dock can be.

vi. Real-Time Monitoring and Control

Most Nigerian docks lack integrated monitoring systems. The pneumatic mobile dry dock overcomes this by incorporating an **automatic control unit** capable of recording and displaying wave conditions, vessel motions across six degrees of freedom, global positioning, and structural inclination in real time. This feature not only improves docking precision and block alignment but also provides valuable operational data for predictive maintenance. Such digital integration

aligns the system with modern ship repair standards, significantly improving safety and efficiency over existing Nigerian facilities

vii. Maneuverability in Creeks and Shallow Waterways

A unique limitation of existing dry-docking systems especially in Nigeria is their inability to access shallow creeks and riverine environments where a significant proportion of the nation's inland and coastal fleets operate. Conventional graving docks are permanently fixed in somewhat deep water harbors, while floating docks are constrained to semi-sheltered coastal locations with sufficient depth and anchorage. As a result, smaller vessels serving the oil and gas industry, local ferries, and patrol craft in the Niger Delta must undertake long transits to access Lagos- or Port Harcourt-based facilities, often through challenging navigation routes.

The pneumatic mobile dry dock introduces a new capability by being specifically designed for tow-assisted maneuverability into creeks and shallow waterways**.** Its lightweight modular construction, combined with the use of pneumatic floaters, allows it to maintain buoyancy and stability even in limited depths. Once positioned, retractable spud legs can be deployed to secure the structure on soft or variable creek beds, enabling safe docking operations in otherwise inaccessible locations. This capability decentralizes ship repair services, bringing maintenance infrastructure closer to the point of operation and drastically reducing vessel downtime in riverine regions.

4.0 CONCLUSION

The study of dry-docking systems highlights the urgent need for maritime industry to adopt modern, reliable, mobile, and affordable docking solutions. In the case of Nigeria, despite the country's strategic location as a maritime hub in West Africa, the capacity of existing Graven docks has steadily declined, both in utilization and relevance, due to their high maintenance costs, limited expansion capacity, and rigid infrastructure requirements. At the same time, the growing reliance on floating docks underscores the industry's preference for more flexible and cost-effective alternatives**.**

However, the downtrend in vessels utilizing Nigeria's docking facilities reflects deeper systemic challenges. Many domestic vessels continue to seek repair services abroad, leading to significant financial losses for the nation's economy and shipowners, while also reducing the competitiveness of local yards. With over a thousand cabotage vessels operating within Nigerian waters and an average of 150–200 vessels requiring dry-docking annually, the absence of adequate infrastructure represents a critical gap.

The proposed mobile dry-docking structure presents a transformational opportunity. Its lightweight, modular design, supported by advanced materials and automated control systems, offers not only mobility but also reliability and cost-efficiency. By reducing dependence on

permanent Graven docks and complementing existing floating dock capacity, this system can help Nigeria address its infrastructure deficit, retain repair revenues, and strengthen its maritime independence**.**

In conclusion, bridging this gap through innovative dry-docking technologies is essential for Nigeria to maintain a competitive maritime industry. A docking system that is adaptable, affordable, and sustainable will not only meet the immediate needs of ship repair and maintenance but also position Nigeria as a regional leader in shipyard services, reducing capital flight and boosting the resilience of its maritime sector.

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