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Advancing Floating Buildings with Emerging Construction Techniques in Lagos Coastal Areas

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ABSTRACT

Lagos, a rapidly urbanizing coastal city, faces increasing challenges related to flooding, land scarcity, and climate change. Conventional construction methods are proving inadequate in addressing these issues, necessitating innovative solutions such as floating buildings. This study explores the potential of emerging construction techniques and advanced technologies in developing sustainable floating buildings in Lagos. By evaluating existing floating structures globally and analysing their applicability to Lagos' coastal environment, this research identifies best practices in materials, structural systems, and energy efficiency. A case study of the Five Cowries Terminal waterfront development in Lagos. The interview of some professionals involved in the development, a review of ten relevant articles from different climes around the world and field note analysis provided insights into the basic considerations for waterfront development. Findings highlight the feasibility of integrating prefabrication, marine-grade materials, and smart technologies into floating architecture, ensuring resilience to water-level fluctuations and environmental sustainability. The study proposes a framework for integrating floating structures into Lagos' urban planning policies, addressing these barriers while promoting climate-adaptive and space-efficient development strategies. Ultimately, this research contributes to the discourse on sustainable urbanisation and resilient coastal infrastructure in flood-prone regions.

***Keywords**: Floating Buildings, Coastal Lagos, Pontoon Architecture, sustainable urbanisation, resilient structure*

INTRODUCTION

Lagos' coastal geography is characterised by significant shoreline movement and environmental challenges, primarily caused by industrialisation and climate change. Land use changes from 1986 to 2016 reveal a dramatic increase in built-up areas and a corresponding loss of wetlands and forestlands, indicating extensive urbanisation and land reclamation activities (Idowu et al., 2022) sociopolitical factors, rapid population increase, and poor infrastructure are the main causes of Lagos's urbanisation problems, which result in a wide range of socioeconomic problems.

The necessity of floating buildings arises from the urgent need to address climate change impacts, particularly rising sea levels and urban land scarcity. Research indicates that floating cities can provide sustainable, eco-friendly living spaces that adapt to changing water levels, thereby mitigating risks associated with flooding and loss of coastal settlements (Dalkiran et al., 2023). Furthermore, advancements in technology have facilitated the design of modular floating structures, which could potentially accommodate a significant portion of the global population, thus alleviating pressure on land resources (Bikker et al., 2024). The American Society of Civil Engineers recognises the development of large-scale floating structures as essential for resilient coastal cities, highlighting their role in sustainable urban planning(Wang, 2023). Overall, floating buildings represent a viable strategy for adapting to environmental challenges while promoting sustainable urban growth (Cascino & Arini, 2022).

Problem Statement

The limited adoption of floating architecture in Lagos can be attributed to several interrelated challenges, including economic, infrastructural, and knowledge barriers. While local artisans might be knowledgeable on basic flood-resilient techniques, they often lack the technical proficiency required for advanced construction methods, limiting their effectiveness in enhancing building resilience (Kemwita et al., 2023). Innovative building typologies, such as floating structures, are essential for addressing climate resilience in flood-prone areas like Makoko; however, their implementation is hindered by a lack of specialised training among architects and practitioners, particularly those early in their careers (Ezema et al., 2024) (Nyandega, 2023).

Aim of Study

The study aims to investigate the potential of emerging technologies and innovative construction methods for developing sustainable floating buildings in Lagos state.

Objective of Study

The study analyses international and local floating structures to identify best practices for Lagos, evaluates cutting-edge technologies and environmentally friendly building techniques appropriate for the city's coastline, investigates the economic, socioeconomic, and environmental feasibility of floating structures for urban growth, and suggests a framework for incorporating them into Lagos' urban planning while resolving issues with infrastructure, design, and regulations.

Significance of Study

This study is significant as it addresses the growing need for sustainable and adaptive urban development in Lagos State, a region highly vulnerable to coastal flooding and land scarcity. By exploring emerging technologies and innovative construction methods for floating buildings, the research contributes to the advancement of resilient and climate-adaptive architecture. The findings can serve as a reference for future research on floating architecture in other flood-prone urban areas, positioning Lagos as a leader in sustainable waterfront infrastructure in Africa.

Scope of Study

The study examines Lagos' coastal environment, assessing how floating structures can be integrated into the city's urban development framework to address challenges such as land scarcity, flooding, and climate change resilience.

To provide a well-rounded analysis, the study also incorporates global case studies, with a particular focus on floating structures in Asia and the Netherlands.

Justification of Study

The justification for this study is rooted in the urgent need for sustainable urban solutions in Lagos State, a rapidly growing megacity facing land scarcity, rising sea levels, and recurrent flooding. With a significant portion of its population residing in low-lying coastal areas, traditional land-based construction methods may no longer be sufficient to accommodate urban expansion.

Limitations of the Study

This study faces several limitations, primarily due to the absence of purpose-built floating buildings in Lagos as direct case studies. While the Makoko community consists of floating structures, they rely on traditional construction methods rather than modern technologies, and the LASWA Five Cowries Terminal is not fully floating. Additionally, the study lacks access to detailed engineering data and financial feasibility reports, focusing instead on the application and adaptation of global floating building techniques to Lagos.

LITERATURE REVIEW

Concept and Evolution of Floating Architecture

Floating architecture has emerged as a transformative response to the twin pressures of climate change and urban expansion, particularly in flood-prone and coastal regions. Originally inspired by 19th-century maritime living, the concept evolved into a structured discipline with the advent of *seasteading* and early speculative projects like Kiyonori Kikutake's Marine City, which introduced modular, mobile urbanism as a counter to land scarcity (Yogesh, 2022; Januszkiewicz et al., 2024). Research during the mid-to-late 20th century, including military applications and naval innovations by figures such as Knud E. Hansen, highlighted the interdisciplinary foundations of floating construction (Cascino & Arini, 2022).

Recent real-world applications, such as the floating settlements in Muara Angke, Jakarta, use modular materials like plastic drums and polystyrene to create low-maintenance, flood-resilient housing (Gunarso & Ariaji, 2022). These interventions are often integrated into underutilized waterfronts, promoting both housing expansion and urban regeneration (Penning-Rowsell, 2020).

Architects like Vincent Callebaut and Bjarke Ingels have expanded the scope of floating architecture with technologically advanced projects such as *Lilypad* and *Oceanix City*, which combine sustainability with futuristic urban planning (Januszkiewicz et al., 2024; Piątek, 2022). The typology now includes not only residential developments but also infrastructure such as floating bridges that support sustainable transport with minimal ecological impact (Pal & Sood, 2023).

Case studies from the Netherlands, including the *Floating Pavilion* and *Waterbuurt*, underscore the practical viability of floating architecture, blending resilience with eco-efficiency. These developments signal a paradigm shift in urbanism, prioritising adaptability, modularity, and environmental stewardship (Piątek, 2022; Januszkiewicz et al., 2024).

Floating structures offer an alternative to conventional coastal development, leveraging buoyancy and modular engineering to adapt to fluctuating water levels and promote energy self-sufficiency (Lee et al., 2024; Giurgiu, 2022). While challenges persist—particularly in regulatory frameworks and ecological integration—ongoing innovations in spatial design and construction technologies continue to push the boundaries of what is possible on water (Wang, 2023; Giurgiu, 2022). As such, floating architecture represents not only a practical adaptation strategy but a visionary rethinking of future cities.

Historical Background of Floating Architecture

The origins of floating architecture can be traced to ancient civilizations that developed water-adaptive dwellings along rivers and coastlines. Early examples include prehistoric pile dwellings from the Neolithic and Bronze Ages in regions like Switzerland and Slovenia, which were elevated above water using timber stilts to mitigate flooding and protect from wildlife (Cascino & Arini, 2021; Penning-Rowsell, 2019). In Southeast Asia, long-established communities such as Kampong Ayer in Brunei and settlements on Tonlé Sap Lake in Cambodia illustrate how traditional floating villages evolved to accommodate seasonal water fluctuations.

During the Middle Ages, particularly in the Netherlands, the practice of living on water matured beyond necessity into a strategic adaptation. The Dutch, facing constant threats from the sea, pioneered floating homes and barges repurposed for residential use, drawing on their advanced hydraulic engineering techniques (Moon, 2014). These early innovations laid the groundwork for modern floating urbanism, blending survival with sustainable infrastructure.

In more recent history, floating architecture has become an intentional response to urbanisation pressures, land scarcity, and climate change. The 20th and 21st centuries saw the development of floating platforms, eco-homes, and resilient infrastructure capable of withstanding extreme weather conditions (Wang et al., 2023). High-profile projects such as Schoonschip in Amsterdam, The Maldives Floating City, and Singapore's floating pavilions exemplify the integration of modular construction, renewable energy, and eco-sensitive design in contemporary water-based architecture (Cascino & Arini, 2021).

Today, floating architecture represents the convergence of traditional practices and modern innovation. It not only addresses immediate threats like sea-level rise and land erosion but also redefines the spatial logic of cities by legitimizing water as a buildable, adaptive, and sustainable urban domain. This historical evolution underscores its growing relevance in architectural and planning discourse globally.

Historical Background of Floating Architecture in Lagos State

Lagos State, a coastal megacity bordered by the Atlantic Ocean and interwoven with lagoons and creeks, has a distinctive history of water-based settlements shaped by geography, socio-economic dynamics, and informal urbanism. Unlike global counterparts that have implemented engineered floating systems, Lagos' floating architecture has traditionally evolved through vernacular, community-driven practices, often lacking formal infrastructural support or technological integration.

The most emblematic of these is Makoko, often dubbed the "Venice of Africa." Established in the 19th century by Egun migrants from Benin and Togo, Makoko emerged as a fishing community along the Lagos Lagoon, grounded in indigenous construction knowledge and adapted to the wetland environment (Faboye, 2019; Olajide & Lawanson, 2022). Dwellings, schools, and public spaces were built on timber stilts, using locally sourced materials such as bamboo and corrugated iron to endure the humid, saline conditions (Adegun, 2020).

While Makoko has demonstrated remarkable cultural resilience and ecological adaptation, its informality has also made it vulnerable to eviction threats, infrastructural neglect, and exclusion from formal urban planning processes (Adelekan, 2018). These conditions have impeded the evolution of floating architecture in Lagos into a structured, sustainable typology.

Nonetheless, the construction of the Makoko Floating School by Kunlé Adeyemi in 2013 signaled a shift toward architecturally engineered floating solutions within the Lagos context. The project served as a proof-of-concept for low-cost, modular, and environmentally responsive floating structures that could address both urban density and climate risks (Adeyemi, 2014). Though not institutionalized, such interventions highlight the potential for integrating traditional practices with contemporary design strategies, positioning Lagos as a key site for future innovation in floating urbanism.

Global Perspectives on Floating Architecture

Floating architecture has gained global attention as a viable solution for urban expansion, climate adaptation, and sustainable living in response to rising sea levels, land scarcity, and coastal urbanisation (Penning-Rowsell, 2019). Across the world, two distinct categories of floating architecture have emerged: vernacular floating settlements, which have organically evolved over centuries in response to environmental and socio-economic factors, and engineered floating infrastructure, which represents modern, technologically advanced solutions for urban and commercial applications. The differences between these two approaches, highlighting their historical evolution, structural characteristics, and socio-economic implications, are also examined.

Vernacular Floating Settlements Vernacular floating settlements are informal, self-sustaining communities that have developed in response to coastal and riverine environments. These settlements typically rely on locally available materials and traditional construction techniques, often without formal planning or government regulation. Examples of such settlements include Makoko in Lagos, the Tonlé Sap floating villages in Cambodia, and the Uros floating islands in Peru.

Makoko, one of the most well-known floating settlements in Africa, emerged in the 19th century as a fishing community established by migrants from the Benin Republic and neighboring regions (Adekola et al., 2019). The settlement consists of stilt houses constructed from wood and bamboo, built over the Lagos Lagoon. Due to the absence of formal infrastructure, residents depend on canoes for transportation, rainwater collection, and makeshift sanitation systems (Eguaroje et al., 2021).

Despite its resilience and adaptive strategies, Makoko faces significant challenges, including flooding, poor sanitation, and government eviction threats due to its informal status (Olajide & Lawanson, 2020). The community exemplifies vernacular floating architecture, where local ingenuity has shaped an adaptive but vulnerable way of life.

The characteristics of Vernacular Floating Settlements are:

- Use of Local Materials – Structures are typically made from timber, bamboo, and thatch, allowing for easy repair and replacement (Kim, 2022).
- Informal Construction Methods – Buildings are constructed without engineering calculations or modern design considerations.
- Social and Economic Resilience – These communities support fishing, trade, and water-based commerce, fostering self-sufficiency (Boano & Hunter, 2021).
- Environmental Challenges – Many vernacular settlements lack waste management systems, leading to pollution and health hazards.

Figure 1: Tonia Sap Floating Village Cambodia

Source; archdaily.com

Figure 2: Makoko Floating Village Lagos, Nigeria Source: vanguard news.com

Engineered Floating Infrastructure: In contrast to vernacular floating settlements, engineered floating infrastructure represents planned, technologically advanced solutions for urban expansion, luxury living, and commercial developments. These structures are designed with sophisticated materials, engineering precision, and sustainability features to address modern urban challenges.

In developed cities, engineered floating infrastructure includes residential, commercial, and recreational structures that integrate advanced construction technologies. Examples include:

- Floating City Prototypes – The Seasteading Institute's Oceanix City proposal envisions a self-sustaining floating city with solar panels, rainwater harvesting, and aquaponic farming (Oceanix, 2022).
- Floating Housing in the Netherlands – The Schoonschip neighborhood in Amsterdam showcases modern floating homes with modular construction, renewable energy systems, and climate resilience features (Koops, 2020).
- Asia's Floating Infrastructure – Singapore has developed floating solar farms, and Japan has experimented with floating hotels and entertainment centers as part of urban expansion (Tan & Lee, 2021).

The characteristics of Engineered Floating Infrastructure are:

- Advanced Construction Materials – Use of concrete pontoons, corrosion-resistant metals, and marine-grade composites for longevity and stability (Moon, 2014).
- Integration of Smart Technologies – Implementation of AI-based water management systems, automated anchoring, and renewable energy solutions (Kim & Park, 2023).

- Formalized Planning and Regulations – Unlike vernacular settlements, engineered floating developments adhere to strict urban planning, safety codes, and government policies.
- Economic Viability and Investment Appeal – Many engineered floating structures cater to luxury markets, tourism, and commercial ventures, distinguishing them from informal floating communities.

comparative Analysis: Vernacular vs. Engineered Floating Infrastructure

Aspect	Vernacular Floating Settlements (e.g., Makoko)	Engineered Floating Infrastructure (e.g., Amsterdam, Singapore)
Construction Materials	Wood, bamboo, thatch	Marine-grade concrete, steel, composites
Building Methods	Informal, traditional techniques	Engineered, prefabricated systems
Infrastructure & Services	Minimal infrastructure, self-sustaining	Integrated utilities, smart technology
Governance & Regulation	Informal, often lacks legal recognition	Regulated, government-approved
Resilience & Sustainability	Adaptive but vulnerable to climate risks	Designed for long-term environmental adaptation
Economic Role	Supports subsistence economy (fishing, trade)	Luxury, commercial, and residential applications

Table 1 Vernacular vs. Engineered Floating Infrastructure

Sustainability and Future Prospects: While both vernacular floating settlements and engineered floating infrastructure serve as responses to water-based living, they differ significantly in their construction methods, resilience, governance, and economic roles. Vernacular settlements such as Makoko demonstrate the adaptive capacity of informal communities, yet they face infrastructural and regulatory challenges. In contrast, engineered floating structures in developed cities are designed with technological innovations, sustainability principles, and economic incentives in mind. The growing global interest in floating architecture suggests that the lessons from both traditional and modern floating communities can inform future sustainable urban planning strategies, particularly in cities like Lagos that are increasingly vulnerable to coastal urbanization challenges.

Emerging Construction Techniques and Materials for Floating Buildings

Floating buildings are emerging as a sustainable solution to address climate change and urbanization challenges. These structures offer advantages such as adaptability to water level fluctuations, relocation potential, and integration of renewable energy systems (Chang-ho Moon, 2012; Habibi, 2015). Advanced construction methods for floating buildings include prefabrication, modular construction, and the use of robotics and 3D printing technologies (Casini, 2022). The development of floating structures requires innovative design principles, flexible installations, and energy-efficient technologies (Jacovic Maksimovic & Krstić-Furundžić, 2020). Floating buildings can incorporate various sustainable features, such as recycled materials, self-supporting plants, and open layouts (Chang-ho Moon, 2012). Additionally, they present opportunities for implementing offshore renewable energy sources like wind, wave, and solar power (Habibi, 2015). As the concept of living on water evolves, floating buildings offer promising solutions for future sustainable development and energy efficiency gains in urban environments.

Advanced Foundation Systems for Floating Buildings

The foundation of floating structures is crucial to their stability, adaptability, and resilience. New techniques ensure that floating buildings are both structurally sound and adaptable to fluctuating water levels.

Pontoon-Based Floating Foundations: one of the most widely used techniques is the floating pontoon foundation, where structures are built on large buoyant platforms made of reinforced concrete or high-density polyethylene (HDPE). These foundations allow for dynamic movement with changing water levels while ensuring stability (Moon, 2014).

- Example: Schoonschip Floating Neighbourhood, Amsterdam – Uses concrete pontoons that provide buoyancy and house essential mechanical systems (Koops, 2020).
- Benefits: Low maintenance, long lifespan, and adaptability to water fluctuations.

Figure 3: Schoonchip Floating Neighbourhood, Amsterdam

Source. Archdaily.com

Semi-Submersible and Amphibious Foundations: some floating buildings utilize semi-submersible foundations, where partially submerged structures remain anchored to the seabed, reducing the impact of waves and currents (Tan & Lee, 2021).

- Example: Floating Pavilions in Rotterdam – Uses a semi-submersible foundation with anchoring mechanisms to withstand water level changes.
- Benefits: Greater stability in rough waters and resistance to extreme weather conditions.

Figure 4: Floating Pavilions in Rotterdam

Source; www. reseearchgate.com

Pile-Supported Hybrid Floating Foundations: hybrid techniques combine floating and pile-supported structures, especially in regions with strong currents or tidal fluctuations. Deep pile foundations are driven into the seabed to provide additional structural support (Xinhao Wang et al., 2023).

- Example: The Five Cowries Terminal, Lagos – Uses deep pile foundation (estimated at 40m depth) for stability while incorporating floating pontoons for docking.
- Benefits: Increased durability and resistance to erosion and wave action.

Figure 5: The Five Cowries Terminal, Lagos

Source: The living spaces.com

Innovative Construction Materials for Floating Architecture

Material selection is critical for ensuring buoyancy, durability, and environmental resilience. New materials enhance the longevity and sustainability of floating buildings.

High-Performance Marine-Grade Concrete: traditional concrete is susceptible to water damage and corrosion in saline environments. Marine-grade concrete, with enhanced resistance to water penetration and corrosion, is now widely used (Penning-Rowsell, 2019).

- Example: The Floating Seahorse Villas, Dubai – Uses marine-grade concrete for underwater sections, ensuring longevity.
- Benefits: Extended lifespan (80–100 years) and resistance to saltwater degradation.

Figure 1: Modular concept System [Land on water project Denmark by mast Architects

Source. www. Archdaily.com.

Lightweight Composite Materials: advancements in composite materials, such as fibre-reinforced polymers (FRP) and carbon fibre, allow for lightweight yet durable floating structures (Kim, 2022).

- Example: Floating Solar Farms in Singapore – Use lightweight composite platforms for solar energy integration.
- Benefits: Reduced weight, high durability, and resistance to marine corrosion.

Recycled and Eco-Friendly Materials: sustainable floating buildings incorporate recycled plastics, bamboo, and reclaimed wood, reducing environmental impact (Boano & Hunter, 2021).

- Example: Makoko Floating School, Lagos – Used bamboo and recycled barrels for buoyancy and sustainability.
- Benefits: Reduces waste and promotes environmental sustainability.

Energy-Efficient and Self-Sustaining Systems: sustainability is a key concern in floating buildings, leading to the adoption of renewable energy sources and self-sustaining systems.

Floating Solar and Wind Energy Integration: floating structures increasingly integrate solar panels and wind turbines to generate power, reducing dependence on traditional energy grids (Koops, 2020).

- Example: Oceanix City Prototype – Features floating solar farms and offshore wind energy systems.
- Benefits: Renewable energy supply, reduced carbon footprint, and cost efficiency.

Figure 2: Oceanix City that features solar farms and off shore wind energy

Source: Archdaily.com

Water Recycling and Waste Management Systems: innovative floating structures include water recycling systems, composting toilets, and waste treatment facilities to ensure minimal environmental impact (Tan & Lee, 2021).

- Example: Floating Hotel in Japan – Uses advanced greywater recycling and sewage treatment technology.
- Benefits: Reduced pollution and increased self-sufficiency.

Climate-Responsive and Adaptive Designs: new designs incorporate passive cooling, green roofs, and automated shading systems to enhance thermal comfort and energy efficiency (Xinhao Wang et al., 2023).

- Example: Rotterdam's Floating Pavilion – Uses double-layer ETFE (ethylene tetrafluoroethylene) cushions for insulation and temperature control.

- Benefits: Energy savings and improved environmental resilience.

Smart Technology Integration in Floating Architecture: the digitalization of construction processes has led to the adoption of smart technologies in floating buildings.

IoT-Based Monitoring and Automation: floating buildings now incorporate Internet of Things (IoT) sensors to monitor water levels, structural integrity, and energy consumption (Kim & Park, 2023).

- Example: Floating Homes in Amsterdam – Use IoT sensors to automatically adjust buoyancy levels based on water fluctuations.
- Benefits: Enhanced safety and efficiency in managing floating structures.

Modular and Prefabricated Construction Techniques: floating buildings increasingly use modular prefabrication, allowing for rapid construction and scalability.

- Example: The Maldives Floating City Project – Built using prefabricated modular sections for efficiency.
- Benefits: Reduces construction time, cost, and environmental impact.

Figure 3: Maldives Floating City Project that features modular construction concept

Source Archdaily.com

AI-Powered Water and Energy Management: artificial intelligence (AI) is now being used for water purification, waste management, and energy optimization in floating buildings (Koops, 2020).

- Example: Oceanix Smart City – Uses AI-driven waste-to-energy systems.
- Benefits: Increased efficiency and long-term sustainability.

Challenges of Coastal Urbanization in Lagos State

Lagos' coastal urbanisation has many drawbacks, especially recurrent flooding and environmental deterioration. Lagos is particularly vulnerable to floods due to its low elevation and proximity to aquatic habitats; this vulnerability is made worse by climate change and the city's growing growth. Inadequate governance and infrastructure exacerbate these issues, having detrimental effects on the natural and built environments. The difficulties and effects of Lagos' coastal urbanisation are covered in detail in the sections that follow.

Recurrent Flooding: Lagos is ranked among the most vulnerable cities to extreme sea levels, with significant population exposure to flooding (Ndimele et al., 2024); informal settlements, such as those in the Idi-Araba area, are particularly affected due to poor-quality buildings and lack of infrastructure (Adegun, 2023); and, the Lekki Peninsula, a rapidly urbanising area, faces high flood risks due to its low-lying topography and storm surge potential (Obiefuna et al., 2021).

Environmental Degradation: Urban expansion in Lagos has led to the loss of ecological assets, including mangroves and swamps, which are crucial for natural flood mitigation (Obiefuna et al., 2021); pollution and wetland loss further destabilise ecosystems, increasing vulnerability to flooding (Ndimele et al., 2024); and, informal urbanisation contributes to environmental degradation, as seen in the coastal informal settlements where natural ecosystems are decimated (Adegun, 2023).

Socio-Economic Impacts: Flooding in Lagos affects livelihoods, and health, and can lead to displacement and fatalities, with women and children being the most vulnerable (Ndimele et al., 2024); the socio-political context, including state failure in service provision, exacerbates flood risks and impacts, particularly for low-income communities (Ekoh & Teron, 2023); while localised strategies, such as community development associations and self-help measures, offer some resilience, they are insufficient without broader governance reforms and infrastructure improvements. Addressing these challenges requires a combination of innovative external initiatives and recognition of natural processes in urban planning to enhance resilience and sustainability in Lagos (Ekoh & Teron, 2023)(Adegun, 2023).

Potential for Floating Building in Lagos State

Faced with rapid urbanization, land scarcity, and increasing flood risks, Lagos State presents fertile ground for the adoption of floating architecture as a climate-resilient and spatially adaptive urban strategy. Drawing from global precedents in Amsterdam and Singapore, Lagos' extensive water networks offer underutilized opportunities for sustainable expansion (Penning-Rowsell, 2019).

Environmental and Climatic Context: Frequent flooding in coastal zones such as Lekki and Victoria Island, driven by sea-level rise and poor drainage systems, underscores the urgency for adaptive infrastructure (Oshodi, 2021). Floating structures, which inherently rise and fall with water levels, provide a non-invasive alternative to land reclamation. Projects like the Makoko Floating School have validated the feasibility of such interventions in Lagos' context (Boano & Hunter, 2021). Scaling these concepts could improve flood resilience while supporting urban growth along waterways (Wang et al., 2023).

Economic and Social Dimensions: Floating developments also offer potential for economic diversification. Inspired by models in the Netherlands and Singapore, Lagos could pursue floating markets, leisure hubs, and Blue Economy assets, including tourism infrastructure like hotels and resorts (Olalekan et al., 2022; Cascino & Arini, 2021). Modular floating homes may also help alleviate the city's severe housing deficit, offering affordable and scalable housing for both formal and informal communities, as demonstrated in several Asian cities (Tan & Lee, 2021).

Technological and Structural Feasibility: Innovations in marine-grade concrete, fiber-reinforced polymers, and prefabrication techniques enhance the viability of floating buildings in high-salinity environments like Lagos (Kim & Park, 2023). Furthermore, the integration of renewable technologies, including solar arrays, wind turbines, and greywater recycling systems, can support off-grid operation, reinforcing sustainability (Koops, 2020).

Altogether, floating architecture offers Lagos a strategic opportunity to reimagine urban growth, mitigate environmental vulnerabilities, and build a more resilient, adaptive, and inclusive cityscape.

Research Gap

Despite growing global interest in floating architecture, its contextual application in Lagos remains under-researched. Most studies focus on developed regions like the Netherlands and Japan, whose regulatory and economic frameworks differ from those in Lagos (Penning-Rowsell, 2019; Koops, 2020). While informal settlements like Makoko exist, there is limited research on adapting modern floating construction techniques to Lagos' urban fabric, particularly regarding material durability, regulatory hurdles, and economic feasibility (Olalekan et al., 2022).

Additionally, opportunities for floating infrastructure in tourism and commercial development, as well as its integration into broader urban planning and impacts on coastal communities, remain largely unexplored (Kim & Park, 2023).

RESEARCH METHODOLOGY

This study adopts a qualitative, interpretivist research framework to examine the advancement of floating buildings and the implementation of emerging construction techniques in Lagos' coastal areas. Rooted in interpretivism, the approach prioritizes understanding human experiences, social dynamics, and contextual realities rather than seeking universal truths. This philosophy supports the exploration of diverse stakeholder perspectives within their cultural and environmental settings.

The qualitative research design was employed to facilitate an in-depth investigation into the social, economic, and environmental implications of floating architecture (Aguilar Solano, 2020). This method is particularly suited to exploring the nuanced experiences of architects, engineers, and members of a floating buildings community in Lagos, allowing for flexible adaptation to emerging insights throughout the study.

A multi-method data collection strategy underpins the methodology. This includes:

- Semi-structured interviews with experts and stakeholders (e.g., ACCL architects, engineers, LASWA officials, residents of floating building in Lagos)
- Field notes on specific conditions and non-verbal cues,
- Case study analysis of the Five Cowries Terminal at Falomo, Lagos, and
- Review of secondary sources, including academic literature and documented case studies on innovative floating construction.

This integrated approach enhances the study's credibility and depth, enabling theoretical understanding as well as practical insights into the feasibility and societal impact of floating infrastructure in Lagos.

A purposive sampling technique was used to ensure participants possess relevant expertise or lived experience concerning floating construction. The study population includes architects, contractors, climate adaptation specialists, government officials, and residents of waterfront communities. This diversity supports a comprehensive understanding of both technical feasibility and community-level implications of floating developments.

Ethical Considerations

Ethical guidelines were maintained and strictly adhered to, including:

1. Informed Consent**:** Participants were briefed about the study's purpose and voluntarily participated.

2. Confidentiality: Respondents' identities were kept anonymous.

3. Data Security: Data was stored securely and used solely for academic purposes.

DATA ANALYSIS AND FINDINGS

This part of the study integrates case study evaluation, interview analysis, and literature review to examine the application of emerging construction techniques in coastal infrastructure, with a focus on the Five Cowries Terminal in Lagos. The case study approach investigates the building's design, construction methodology, material usage, and environmental adaptability, situating it within the broader context of resilient floating architecture.

To supplement the case analysis, semi-structured interviews with architects, engineers, and policymakers were thematically analyzed to identify recurring challenges, innovations, and policy considerations. Insights reveal the importance of contextual adaptability, regulatory flexibility, and material resilience in shaping sustainable floating developments.

A review of 10 peer-reviewed studies (2020–2025), sourced from platforms like Google Scholar, ScienceDirect, and ResearchGate, further contextualizes the Lagos experience. These studies highlight comparable environmental and architectural strategies, offering valuable frameworks and best practices for implementation.

Together, these data sources provide a comprehensive and comparative understanding of the theoretical and practical implications of floating construction in Lagos' coastal zones, bridging the research-to-practice gap.

Case Study Analysis

The Five Cowries Terminal, located in Falomo, Ikoyi, along the Lagos Lagoon, serves as both a transportation hub and the headquarters of the Lagos State Waterways Authority (LASWA). Commissioned on August 30, 2018, the terminal was developed through a public-private partnership, constructed and furnished by MTN Nigeria before being handed over to the Lagos State Government.

This case study highlights the terminal as a model of contemporary, sustainable infrastructure, aligning modern architectural design with the goals of urban mobility and climate adaptation. Key areas of analysis include the project's construction techniques, material resilience in a coastal environment, and its role in enhancing water-based public transport. The terminal illustrates how floating and water-adjacent structures can be effectively integrated into Lagos' broader urban and environmental strategies. The construction team includes:

Client/ Developer: Lagos State Waterways Authority (LASWA) and MTN Nigeria

Architects: Adeniyi Coker Consultants Ltd (ACCL)

Main Contractor: Cappa and D'alberto Plc

Structural Engineers: UF-A Consultants

Quantity Surveyor: Du-Franc & Partners Ltd

Architectural and Structural Design

The Five Cowries Terminal combines modern design with functionality, covering a gross area of 2,010m². The architecture emphasizes sustainability and resilience, tailored to a coastal environment, with features such as natural ventilation and lighting to reduce reliance on artificial cooling. The design optimizes its waterfront setting, incorporating a full-height curtain wall on the southern façade for panoramic lagoon views, while circular perforated windows on the east and west facades enhance light and visual appeal. The northern façade integrates with the roofline, concealing service areas and maintaining a sleek aesthetic. The terminal's white color palette highlights its geometric form against the coastal backdrop.

Strategically located, the terminal is designed to be striking from various perspectives. The east and west wings house essential support facilities, while the terminal includes docking areas, administrative offices, passenger zones, and a café with a private lounge. A floating concrete pontoon adapts to tidal changes, improving accessibility and operational efficiency. The development also features a multi-level car park with 800 spaces, addressing the area's parking needs.

Figure 9: Entrance (North View)

Figure 10: Ramp Leading to Jetty

Figure 11: Multistorey Parking Build

Figure 12: Lagoon View (South View)

Figure 13: West View Showing Cladding/ Openings

Figure 14: Terminal Side View/ Parking

Figure 15: Waiting Lounge

Figure 16: Access Control

Figure 17: Waiting Lounge with 1st Floor View

Figure 18: East View Circular Window Opening

Construction Methods and Materials

The Five Cowries Terminal was built using a combination of conventional and innovative techniques, emphasizing durability and adaptability to its coastal environment. Prefabricated components, such as precast concrete retaining walls, were used to enhance precision and reduce environmental impact. Marine-grade concrete and corrosion-resistant steel were selected to withstand saline conditions and ensure structural longevity, with materials designed to last 80 to 100 years. Additionally, the terminal incorporates flood-resistant features to adapt to rising water levels, enhancing its resilience and suitability for waterfront infrastructure.

Environmental Adaptability and Sustainability

The Five Cowries Terminal incorporates sustainable strategies to minimize its environmental impact on the waterfront. Key measures include erosion control through reinforced embankments, efficient waste management and water treatment systems to protect the lagoon, and the use of solar-powered lighting and passive cooling to enhance energy efficiency. These features ensure the terminal remains environmentally responsible and resilient.

==================================Socio-Economic and Urban Impact

The Five Cowries Terminal significantly contributes to reducing road congestion in Lagos by offering a reliable water transport alternative. It enhances mobility, especially between Lagos Island and the mainland, while supporting economic growth through commercial activity and job creation. Additionally, the terminal aligns with Lagos State's urban development agenda, promoting the modernization of the city's transportation infrastructure.

Challenges and Future Prospects

While the Five Cowries Terminal has made notable contributions to transportation and urban development in Lagos, it faces several ongoing challenges. Maintenance remains a concern due to exposure to harsh coastal conditions, and traffic congestion around the terminal, particularly in Falomo, limits accessibility. Despite the inclusion of a multi-level car park, peak-time demand strains available parking. The terminal's capacity is also limited, and expansion is constrained by the built-up Ikoyi waterfront. Environmental issues, such as potential water pollution and marine disruption, pose additional concerns. Operational challenges related to fluctuating water levels and safety protocols further underscore the need for improved monitoring and emergency preparedness. Regulatory inconsistencies and coordination issues between LASWA and private operators also impact efficiency.

Looking forward, potential improvements include adopting fully floating structures, integrating smart technology for enhanced operations, and expanding capacity to meet growing commuter demand. Despite its challenges, the terminal remains a model for sustainable waterfront infrastructure and plays a pivotal role in shaping Lagos' future in resilient urban development.

Interview Analysis – ACCL

An interview with the architect involved in the LASWA terminal project provided valuable insights into the potential of floating architecture in Lagos. Although the terminal is not a floating building, its design offers relevant lessons. Structurally, foundation design was identified as a major cost factor, with pile foundations used for stability—an approach also applicable to floating structures requiring engineered buoyancy and anchoring. The discussion emphasized the need for floating buildings to align with community needs, urban planning, and infrastructure, highlighting the importance of contextual and environmental assessments.

Economically, while floating buildings can address housing challenges by utilizing underused water spaces, high initial costs and environmental concerns—such as pollution—pose challenges. Modular and prefabricated methods are promising but currently expensive in Lagos. Environmentally sustainable materials and green technologies were recommended to mitigate ecological impact.

Policy-wise, the interview stressed the need for robust government regulations aligned with international standards, including support for safety, sustainability, and innovation. Overall, the LASWA terminal serves as a reference point for future floating developments, demonstrating the importance of careful site analysis, material durability, and climate-responsive design in advancing resilient urban infrastructure in coastal Lagos.

Interview and Observation Analysis – LASWA Project Team

An interview with the LASWA project team, alongside on-site observations, provided detailed insights into the design, construction, and operational management of the Five Cowries Terminal. Structurally, the terminal sits adjacent to water, with only the jetty and floating pontoon directly over it, supported by deep pile foundations and protected by reinforced shoreline systems. These measures, based on environmental impact assessments, ensure long-term durability against water-induced degradation.

Shoreline protection techniques and high-quality, water-resistant materials were used to combat erosion and enhance the structure's lifespan. Although minor vibrations occur due to boat wakes, officials confirmed the building's structural integrity remains unaffected, because of its buffering retaining wall. Flooding is not a significant issue at the site due to mild water currents and effective drainage, with the floating pontoon adapting to tidal changes every four hours.

The terminal has been well received by the public, appreciated for its aesthetic integration and architectural uniqueness—being the only Nigerian building with a floating pontoon. Its design supports a park-and-ride transport model through a seven-level car park, easing road congestion and promoting water-based commuting.

Regular maintenance is critical, especially due to water-induced wear; pontoons are replaced every seven years, with corrosion-resistant materials or coatings used to preserve structural components.

Figure 19: Stacked disused pontoons due to prolonged water exposure at Five Cowrie terminal

Figure 20: Damaged concrete pontoons due to prolonged water exposure

Research Papers Review – Existing Floating Buildings in Europe and Asia

The ten articles selected from the reviewed literature are presented in Table 2. The table outlines the author, year, and country of study, along with the title, key findings, and construction techniques related to floating architecture. These studies highlight various floating building typologies, construction methods, and their practical applications in different regions, focusing on energy integration, climate resilience, and modular design. Additionally, the table provides insights into the decision-making frameworks and engineering solutions adopted in developed and developing countries to implement floating infrastructure successfully.

Author/Year/Country	**Paper Title**	**Study Focus (Floating Building Types & Construction Techniques)**	**Key Findings**	**Challenges**
Sembcorp Tengeh Floating Solar Farm (2021, Singapore)	Sembcorp Tengeh Floating Solar Farm	Large-scale floating solar farm, 60MW capacity, HDPE floats, drone imaging for defect detection	Maximizes land use, contributes to renewable energy goals, minimal environmental impact	High initial cost, need for specialized engineering, maintenance of floating solar panels
Storbjörk & Hjerpe (2022, Sweden)	Stuck in Experimentation: Exploring Practical Experiences and Challenges of Floating Housing in Sweden	Floating housing as a climate adaptation solution; examines urban planning and private-sector involvement	Floating houses provide local identity but are difficult to scale, lack of strong municipal support	Challenges in upscaling, regulatory issues, limited public acceptance
Huebner (2025, Singapore)	Coastal Urban Climate Adaptation and Floating Solutions	Historical and future potential of floating homes, floating offices, and settlements	Floating homes offer lower environmental impact than land reclamation, gaining global attention (e.g., Maldives, Busan, NEOM)	Social acceptance, regulatory constraints, and cost remain barriers to adoption
Stopp & Strangfeld (2017, Germany)	Floating Architecture: Construction on and Near Water	Compilation of case studies on floating homes, offices, and communities	Floating structures provide sustainable urban expansion and climate resilience	Engineering complexity, material costs, and regulatory uncertainties
Petersen (2024, Sweden)	Floating Community: Seasteading as a Solution for Rising Seas	Floating communities as a solution for urban expansion and disaster resilience	Potential for expansion to different cities, adaptable to various uses (e.g., refugee housing, event accommodations)	High investment cost, integration with existing urban infrastructure
Endangsih & Ikaputra (2020, Indonesia)	Floating Houses Technology as Alternative Living on Water	Floating houses as a solution for housing shortages and flood adaptation	Floating homes provide mobility and resilience to rising sea levels	Cost of materials, lack of standardized regulations
Kartheekeyan et al. (2024, UAE)	Exploring the Potential of Floating Architecture & Energy Challenges in the UAE	Floating structures for renewable energy generation and climate resilience	Potential to integrate solar and wind energy, reduce environmental footprint	High energy demands, lack of large-scale implementation
Gupta (2025, India)	Floating Architecture: A Sustainable and Futuristic Approach	Sustainable floating design, alignment with SDGs, and material innovations	Floating buildings reduce land pressure and support climate resilience	Need for specialized materials, high initial cost
Attar et al. (2023, Middle East)	Floating Photovoltaics: Assessing the Potential,	Floating solar farms as a renewable energy solution	Higher energy efficiency due to water cooling effect, reduced land use	Maintenance challenges, vulnerability to extreme weather

	Advantages, and Challenges			
Nguyen et al. (2024, Vietnam)	Architectural Approaches to Floating Housing in Vietnam	Floating housing adaptation to climate change and urbanization	Effective for mitigating flood risks, supports coastal communities	Cultural acceptance, regulatory challenges, affordability

Table 2 Research Papers Review

Research Results and Discussion

The analysis of ten academic studies highlights the growing global interest in floating architecture as a solution for urban challenges like flooding, energy shortages, and land scarcity. These findings are grouped into key themes, with implications for Lagos:

Floating Solar Farms: Studies show that floating photovoltaic (FPV) systems optimize energy generation and reduce land use. Notable examples include the Sembcorp Tengeh Floating Solar Farm in Singapore.

The implication for Lagos is that, given energy shortages and limited land, FPV systems can be integrated with floating buildings to offer off-grid, renewable energy solutions.

Floating Housing for Climate Adaptation: Case studies from Sweden, Vietnam, and Indonesia demonstrate modular, prefabricated, and locally adapted floating housing techniques for flood-prone areas.

The implication for Lagos is that areas like Makoko could benefit from modular, anchored floating homes that offer structural durability, improved sanitation, and better integration with urban infrastructure.

Large-Scale Floating Cities: Examples from Singapore and the UAE showcase floating districts powered by renewable energy and equipped with self-sustaining water systems. The implication for Lagos is that floating cities could help decongest urban areas like Lekki and Eko Atlantic, offering climate-resilient urban expansion. However, implementation will require strong policy support and infrastructure investment.

Modular and Prefabricated Construction: Prefabricated floating pavilions and settlements have shown benefits in construction speed, adaptability, and sustainability.
Implication for Lagos: Modular prefabrication can reduce building time and costs while allowing scalable development across different income groups.

Challenges and Considerations

Regulatory Barriers: Many countries face legal ambiguity around floating infrastructure, which limits growth. Lagos Needs clear zoning laws, safety standards, and policy incentives for floating buildings.

Economic Feasibility: High initial costs and long-term maintenance are major hurdles. Lagos Needs the use of cost-effective, locally sourced materials, as well as financial support through PPPs and international partnerships.

CONCLUSION

This study explored the potential of floating architecture as a sustainable solution for Lagos, addressing urban challenges such as land scarcity, climate change, flooding, and congestion. By examining global case studies from Singapore, Sweden, Indonesia, the UAE, and Vietnam, the research highlights the success of floating solar farms, modular housing, and large-scale urban districts. These developments provide renewable energy, expand urban spaces, and enhance climate resilience, presenting a viable alternative to land reclamation. The study suggests that floating buildings could be beneficial in Lagos, especially in flood-prone areas like Makoko, Lekki, and Badagry. However, barriers such as regulatory gaps, high costs, infrastructure integration issues, and public perception hinder large-scale adoption. To overcome these challenges, the study proposes an implementation framework that combines policy development, technological advancements, and community involvement.

RECOMMENDATIONS

To successfully implement floating architecture in Lagos, a multi-faceted approach is necessary, involving government, urban planners, private investors, and local communities.

Policy and regulatory development is essential. The Lagos State government should establish clear zoning and safety regulations for floating infrastructure, encouraging public-private partnerships through incentives such as tax breaks and grants. Additionally, floating developments should be integrated into Lagos' long-term urban planning to align with sustainability goals.

Technological and infrastructural advancements are also crucial. Prefabricated modular construction methods should be utilized for cost-effective and rapid deployment. Floating solar systems, wind turbines, and energy storage solutions can ensure energy self-sufficiency, while efficient water and waste management systems will reduce environmental impact.

Economic viability and community engagement must be prioritized. Financial incentives, including government funding programs, should support local developers. Public awareness campaigns and stakeholder consultations are key to increasing acceptance and involvement in floating architecture projects.

Framework for Implementation

The study proposes a phased approach to integrating floating architecture into Lagos' urban planning policies, addressing regulatory, infrastructural, and economic challenges.

Action Plan	Key Stakeholders	Short-Term (0-3 years)	Medium-Term (3-7 years)	Long-Term (7+ years)
Policy Development & Zoning	Lagos State Government, Urban Planning Authorities	Draft floating infrastructure policies	Establish pilot floating zones	Full-scale integration into urban policies
Research & Development	Universities, Engineering Firms, NGOs	Conduct feasibility studies	Test and refine floating construction methods	Develop large-scale floating settlements
Investment & Funding	Private Developers, Financial Institutions	Establish PPPs and government incentives	Secure financing for pilot projects	Expand floating communities
Renewable Energy & Infrastructure	Ministry of Energy, Environmental Agencies	Pilot floating solar farms	Integrate renewable energy in floating buildings	Achieve full energy self-sufficiency
Public Awareness & Community Involvement	Local Governments, Media, NGOs	Launch public education campaigns	Conduct public consultations and training programs	Promote large-scale adoption of floating architecture

Table 3 Framework for Implementation

CONTRIBUTION TO KNOWLEDGE

This study makes meaningful contributions to academic scholarship, professional practice, and policy development in the emerging field of floating architecture, with a specific focus on its application within the African urban context.

Theoretically, the research expands the limited body of knowledge on floating architecture in Lagos by contextualizing it within coastal urban development and climate resilience. It bridges traditional informal settlements, such as Makoko, with modern engineered floating systems, offering a new framework for understanding sustainable urban adaptation.

Practically, the study provides a structured model for integrating floating infrastructure into Lagos' urban planning processes. It outlines strategies involving modular construction, renewable energy integration, and innovative financing to reduce urban congestion and enhance sustainability in flood-prone zones.

From a policy perspective, the study recommends specific zoning laws, tax incentives, and government-backed financing mechanisms tailored to floating developments. These proposals offer actionable insights for policymakers in Lagos and other African coastal cities seeking resilient urban solutions.

In terms of engineering and design, the study identifies best practices for construction materials and technologies suited to marine environments. It highlights the potential of smart floating infrastructure incorporating IoT, renewable energy systems, and AI-driven planning to improve performance and scalability.

Overall, the study positions floating architecture as a viable solution to Lagos' challenges of land scarcity, flooding, and energy insecurity. By incorporating these findings into planning policy, Lagos can advance toward a more resilient and sustainable urban future. Further research is recommended to explore local material use, socio-economic impacts, and community-aligned pilot projects.

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