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JOURNAL OF SPATIAL INFORMATION SCIENCES
VOL. 2, ISSUE 1, PP 144–158, 2025 DOI: https://doi.org/10.5281/zenodo.14860903
PUBLISHED 12-02-2025
www.journals.unizik.edu.ng/jsis

GEOSPATIAL ANALYSIS OF JETTY DISTRIBUTION AND ACCESSIBILITY IN PORT HARCOURT METROPOLIS, RIVERS STATE, NIGERIA

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DOI: https://doi.org/10.5281/zenodo.14860903

Abstract

A jetty is a structure extending into a body of water to facilitate vessel berthing, cargo handling, and passenger movement. Port Harcourt Metropolis, a vital hub for oil and gas and maritime activities, lacks comprehensive spatial data on jetties, affecting urban development and maritime efficiency. This study assessed the spatial distribution of jetties in the metropolis using a Garmin 78csx GPS receiver for coordinate acquisition and QGIS 3.28 for mapping. A spatial database was developed, and compliance with Nigerian Port Authority (NPA) standards was evaluated. Results indicate 51 jetties, comprising 46 private and 5 public, with 29 functional, 21 non-functional, and 1 under construction. Additionally, 16 jetties are floating, while 35 are permanent. NPA PTOL is the largest (57,273.68 m²), while Pelfaco is the smallest (99.52 m²). The study recommends increasing jetties in strategic locations to enhance maritime operations.

Keywords: Spatial Distribution, Jetties, QGIS, GPS, Map

Introduction

Nigeria has an enormous potential for creating an effective system of inland water transportation due to its abundance of rivers, streams, creeks, and coastal lagoons [14]. The ability to convey people and commodities to locations distant from the sea is a special advantage of this kind of transportation. It can transport heavy loads over great distances at a reasonable price. Boats, ferries, and other vessels are the main means of transportation in this mode of transportation, which makes use of lakes, creeks, naturally navigable rivers, and coastal areas [14].
The jetty is an essential part of the infrastructure for inland waterway transportation. A jetty is a structure that projects into the water from the shoreline coast [5]. It is usually built to prevent silting and erosion at a harbor entry or channel. In either word, it is an artificial structure that has been carved out of a river, lake, or sea. [5] emphasized that the historic purpose of jetties has been to moor and/or load ships. They are a long, narrow construction that shields a coastline from the tides and currents; they may also be intended for recreational use. Jetties are often constructed from concrete, stone, wood, or dirt [5]. They extend from the shoreline into the water and serve as a barrier against erosion caused by waves, tides, and currents, thus safeguarding the shoreline of a body of water. They also serve the purpose of docking ships and unloading cargos, it can also be utilized to link the land with deep water farther off from the coast [5]. Generally speaking, jetties can be divided into two categories based on how they are used: cargo jetty and

passenger jetty. Jetties are essential for loading and unloading goods, fueling operations, and other nautical tasks in commercial ports. They facilitate the day-to-day activities of fishing vessels in fishing villages, and they supply the infrastructure required for safe and effective boarding and landing in passenger ports. Jetties are essential parts of the world's ports and harbors, acting as vital hubs for the maritime industry. It is impossible to overestimate their significance in supporting industrial operations, maritime trade, and navigation [14]. Jetties are essential for tourism, business, leisure, and social connections in coastal cities. Nevertheless, there are fewer functional jetties available now than there were a few years ago, even in coastal communities with an increasing number of jetty users. Due to this decrease, there are now restrictions on access and a reduction in the advantages that these structures offer to nearby communities and businesses [6].

The metropolitan city of Port Harcourt, located in southern Nigeria, serves as an important center for maritime operations and has a vast network of strategically placed jetties all along its coastline. Historically, these jetties have played a crucial role in supporting trade, transportation, and industrial activities, which has greatly boosted the local economy. Being a significant import and export gateway that connects the area to both domestic and international trade channels highlights Port Harcourt's marine significance [5].

Port Harcourt Metropolis faces significant challenges due to the lack of up-to-date spatial information on jetties and an insufficient number of these facilities to support the city's rapid growth. Jetties play a crucial role in maritime operations, industrial activities, and urban development, yet their accessibility and distribution remain inadequate. As key transportation links, jetties facilitate the movement of goods such as fish, timber, and petroleum products between Port Harcourt and surrounding communities. The absence or limited availability of jetties prolongs transportation time, disrupts trade, and hinders economic activities. Furthermore, the city's rapid industrialization and urban expansion have placed increasing demands on maritime infrastructure. Without proper evaluation, mapping, and expansion of jetties, the existing infrastructure may become insufficient to support Port Harcourt's growing economic and social needs. This underscores the urgent need for a comprehensive spatial assessment and strategic planning to improve maritime connectivity and optimize infrastructure development.

The study focus is to assess the spatial distribution of jetties in Port Harcourt Metropolis, Rivers State Nigeria by determining spatial information of jetties, analyzing its proximity to the nearest landmark, assessing the compliance of Jetties to Nigerian Port Authority (NPA) Operational requirements and producing spatial distribution map of jetties within the Port Harcourt Metropolis.

Understanding the spatial distribution of characteristics and how they are arranged on the surface of the Earth is vital to the study of geomatics. The positions and configurations of cultural and natural features are ascertained through mapping surveys, from which the data is graphically depicted on maps [8]. The idea of spatial distribution is essential to this process because it makes it possible to use Geographic Information System (GIS) techniques which is a system for gathering, storing, verifying, integrating, manipulating, analyzing, and displaying data that is spatially referenced to the Earth in order to analyze and visualize the geographic spread and arrangement of phenomena. Because GIS integrates data and procedures in ways that permit both new and advanced forms of geographical analysis and modeling that are not possible with manual approaches like map overlay analysis; it is a strong technology or tool. Large amounts of data can be mapped, modeled, queried, and analyzed using GIS and kept together in a single database [7]. GIS is distinct because it requires spatial data, which is tied to actual place. The spatial distribution of jetty locations in the Port Harcourt Metropolis can be mapped using GIS technique, enabling spatial analysis and better decision-making for relevant jetty authorities like NIWA (National Inland Waterway Authority).

Study Area Description

The study is Port Harcourt metropolis comprising of the two Local Government Areas (LGA) that makes up the Port Harcourt metropolitan area in Rivers State, Nigeria, is along the Bonny River, an eastern tributary of the Niger River.

The City of Port Harcourt is a significant urban hub in Southern Nigeria. The research area encompasses the coastal zones and water bodies that house several jetties that are essential to the region's marine infrastructure. This location was chosen because of its economic importance, vibrant marine life, and extensive network of jetties that facilitate trade, transit, and industrial activity. Its shoreline is dotted with several jetties, creating a complicated urban landscape. These jetties enable industrial activity as well as facilitate the import and export of goods, among other uses. Because the study area serves as a major hub for maritime operations in the area, it is crucial to conduct a thorough geospatial evaluation in order to improve knowledge and guide sustainable development practices [4].

Location: Port Harcourt metropolis is geographically positioned within the coordinates of Latitude 4°56'42.59"N and Longitude 6°53'7.10"E to the top, and Latitude 4°44'11.07"N and Longitude 6°53'15.34"E to the bottom, forming a polygonal area that defines the study region. The city borders the Local Government Areas (LGAs) of Degema, Emuoha, Ikwerre, Etche, Oyigbo, Eleme, & Okrika. Strategically located at the mouth of the Bonny River in Rivers State, it is approximately 25 km from the Atlantic Ocean, situated between the Dockyard Creek/Bonny River and Amadi Creek. The city's average elevation is around 12 meters above sea level [1]. Port Harcourt metropolis spans across two LGAs: Port Harcourt and Obio/Akpor, as depicted in Figure 1.1.

Topography: The relief of Port Harcourt metropolis is characterized by a low-lying plain with tidal influences impacting the numerous rivers, creeks, swamps, and the nearby Atlantic Ocean. The region has a gently sloping terrain (with elevations averaging between 30m and 50m) in a northwest-southeast direction. The dry land is marked by an upper layer of silt and sand, with the general topography being mostly flat and lying below 20 meters above sea level, sloping gently towards the south [4]. The region's topography falls within the coastal belt dominated by low-lying coastal plains, which are part of the Agbada and Akata formations. This flat landscape, characterized by a labyrinth of swamps, creeks, and waterways, presents challenges for water flow and surface runoff. Major water bodies such as the Bonny River, New Calabar River, and Andoni River connect with the intricate network of creeks and waterways, also serving as conduits for Atlantic Ocean water into the area [11].

Climate: Port Harcourt metropolis falls within the Koppen Tropical Rainy Af climatic zone. The area experiences consistently high temperatures throughout the year, with a mean maximum of around 34°C and a mean minimum of 21°C. The city experiences two distinct seasons: the rainy season and a short dry season, with the latter occurring mainly in December and January. Harmattan is minimally felt in Port Harcourt, and the heaviest rainfall typically occurs in September. The average temperature ranges between 25°C and 28°C, with sparse vegetation, mainly in areas yet to be developed. The proximity to the ocean contributes to the prevalence of freshwater vegetation [4]. The climate, which is influenced by both maritime and continental air masses, results in high temperatures and humidity year-round. The soil is primarily organic, with mangrove swamp alluvial soil found in the northern coastal sediment zones, which are brownish on the surface. Port Harcourt serves as the hub of Nigeria's petroleum industry, alongside a variety of manufacturing and maritime industries, establishing the area as a key economic node [11].

Population: According to the 1991 National Population Census, the combined population of Port Harcourt and Obio/Akpor LGAs was 703,416. By 2006, this figure had increased to 1,000,908 [1]. The rapid population growth has been driven by industrialization and urban sprawl, where small communities have merged to form a megacity, attracting a continuous influx of people [16].

Occupation: Traditional occupations in the study area include fishing, farming, lumbering, and hunting. However, rapid population growth has transformed the occupational landscape, leading to an increase in construction, engineering, civil service, administration, manufacturing, mining, sand dredging, printing, and other public services.

Geology: The soil in Port Harcourt consists of various superficial deposits overlaying thick tertiary sandy and clayey layers, which can be over 100 meters thick in some areas. The high rainfall and temperature levels in the area promote intense chemical weathering of rocks, resulting in the formation of clay minerals that are widespread in the region. The area lies within the sedimentary coastal formations of the Niger Delta, with geological conditions influenced by its proximity to the Atlantic Ocean and the equatorial monsoon climate. Rainfall and temperature patterns are influenced by both maritime and continental air masses [12].

Economy: The economy of Port Harcourt is diverse, with major activities including farming, fishing, trading, craft-making, canoe carving, and mineral exploration. The area's rich oil resources and numerous sea ports and petrochemical plants offer substantial economic benefits, attracting a large immigrant population and accelerating urban growth.

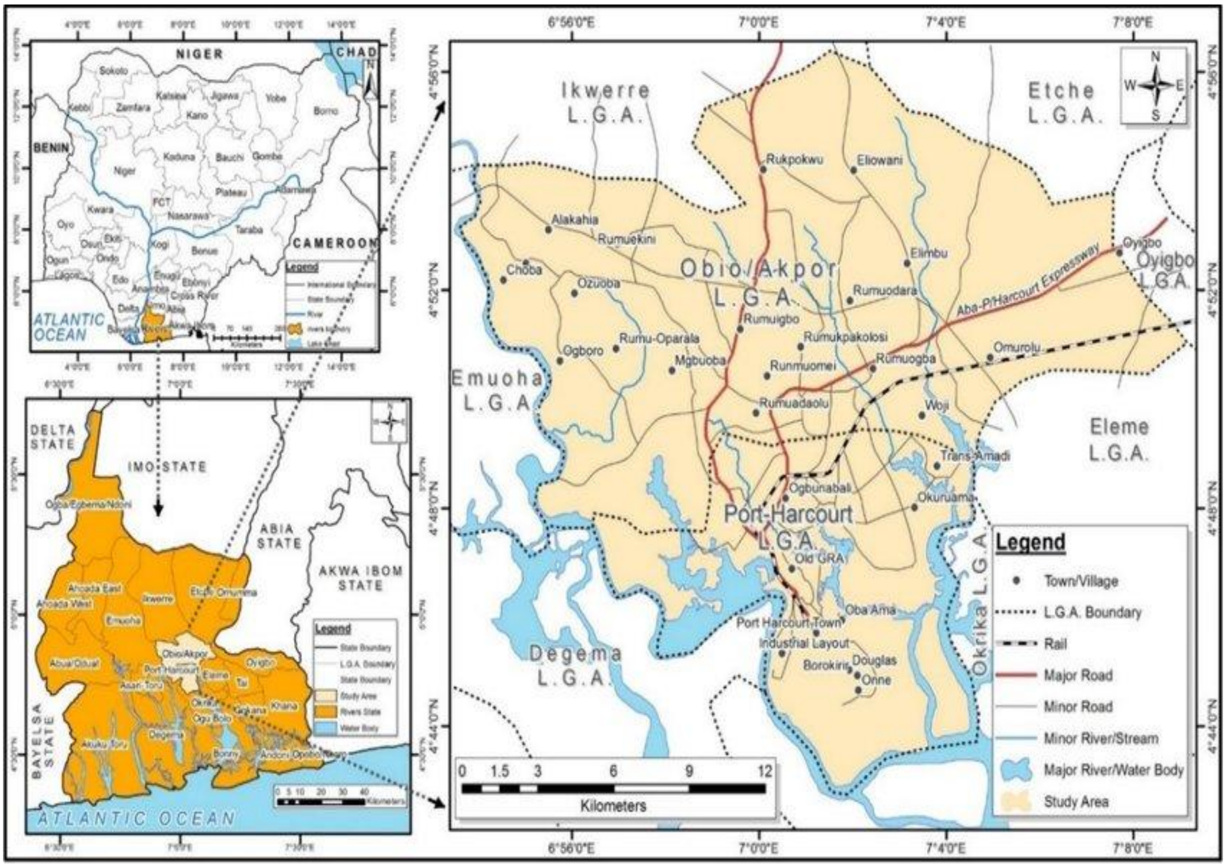

Figure 1: Map of Port Harcourt Metropolis

Materials and Methods

Global Positioning System (GPS) and Geospatial Information System (GIS) technique would be integrated to achieve the objectives of the study. Instrument used in course of this research work is shown in table 1.

Table 1: Software and Hardware Selection

Source: Author's Field Work, 2024

S/N	Software	Hardware	Equipment
1.	QGIS	Laptop	100m Steel tape
2.	Microsoft Word	Phone camera	Garmin 76csx GPS Receiver (Handheld)
3.	Microsoft Excel	Printer	
4.	Google earth	Field Book	

Source: Author's Field Work, 2024

Data Acquisition

Primary Data Sources: This refers to data obtained from field's direct observation and it involves a physical visit to the locations of the sites in order to determine spatial information of the jetties.

Ground truthing/Validation (Measurement/Observation): The coordinates of the different Jetties was gotten with the use of the Hand-held GPS Receiver and a camera was also used to take photographs of some jetties in the study area.

The Principle of GPS Technique: The techniques of GPS was utilized to determine the spatial locations (coordinates) of various jetties within the study area. This was done by the use of a handheld GPS receiver (as specified in table 1, which, as stated by [9] enables the precise determination of a receiver's location by calculating distances from satellites. These distances, known as ranges, are measured from the satellite to the receiver using timing and signal data. According to [8], GPS operates similarly to the process of resection used in traditional ground surveying, where distances and angles are observed from an unknown point to known control points.

The Handheld GPS Receiver which utilizes the GPS point positioning mode which measures the code pseudo ranges to determine the position of the observer instantaneously as long as four or more satellites are visible at the receiver. This technique relies on measuring range distances between satellites and receivers. A range distance is the distance between two objects. In this case, GPS signals travel at approximately the speed of light, and the range distance is calculated based on the travel time of the signal from the satellite to the receiver, using the formula: [3] as:

$$\mathbf{R = c \times t} \qquad (1)$$

Where;

R is range from Satellite in space to receiver on the Earth's surface,

c is on light in space, and

t is time takes for signal to reach the receiver from satellite.

GPS is now the most common method for field data collection in GIS due to its accuracy, affordability, and ease of use. This technique was useful in spatially locating jetties within the study area by visiting various jetty locations and using the handheld GPS receiver to obtain the planimetric coordinates of jetties within the Port Harcourt metropolis.

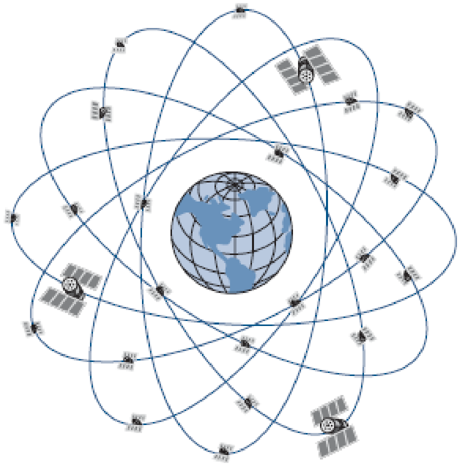

Figure 2: GPS Satellites in Orbit around the Earth [9]

Secondary Data Sources: This entails work that have been done by another researcher or author that was referenced or vital to achieve this research work such as; related literatures and textbooks.

For this research work, attribute data of jetties would be obtained from NPA, NIWA and NIMASA.

Open Source Data: According to [3], open source data simply means there is no restriction in the usage of such type of data, therefore it implies that there is free access to this type of data. For the actualization of this research work, some open source data would be utilized as shown in table 2

Table 2: Open Source Data

S/N	Open Source Data	Significance	Data Types
1	Google Earth	Charting of Coordinates	Imagery, raster
2	Google Labels	Ground features identification/names	Vector
3	OpenStreetMap	Highly detailed GIS data with different levels of accuracy and completeness	Vector data such as buildings, roads, vegetation and waterways

Source: Author's Field Work, 2024

OpenStreetMap (OSM) is a free, editable map of the whole world that is largely built by volunteers from scratch and released with an open content license so it is without restriction of use. OSM is a free, open geographic database updated and maintained by a community of volunteers via open collaboration [3].

OpenStreetMap includes data about roads, buildings, addresses, shops and businesses, points of interest, railways, trails, transit, and land use, natural and artificial features.

For this study, OSM would be used as it provides detailed and up-to-date geographical information, this data includes information on roads, buildings, land use, and other relevant features within Port Harcourt metropolis. The OpenStreetMap is an additional plugins and layer in QGIS which serves as layer for various features that would have been digitized from a base map. The OSM is already a georeferenced and digitized map layer in QGIS. However, field observations is neccessary to ensure accuracy and relevance because familiarity with the terrain of study would be another way to validate the points of interest when imported to QGIS and superimposed on the OSM. The integration of OSM and field observation enhances a comprehensive and reliable dataset to support the analysis and findings of the research.

Google Earth Satellite Imagery and Labels: is another additional plugins and layer in QGIS that can be added as a map layer or background and various points can be superimposed on. The google labels simply shows names of roads and places, it also highlights road networks.

Data Processing

The processing of the data was carried out on QGIS 3.28 software utilizing the following steps or procedures:

Creation of Shapefile and Validation of Coordinate Points: The shapefile of jetties was created by saving the coordinates of various jetties as CSV (Comma Seperated Value, delimited text) file extension through Microsoft Excel and was later imported to QGIS environment/software through the layer tool, and further exported as a shapefile.

The coordinate acquired were validated on QGIS to ascertain if the position of the various jetties falls within the confines of the study area and this was achieved by launching Google earth satellite imagery as a layer in QGIS and importing the coordinates of the jetties. This was done to ascertain if the obtained coordinates during data acquisition are insitu or falls within the study area.

Utilization of Open Source Data: In this research work, after importing the shape file of the jetties to QGIS environment as a layer, an open source data known as Open Street Map (OSM) was used to show the roads leading to the various jetties as shown in figure 3 and other necessary features needed for the map where some vector operations were also performed.

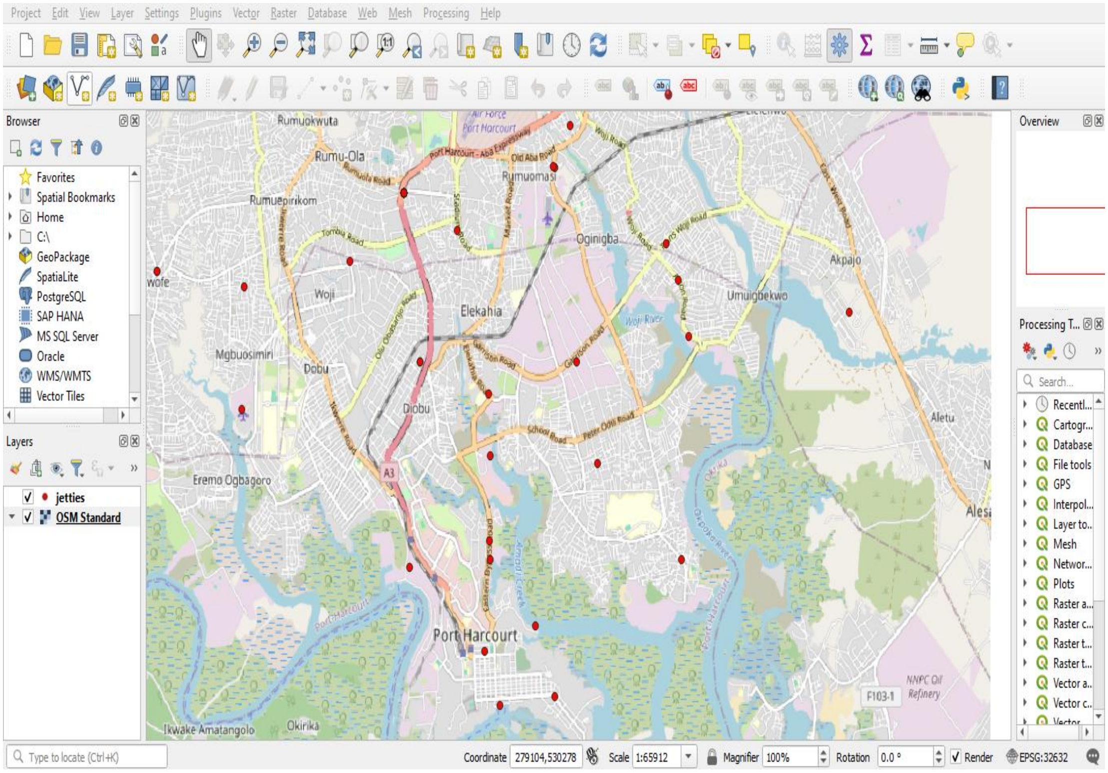

Figure 3: Geographical Spread of Jetties with the OSM Layer

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PUBLISHED 12-02-2025
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Creation of the Database: The imported data containing the coordinates of the various jetties along with the attributes describing them was converted to a shapefile. A shapefile is a widely used geospatial vector data format for geographic information system (GIS) software. It was developed by ESRI, a leading provider of GIS software. A shapefile stores geometric and attribute data for geographic features and is composed of multiple files with specific extensions.

Map production: QGIS software would be used to produce the maps; the coordinates and attributes of various jetties that were saved in Microsoft excel as a CSV (Comma Separated Value) file would be imported to QGIS as a delimited text, then OSM was also launched to validate the point. The different layers that have been imported were modified and different point colours were selected for each of the layers and to further enhance the data usage, the layers were exported to a shapefile format. After getting the shapefile from the CSV data as explained earlier, the shapefile were imported to QGIS under the print layout, the points were imported and the OSM on the map canvas were added then other map elements were updated accordingly and a suitable scale was selected and the map was exported to PDF (Portable Document Format).

Results and Discussion

Spatial Information of Jetties

Table 3: A Specimen of the Spatial Information of Jetties in Port Harcourt Metropolis

S/N	Name of Jetties	Address	Eastings (m)	Northings (m)
1	Pelfaco Jetty	Rumueprikom Iwofe	270233.645	531930.487
2	Aveon Jetty	Rumueprikom Nkpo	271807.645	530013.583
3	AGIP Jetty	Agip, Rumuolumeni, Port Harcourt	275006.088	530796.751
4	Octopus Jetty	Eagle Island, nkpolu Oroworukwo	275243.046	529016.925
5	SCNL Jetty	Eagle Island	274396.357	527289.759
6	Naval Shipyard Jetty	Bundu	278487.908	526018.262
7	Ibeto Jetty	Bundu	278440.696	525647.004
8	Bonny Jetty	Creek Road	280819.929	526193.995
9	Akpos Marine Jetty	Marine Base	281531.364	527411.989
10	NIWA Jetty	Marine Base	281222.469	527687.944
11	Epernal Group Jetty	Marine Base	280554.126	527836.942
12	Solevad & Associates Jetty	Eastern Bypass	280596.413	528314.291
13	Abonnema Wharf Jetty	Abonnema Wharf	278394.548	528047.750
14	Amadi Base NLNG Jetty	Amadi Ama	280517.109	530246.963
15	Roberger Jetty	Slaughter	283516.273	532510.054
16	Julius Berger Jetty	Slaughter	283611.826	532441.231

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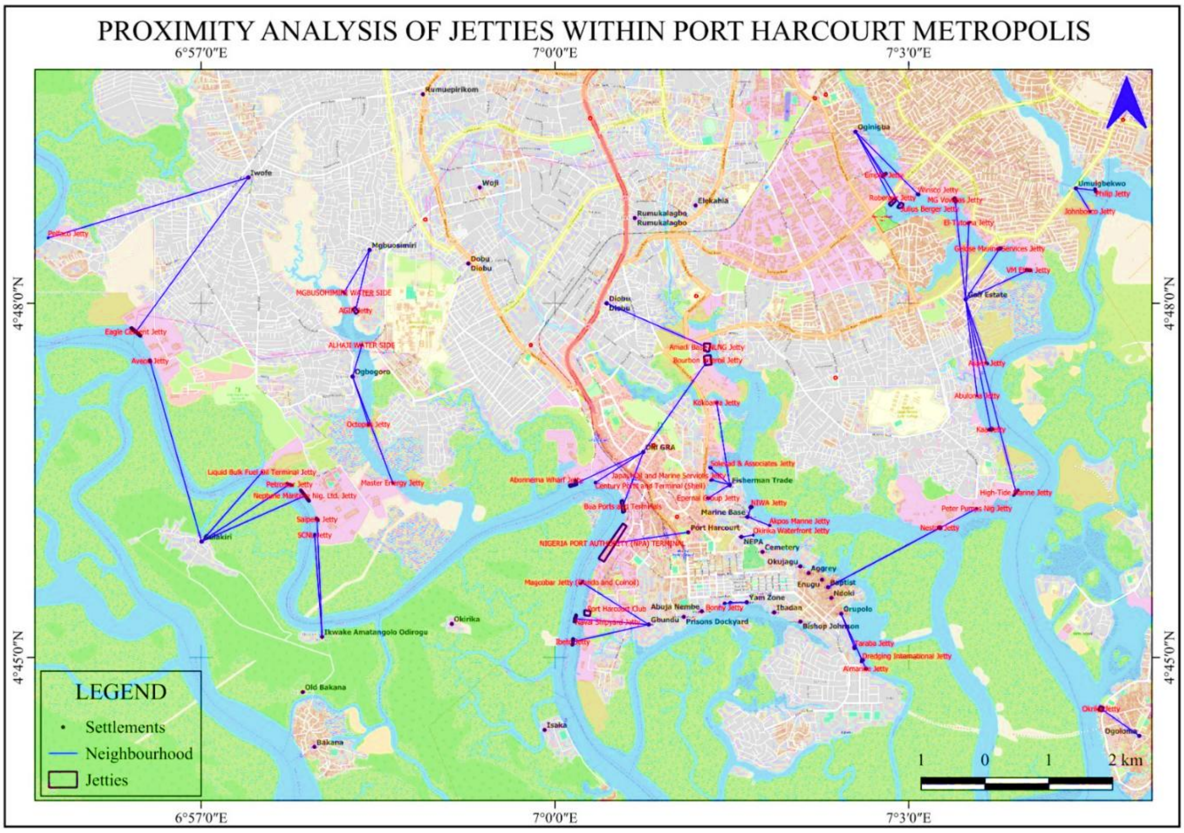

Figure 4: Spatial Distribution Map Showing the Linear Proximity Analysis of Jetties within the Port Harcourt Metropolis

Table 4: A Specimen of the Distance between Jetties to the Nearest Landmark within Port Harcourt Metropolis

S/N	Names	Location	HubName	HubDist (m)
1.	Pelfaco Jetty	Rumueprikom Iwofe	Iwofe	3278.890
2.	Aveon Jetty	Rumueprikom Nkpo	Gulakiri	2933.246
3.	AGIP Jetty	Agip, Rumuolumeni, Port Harcourt	Mgbuosimiri	971.488
4.	Octopus Jetty	Eagle Island, nkpolu Oroworukwo	Ogbogoro	787.807
5.	SCNL Jetty	Eagle Island	Ikwake Amatangolo Odirogu	1593.570
6.	Naval Shipyard Jetty	Bundu	Gbundu	1153.660
7.	Ibeto Jetty	Bundu	Gbundu	1219.954
8.	Bonny Jetty	Creek Road	Yam Zone	347.616
9.	Akpos Marine Jetty	Marine Base	Marine Base	369.628
10.	NIWA Jetty	Marine Base	Marine Base	162.285
11.	Epernal Group Jetty	Marine Base	Fisherman Trade	395.741
12.	Solevad & Associates Jetty	Eastern Bypass	Fisherman Trade	403.157

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Spatial Distribution Pattern

Table 5: Number of Jetties within Communities in Port Harcourt Metropolis

S/N	Communities	No. of Jetties
1	Abuloma	10
2	Borokiri	16
3	Elelenwo	5
4	Nkpolu Oroworukwo	3
5	Rumueme	1
6	Rumueprikom	2
7	Rumuolumeni	10
8	Woji	4
9	**Total**	**51**

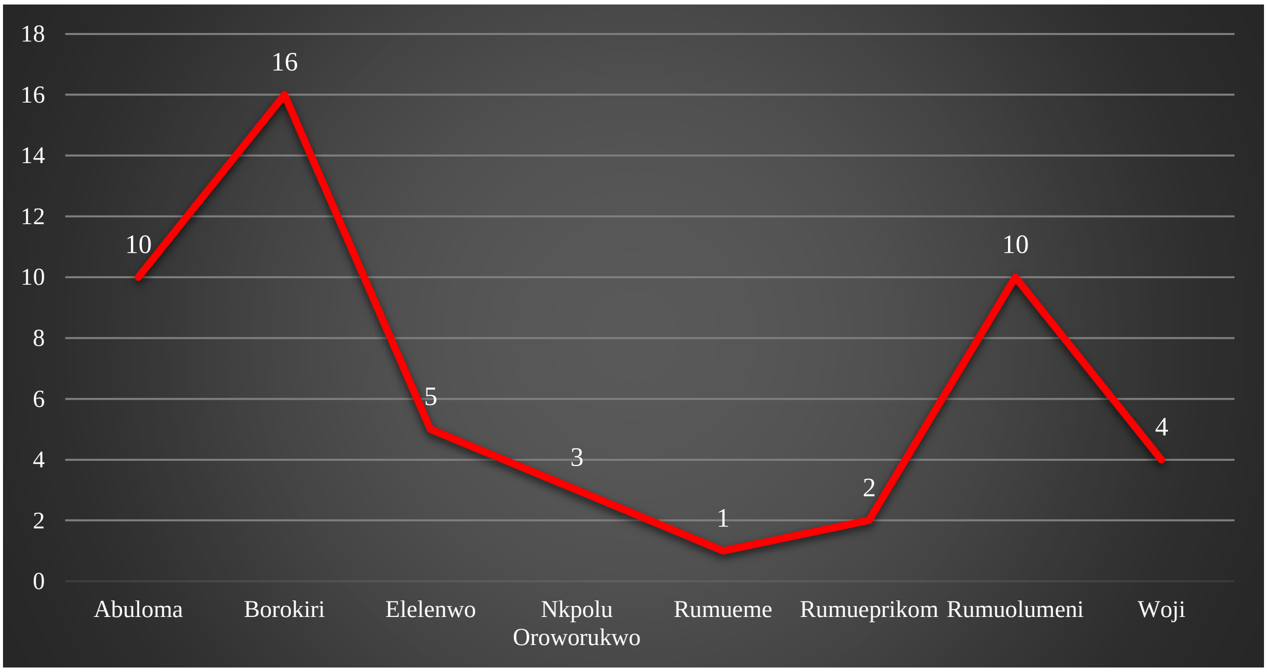

Figure 5: Graphical Illustration of the Spatial Distribution of Jetties within Communities in Port Harcourt Metropolis

NPA's Operational Requirements of a Jetty

Jetty handbook (2017) by NPA highlighted four operational requirements which are;
1. Proof of holding bay inside and outside the jetty.
2. Flow meter installation
3. Office accommodation
4. Ship profile/ Digital board

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Table 6: The Compliance Level of Jetties in Port Harcourt Metropolis to NPA's Operational Requirements

S/N	NPA's Operational Requirements (NPA's OR)	No. of Jetties with NPA's OR	No. of Jetties without NPA's OR	Total	Remark
1.	Holding Bay	40	11	51	Jetties that do not have holding bay are; Octopus, Bonny, NIWA, Abonnema Wharf, Okrika, Mgbuoshimini, Alhaji, Abuloma, Kokoama, Nembe and Port Harcourt club jetties.
2.	Flow Meter/Way Bridge	47	4	51	Most Jetties that are Liquid and Solid Bulk uses flow meter and way-bridge respectively except Mgbuoshimini, Alhaji, Nembe and Okrika waterside jetty
3.	Office	47	4	51	Most Jetties except Mgbuoshimini Alhaji, Octopus and Okrika waterside jetty
4.	Ship Profile/ Digital Board	2	49	51	Only LNG & SHELL has digital board that display ship and jetty info. However, some

Figure 6: A Sample of the Spatial Distribution Map showing Abonnema wharf Jetty in Port Harcourt Metropolis

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	jetties have display boards that are not digital

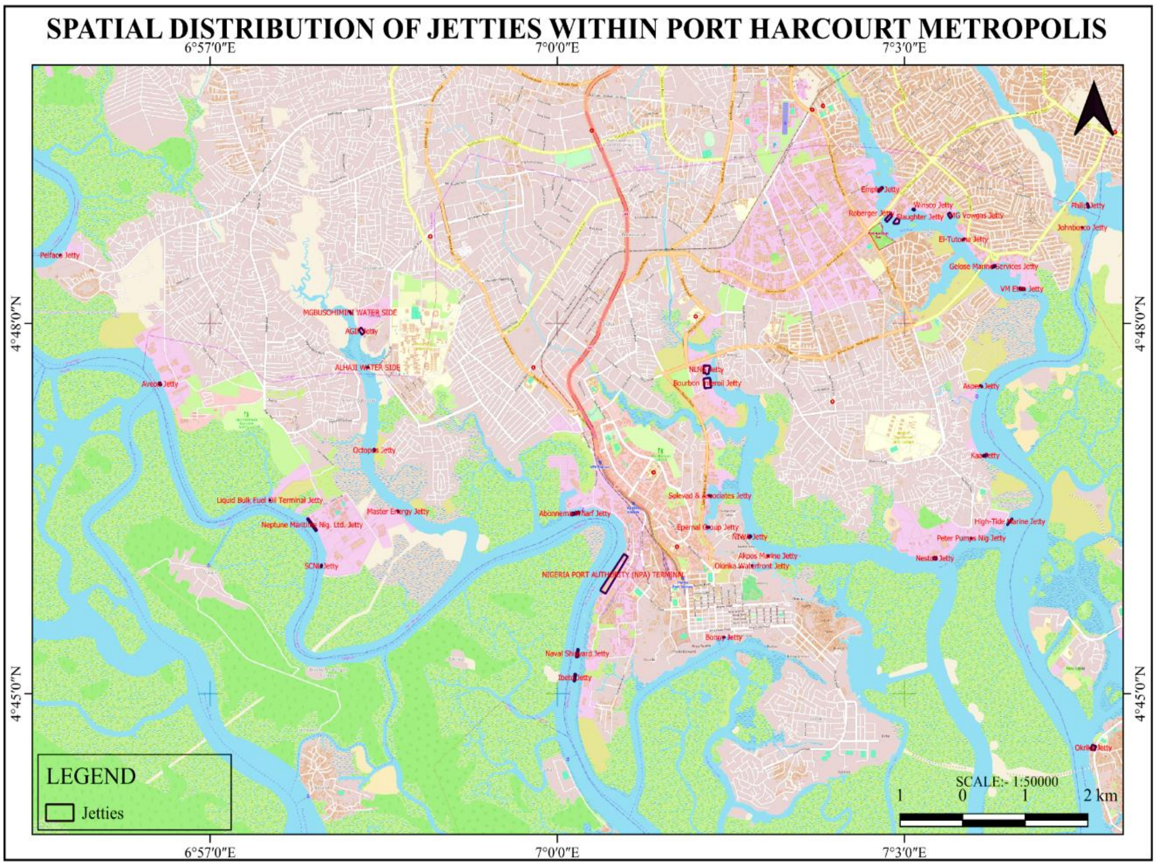

Figure 7: Spatial Distribution Map of Jetties within Port Harcourt Metropolis

Findings and Discussion

The findings of this study addresses the significant challenges identified in the statement of the problem regarding the absence of up-to-date spatial information on jetties within Port Harcourt Metropolis. The research identified a total of 51 jetties across the study area, emphasizing their critical role in supporting maritime activities, urban development, and transportation connectivity between the metropolis and surrounding towns. Hence, these findings are presented in tables, figures, and charts to illustrate the spatial and attribute information of the jetties.

Table 4.1 provides the spatial coordinates of the jetties obtained during data acquisition, which form the basis for mapping and analysis. This comprehensive spatial data underscores the importance of the jetties as key infrastructure supporting the transportation of goods such as fish, timber, and petroleum products. The absence of some jetties in certain areas may hinder efficient connectivity, as highlighted in the statement of the problem. Therefore, there is a need for the increment of jetties in critical/strategic locations within the Port Harcourt Metropolis.

Table 4.2 showcases the database of jetties, revealing important spatial characteristics, including perimeter, area, depth, and projected distance from the shoreline. It reveals that NPA PTOL is the biggest jetty with an area spanning 57273.68 SQ.MTRS approximately 6 hectares while Pelfaco jetty is the smallest jetty with an area of 99.523 SQ.MTRS. These attributes are crucial for evaluating the functionality and capacity of the jetties to meet the growing demands of Port Harcourt's rapid industrialization and urban expansion.

Table 4.3 highlights the distribution of jetties across eight communities within the metropolis, with Borokiri recording the highest number (16). This concentration of jetties in Borokiri reflects its strategic importance in maritime activities and supports the clustering pattern observed in the spatial distribution. Figure 4.1 provides a clear visual representation of the jetty distribution across the communities, reinforcing these findings.

Figure 7, the spatial distribution map of jetties, illustrates their geographic spread within the study area. The clustered distribution pattern aligns with the challenges outlined in the statement of the problem, emphasizing disparities in accessibility and the need for equitable spatial planning to address the growing demand for maritime infrastructure.

The findings highlight the critical role of jetties in Port Harcourt Metropolis and the necessity for updated spatial information to optimize their functionality. The results provide a foundation for informed decision-making to enhance maritime connectivity, support urban development, and address the increasing demands on the city's maritime infrastructure.

Conclusion

The absence of comprehensive spatial information regarding jetties in Port Harcourt Metropolis has significant and multifaceted implications for the city's key sectors, particularly maritime services, urban infrastructure development, and the oil and gas industry. Port Harcourt serves as a critical hub for these activities, and the efficiency and coordination of operations in these sectors are paramount to the region's economic vitality and strategic importance.

Jetties are pivotal to maritime activities, providing essential points for docking, loading, and unloading of goods and passengers. Without detailed spatial data, maritime operations are hampered by inefficiencies, leading to increased operational costs, delays, and suboptimal resource utilization. The lack of precise information disrupts logistical planning, complicates navigation, and heightens the risk of accidents, further exacerbating operational challenges. Furthermore, the transportation of goods and services, which is integral to the economic backbone of Port Harcourt, suffers from inefficiencies and increased costs due to the lack of spatial data. Accurate information about jetty locations and capacities is essential for optimizing routes, schedules, and logistics operations. Without it, the city faces challenges in maintaining the flow of goods and services, leading to delays, higher costs, and reduced competitiveness in the regional and global markets.

Recommendation

To address the uneven distribution of jetties and improve connectivity, new jetties should be strategically constructed in underserved areas, while existing facilities should be upgraded to enhance their capacity and support the growing demands of urbanization and industrial activities.

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