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A geographic analysis of bus stop locations in obio/akpor lga, rivers state

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Abstract

Urban transportation is a critical component of sustainable city development, facilitating the movement of people and goods while influencing the efficiency of daily activities. The study aimed to analyze the geographic locations of bus stop in Obio/Akpor LGA, Rivers State. The objective was to analyze the pattern of bus stop using proximity analysis. The materials used were Global Positioning System (GPS-Garmin 78SC), Satellite image, 30 metres tape and a Geographic Information Systems (GIS) approach was used to map and analyze the spatial data of bus stops. The research also evaluated accessibility by calculating the average distance between bus stops and high-density residential zones. The results indicated uneven distribution of bus stops, 43 built bus stops with high concentrations along major roads and in densely populated areas, while peri-urban and newly developing regions were underserved. Also, the distance from the bus stop to the roads were found to be ranging from 3.17m, 2.55m and 1.78m to the road. Some areas were found to be over 1 km away from the nearest bus stop, negatively impacting access to public transport and limiting mobility, especially in peripheral zones. Based on these findings, the study recommended the strategic placement of new bus stops in underserved areas, particularly in rapidly growing suburban and peri-urban regions. Regular assessments of transport infrastructure should also be carried out to accommodate urban expansion. In conclusion, these recommendations, if implemented, would improve the spatial distribution of bus stops, reduce travel distances, and increase the efficiency and accessibility of the public transport network in Obio/Akpor LGA.

Keywords: Mapping of Bus Stops, Remote Sensing, GIS

1. Introduction

Urban transportation is a critical component of sustainable city development, facilitating the movement of people and goods while influencing the efficiency of daily activities. In rapidly urbanizing areas such as Obio/Akpor, Rivers State, Nigeria. The spatial distribution of public transportation infrastructure, particularly bus stops, plays a significant role in determining the accessibility and convenience of mobility for residents. Bus stops serve as critical nodes in the public transport network, and their distribution impacts commuting patterns, access to services, and overall urban connectivity (Litman, 2021).

The increasing population and urban expansion in Obio/Akpor have placed significant pressure on the existing transportation infrastructure. As more areas develop and grow, particularly in peri-urban regions, ensuring an equitable and efficient distribution of bus stops becomes a challenge. The absence of properly placed bus stops can lead to long walking distances, reduced reliance on public transportation, and an increase in the use of private vehicles, thereby contributing to traffic congestion and environmental degradation (Sarkar & Sekhar, 2018).

Key urban areas within Obio/Akpor include: Rumuokoro, Rumuola, Rumuodara, and Choba, among others. It also hosts the University of Port Harcourt, several commercial establishments, and a network of major roads that connect the area to Port Harcourt and surrounding regions. Despite its growth, the rapid urbanization has presented challenges, particularly in terms of infrastructure and service delivery. The demand for public services, including transportation, has increased as the population expands (World Bank, 2019).

The transportation system in Obio/Akpor is a critical component of daily life, with buses being the primary mode of public transport. However, the spatial distribution of bus stops and transportation infrastructure has not kept pace with the growing population and urban sprawl. This imbalance has led to transportation inefficiencies, affecting the movement of people and goods across the local government area. Understanding the distribution of bus stops is essential for enhancing public transport accessibility, reducing traffic congestion, and improving the overall urban mobility system in Obio/Akpor (Ahmed & Zubair, 2018). In this context, studying the spatial distribution of bus stops in Obio/Akpor provides valuable insights into the current state of public transportation and helps identify areas where improvements are needed to meet the growing demands of the population (Litman, 2021).

The study would focus on analyzing the spatial distribution of bus stops in Obio/Akpor to create a gap by using Geographic Information Systems (GIS) and remote sensing to map and assess the current network of roads within the area of interest.

1.1 Statement of the Problem

The spatial distribution of bus stops in Obio/Akpor Local Government Area remains largely unexamined, leading to significant inefficiencies in the public transportation system as a result of poorly guided decisions. This lack of understanding and unguided decisions due to lack of spatial information contributes to inadequate service coverage, longer wait times, and reduced accessibility for commuters. As a result, many residents face challenges in reaching their destinations, which negatively impacts their mobility and overall quality of life.

The failure to conduct a proper spatial distribution of bus stops in Obio Akpor can lead to several negative consequences that impact both the efficiency of public transportation and the quality of life for residents. Some of these key consequences include: limited accessibility to public transport, increased traffic congestion, inefficient public transport system, social and economic disparities. Others are environmental impact, strain on existing infrastructure, decreased urban mobility and economic loss.

1.2 Aim of the study

The aim of the study is to examine the spatial distribution of bus stops in Obio/Akpor Local Government Area, Rivers State to aid physical planning within the Local Government Area.

1.3 Objectives of the Study

The objectives of the study are to:

1. Design a database of bus stops within the study area

3. Analyze the pattern of bus stop using proximity analysis

4. Produce a map showing the spatial distribution of bus stops in Obio/Akpor Local Government Area

2. Literature review

The reviews visualize related literature on geographic analysis of bus stops to strengthen the study. One significant study by Murray (2001) examined the spatial distribution of bus stops in urban environments using GIS. Murray used Geographic Information Systems (GIS) to map and analyze the spatial distribution of bus stops in urban areas. The research emphasized that the efficiency of a public transportation system is highly dependent on the strategic placement of bus stops. The research used existing spatial data on bus stop locations, population density, and urban land use patterns in carrying out the research. Accessibility to bus stops was inadequate in 35% of urban areas studied. Optimal bus stop spacing was found to be 400–500 meters in urban areas to balance coverage and efficiency. The research found that inadequate distribution leads to accessibility issues, especially in densely populated urban centers. The analysis highlighted the need for balancing bus stop coverage with population density and land use characteristics to optimize public transit systems.

In another notable work, Delmelle and Casas (2012) used GIS to analyze the spatial distribution of bus stops in Bogotá, Colombia. The study aimed to assess the accessibility of public transportation in low-income neighbourhoods. This study used GIS to conduct a spatial analysis of bus stops in Bogotá, Colombia. Spatial optimization techniques were applied to assess the accessibility of bus stops in low-income neighbourhoods and compare coverage across different areas. GIS data on bus stop locations, socio-economic data of neighbourhood, and spatial optimization models were used. Bus stop density in high-income areas was 2–3 times greater than in low-income neighbourhoods. 40% of low-income neighbourhoods were located more than 500 meters from the nearest bus stop. The results indicated that many bus stops were concentrated in wealthy areas, leaving underserved regions with inadequate public transportation access. Delmelle and Casas suggested using spatial optimization techniques to ensure equitable bus stop distribution across urban areas.

A study by Zhao et al., (2014) explored the relationship between bus stop distribution and population density in Beijing, China, using GIS-based spatial analysis. The researchers evaluated whether bus stop placement aligned with population density patterns. Spatial autocorrelation techniques were used to identify clustering patterns in bus stop locations. GIS data on bus stops, population density data, and urban zoning maps were used in his research. A positive correlation ($R = 0.65$) was found between population density and bus stop concentration, some low-density areas had a bus stop coverage ratio 30% higher than needed, while high-density zones were 15% under-served, though some low-density areas were over-served, while others were under-served. The research highlighted the importance of continuous monitoring and adjustment of bus stop networks to match shifting population dynamics.

Currie (2010) conducted an influential study that looked at the spatial distribution of bus stops and its impact on social inclusion in Melbourne, Australia. The study analyzed how well public transport services were distributed in low-income communities. Currie employed GIS to analyze the distribution of bus stops in relation to social inclusion in Melbourne, Australia. The study incorporated socio-economic data to assess how well public transport services were distributed in low-income communities. GIS data on bus stops, socio-economic data, and social inclusion indices were used in the research. Areas with poor bus stop access had employment rates 20% lower than those with adequate access. Over 50% of low-income households were located beyond the recommended 400 meters from a bus stop. Currie's findings indicated that areas with poor access to bus stops also had lower levels of employment and education, highlighting the link between transportation access and social equity.

A more recent study by Zarei et al., (2019) utilized hotspot and heat mapping techniques to analyze the distribution of bus stops in Mashhad, Iran. The researchers aimed to identify underserved areas that lacked adequate public transportation services. A GIS software was used to analyze bus stop distribution in

Mashhad, Iran. The study identified underserved areas by mapping hotspots where high traffic areas lacked adequate bus stop services. GIS data on bus stops, urban population data, and spatial heat map models were used. 35% of Mashhad's urban area was identified as underserved, lacking adequate bus stop coverage. Peripheral regions required an additional 20–30% increase in bus stops to meet demand. Heat maps revealed that high-demand zones lacked bus stops despite being within 300 meters of residential clusters. The study found that many peripheral areas were poorly served, suggesting a need for additional bus stops in these locations. The study also emphasized that heat mapping can be a valuable tool for identifying gaps in service coverage.

A pioneering study by Kimpel et al. (2007) focused on the optimal placement of bus stops using GIS in Portland, Oregon. The research employed a combination of spatial analysis and optimization algorithms to suggest improvements in bus stop placement based on traffic flow and population density. Kimpel and colleagues combined spatial analysis with optimization algorithms to study bus stop placement in Portland, Oregon. The method involved using traffic flow and population density data to suggest improvements in bus stop placement. GIS data on bus stops, traffic flow data, population density data, and optimization models were employed. Optimized bus stop placement reduced average travel time by 15–20%. Improved bus stop spacing led to an 18% increase in service reliability. Proposed stop spacing of 400–600 meters based on population density and traffic flow data. The study concluded that optimizing the distribution of bus stops could significantly enhance the efficiency and convenience of the public transit system.

2.1 Review of concept

2.1.1 Spatial Mapping of Bus Stop

Spatial mapping is a technique used to analyze the distribution of physical features in a given area. In the context of bus stops, spatial mapping, particularly through the use of GIS (Geographic Information Systems), provides a visual representation of their locations and their proximity to other urban features, such as roads and population centers. GIS applications are crucial for examining the adequacy of bus stop placement (Liu, & Shen, 2020).

2.1.2 Public Transportation

Public transportation is fundamental to urban mobility, providing efficient travel options for residents. The location and accessibility of bus stops play a significant role in determining how effective the public transport system is in serving its population. Properly distributed bus stops enhance commuters' accessibility, reduce travel time, and promote the use of public transportation (Currie & Delbosc, 2011).

2.1.3 The Role of Remote Sensing and GIS in Bus Stop Management

Remote sensing and GIS technologies have revolutionized the management of bus stop networks. These technologies help identify optimal bus stop locations, analyze traffic patterns, and evaluate the distribution of stops in relation to population density and land use. Through spatial analysis, transportation planners can ensure that bus stops are placed in strategic locations to meet the needs of commuters (Rahman & Zhang, 2020).

2.1.4 Hotspot Mapping

Hotspot mapping is a spatial analysis technique used to identify areas of high activity or concentration. In the context of bus stop planning, hotspot mapping helps pinpoint areas with heavy commuter traffic, which may require additional bus stops or enhanced services. This technique supports the efficient allocation of public transportation resources (Andresen, 2016).

2.1.5 Heat Mapping

Heat mapping is used to visualize the distribution of bus stops and identify areas where there may be inadequate coverage. By creating visual representations of areas with high and low bus stop density, heat maps can guide planners to focus on underserved regions and adjust bus stop locations accordingly (Kwan, 2016).

2.1.6 Bus Stop Location Quotient

The bus stop location quotient is a quantitative measure used to assess the adequacy of bus stop distribution relative to population density. It compares the number of bus stops in a given area to the population, helping to determine whether an area has sufficient transportation services. Areas with a low quotient may require additional bus stops to ensure equitable service (Pearce & Maddison, 2009).

3. METHODOLOGY

The study dwell more on quantitative approach were measurement and observations where carry out through segmentation phases.

3.1 Material Used

Instruments used in course of this research work were Garmin 78csx GPS receiver, 100m Steel tape, Reflective jackets, field book, car for transportation.

Table 1: Software and Hardware used

S/N	Software	Hardware
1	QGIS	Laptop
2	Microsoft Word	Phone
3	Microsoft Excel	Paper Map
4	Google Earth Satellite imagery	Printer
5	UTM Geo Map	Garmin 78csx GNSS Receiver
6	Open Street Map	Tape

3.2 Data Acquisition

Data acquisition is essential for all surveying and GIS analysis processes, serving as the first step in creating a GIS database. A handheld GPS receiver (Garmin 78csx GNSS Receiver) was used to capture the coordinates of various bus stops. In this research, both primary and secondary methods were applied to achieve the project's objective. Obtaining geospatial data (including spatial and attribute data) for various bus stops within the study area. Measurements for each bus stop were also collected, with length and width measured in meters. Additionally, the average distance between the bus stops and the road was also measured in meters. Finally, environmental information for each bus stop was documented. Secondary data sources included information from Google Earth, Landsat imagery, and other sources obtained through scanning.

3.3 Data Processing

3.3.1 Error Checking

To ensure data quality and reliability, several key aspects were carefully checked. Data completeness was confirmed by ensuring all expected bus stops were included in the dataset, with attention to any missing or incomplete entries. Spatial accuracy involved verifying geographic coordinates (latitude and longitude), ideally cross-referencing with accurate maps or GPS data. Duplication checks were also performed to prevent skewed analysis, particularly when combining data from multiple sources without proper duplication.

The method of tracing geographic features from another dataset (usually an aerial, satellite image, or scanned image of a map) directly on the computer screen. In this research work, after importing the shape file of the various bus stop 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 bus stops and other necessary features needed for the map where some vector operations were also performed.

3.4 Data Analysis

3.4.1 Proximity Analysis

Proximity analysis for bus stops was conducted by applying a buffering technique around each stop, using a specified radius based on relevant standards or guidelines. For example, the standard distance for convenient pedestrian access to a bus stop was 200 meters, buffer zones of 200 meters and 500 meters, created around each stop to indicate areas within walking distance.

3.4.2 Surface Raster Analysis

The raster surface was filtered using Gaussian 3by 3 filter to remove the noise on the image, mostly the edge effects as contained in the convolution filters. A cleared image of visualization also coresponded to the correct position of the bus stops after slight adjustment of the edge effects with respect to the data mining.

3.5 Map Production

Map production involves arranging elements on a page to make information easily understandable, even with minimal text. The map was done with the help of QGIS after features creation and editing.

3.6 Study Area

The study area is located between latitudes 4°30’N and 5°30’N and longitudes 6°30’E and 7°30’E. This positioning places Obio/Akpor within the tropical zone of Nigeria, contributing to its urban growth and economic development. Obio/Akpor Local Government Area is predominantly urbanized, with a vibrant mix of economic activities. The area supports significant commerce, industrial ventures, and some agricultural activities. Due to its strategic importance in Rivers State, it serves as a hub for businesses and industries, contributing to the need for a well-planned transportation system, including the provision of efficient public bus services. The local government area is home to a diverse population with various ethnic groups, though it is predominantly occupied by the Ikwerre people, who are indigenous to the region. Obio/Akpor is characterized by a mix of urban, suburban, and semi-rural areas, and its population has steadily increased due to its proximity to Port Harcourt, the state capital, and the economic opportunities it offers. As a result, there has been continuous expansion in housing, businesses, and industrial activities, making it one of the most densely populated LGAs in Rivers State (Ehule et al., 2020).

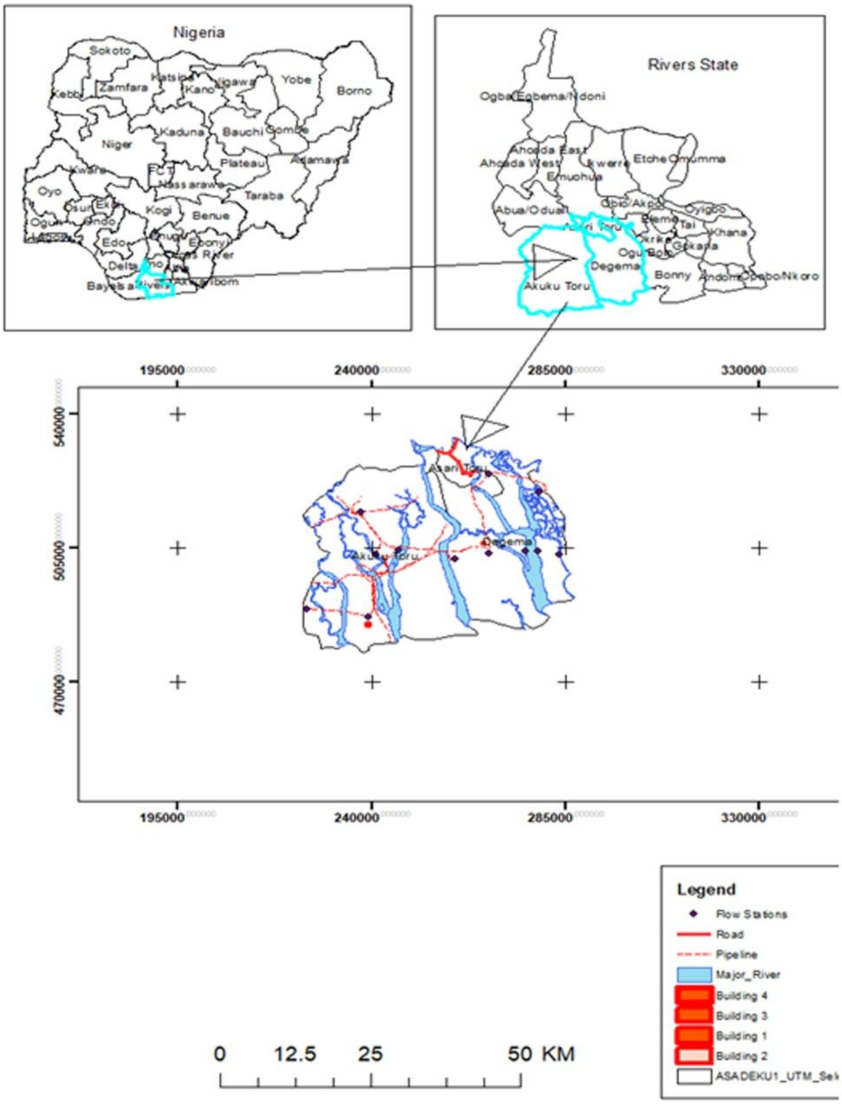

Figure 1: Map of study area

4.0 results and discussion

4.1 Results of Findings

The research findings revealed a total of one hundred twenty-eight (128) bus stops within the study area. Forty-three of these bus stops feature have built structures and are represented as polygon features, complete with their spatial locations and attribute data (Table 2). In contrast, eighty-five (85) bus stops, which do not have built structures, are recorded as point data (Table 1). Moreover, attribute information about bus stop locations were duly exercised in the study to indicate a clear picture of the discussion. These are information of the respective bus stop such as shelter, distance from road network, area, environmental status and feature type. For instance, during the hot and rainy season, commuters normally find a place of rest or stationed to get vehicles from one place to another within and outside the state of origin. Some of these bus stops are built while others are not depending on its location. The imperative of the study is that it accommodates commuters during these period of time which maybe convenience or not at the point of need.

Among others, Agip Bus Stop 2, Rivers State College of Health Bus Stop, Union Bank / Ikwerre Road Bus Stop, and Whimpy have a good shelter, varying area dimension from (18m2 to 16m2) and better environmental status. Retrogressively, Rumuokwuta, Rumuigbo and Rumiuigbo does not have shelter for bus stop having good environmental condition (Table 3). Roads in relation to bus stop were also analysed, the study noted variability of road distance to bus stop as documented in Table 3. More so, the least distance recorded 1.72metres while the highest showed 3.91metres in the area of study.

The study indicated that the bus stops in Obio Akpor LGA are well-served in the central region but under-served in the northern and southern areas. The study however, advocating for construction of bus stops in underserved regions, especially along roads without built structures (morphology), to improve connectivity and create a more balanced and efficient transportation network.

Table 2: Geospatial Coordinates of Unbuilt Bus Stops in Obio/Akpor Local Government Area

S/N	Name	Latitude	Longitude
1	Agip Ada George bus Stop	532183.325	276049.421
2	Agip Ade George Bus Stop 2	532130.866	276049.266
3	Happy Food Bus Stop	532519.996	275903.703
4	Chinda Bus Stop	532705.001	275794.125
5	Chinda Bus Stop	533363.143	275706.679
6	Chinda Bus Stop 2	533340.657	275682.100
7	Open Door	533736.635	275640.560
8	Peperoni Bus Stop	534139.984	275527.850
9	Total Child	534074.286	274863.845
10	Michael's Bus Stop	534019.699	274557.460
11	Gas Bus Stop	533996.283	274364.897
12	Jaros Base Bus Stop	533942.603	274234.605
13	OPM Bus Stop	533575.742	273818.599
14	St Johns Bus Stop	533061.388	273389.710
15	St Johns Bus Stop 2	533044.329	273406.241
16	Life Forte Bus Stop	532825.036	273215.790
17	Big Tree Market	532644.834	273064.928
18	Aker Junction	532404.793	272449.401
19	IAU School Gate	531683.696	270930.830
20	Eagle Junction	532234.889	271910.863
21	Location	536662.468	275416.151
22	Elioparanwo Bus Stop	534601.287	275523.275
23	Gateway Junction	534622.869	275400.330
24	Psychiatric Road Junction	534663.642	277544.192
25	Obirikwerre by NTA junction	538521.584	273282.719
26	NTA Bus Stop	538013.797	274254.545

27	Ozuoba Junction	538733.278	270321.807
28	AGS Bus Stop	538860.472	270076.446
29	Indomie Gate	540260.704	267478.972
30	Okocha St	540522.613	267247.766
31	Ahunwa Road	540302.868	267454.010
32	Wasor Junction	540861.927	267419.205
33	Ahunwa Road	541072.791	267627.064
34	Aliko Junction	541217.333	267729.705
35	Uniport Junction Market Bus Stop	541786.637	267882.039
36	Rumuekini Junction	540051.337	271637.694
37	Salvation Bus Stop	540203.870	271196.854
38	NDDC Bus Stop	540353.095	270481.983
39	NYSC Bus Stop	540429.601	270096.915
40	Rumualogu Bus Stop	540525.428	269802.686
41	Blue Roof Bus Stop	540998.174	269070.726
42	Igbogo Bus Stop	541187.603	268794.473
43	George Ave Bus Stop	533718.565	273096.251
44	Gateway Bus Stop	533887.206	273038.385
45	Elioparanwo Bus Stop	534392.037	272934.139
46	Peace Avenue Bus Stop	534934.939	272334.599
47	5th Avenue	534896.227	272413.038
48	El-Olam Avenue	535552.266	271854.764
49	St John Anglican Church	536308.721	270998.948
50	Town Hall Bus Stop	536136.258	270333.969
51	Market Road Bus Stop	537973.035	270085.380
52	Akani Close Bus Stop	537791.033	270193.925
53	Rumudara Junction	537534.760	281506.587
54	Market Road	537014.974	281647.991
55	Okporo Junction	535369.806	282603.017
56	1st Artillery	535707.921	282419.889
57	2nd Artillery	535833.053	282808.37
58	Genesis Bus Stop	536693.794	284504.861
59	Tank	537986.498	284464.665
60	Elimbu	538914.387	284189.695
61	Farm Road bus Stop	540579.551	283407.143
62	Eneka Bus Stop	541443.344	282623.385
63	Enerco Bus Stop	538528.696	286135.900
64	Royal Avenue	538984.047	286157.930
65	Road 6	540605.084	286482.479
66	YKC bus Stop	533373.901	284267.613
67	Ogbatai Bus Stop	533841.053	284914.005

68	Eze Gbaka-Gbaka Bus Stop	533935.513	285233.528
69	Akwu Bus Stop	534003.375	285665.211
70	Elelenwo/Woji Junction	534131.837	286080.972
71	Calculux bus Stop	534095.444	286207.560
72	SandFIll Bus Stop	533735.746	286937.236
73	SandFill Phase 1	533961.874	286398.651
74	RSTV Gate	534045.822	286317.610
75	CRA bus Stop	534374.950	285955.789
76	Rumuodani Road	534524.305	285978.714
77	Wodi Bus Stop	535020.834	286011.081
78	Station Bus Stop	535400.311	285759.599
79	Elelenwo Market Bus Stop	535486.339	285709.386
80	Kilimanjaro Bus Stop	535800.708	285392.945
81	School Road Bus Stop	536404.328	285207.023
82	Civic Center	537459.203	284538.152
83	Rumuesara Bus Stop	542423.113	281694.898
84	Obirikwerre Flyover	539193.193	273156.222

Table 3: Built Bus Stops in Obio/Akpor Local Government Area

Id	Road Name	Eastings	Northings	
1	Agip Bus Stop 1	276392	532520	
		276393	532515	
		276389	532514	
		276389	532521	
2	Agip Bus Stop 2	276352	532513	
		276356	532512	
		276358	532508	
		276357	532502	
3	Rivers State College Of Health Bus Stop	276346	532727	
		276347	532721	
		276345	532721	
		276345	532727	
4	Union Bank / Ikwerre Road Bus Stop	276119	533800	
		276116	533800	
		276120	533807	
		276119	533808	
5	Wimpey	276294	534367	
		276292	537367	
		276296	534371	
		276297	534309	
6	Rumuokwuta	276824	534961	
		276825	534960	

		276822	534953	
		276819	534954	
7	Rumuigbo	277219	536420	
		277222	536420	
		277218	536416	
		277213	536417	
8	Rumiuigbo	277336	536861	
		277338	536860	
		277339	536855	
		277333	536856	

9	Army Barrac	277563	537707
		277565	537705
		277562	537701
		277560	537701
10	Rumuokoro	278080	538287
		278077	538288
		278073	538293
		278081	538292
11	Rumuokoro	277829	538307
		277829	538308
		277826	538309
		277824	538310
12	Oil Mil 1	285334.61	536897.94
		285325.05	536890.41
		285322.09	536893.36
		285331.52	536900.47
13	Oil Mil 2	285356.96	536882.15
		285359.21	536878.47
		285350.12	536871.12
		285347.62	536874.91
14	Rumuodomaya	278108.62	538921.25
		278112.54	538921.56
		278111.45	538907.23
		278108.88	538908.4
15	Ikwerre Road	278129	539128
		278127	539130
		278129	539137
		278133	539135

16	Presidential Bus Stop - 1 Aba-Express Road	278669	533948
		278665	533946
		278660	533955
		278665	533959
17	Presidential Aba-Express Road 2	278675	534072
		278678	534071
		278672	534085
		278676	534088

18	Rumuola Bus Stop	278729.92	534382.66
		278733.78	534381.35
		278727.44	534370.52
		278724.19	534372.62
19	Bori Camp 1	279231	534746
		279229	534751
		279240	534759
		279242	534755
20	Bori Camp 2	279246	534780
		279211	534774
		279212	534777
		279222	534785
21	Pleasure Park 1	279405	534895
		279402	534894
		279412	534897
		279413	534895
22	Pleasure Park 2	279497.40	534890.22
		279488.65	534888.02
		279487.90	534889.42
		279496.10	534891.83
23	Air Force	279979	534874
		279994	534816
		279999	534872
		279980	534874
24	Air Force 2	279986	534909
		279987	534910
		280001	534908
		280002	534907

25	First Bank	280608	534892
		280604	534891
		280620	534901
		289062	534901
26	Habitat Exclusive	278205	539181
		278206	539179
		278203	539175
		278200	539177

27	Rumuodomaya	278418	539518
		278415	539518
		278418	539521
		278419	539520
28	Adp Bus Stop	278423	539476
		278428	539480
		278429	539479
		278425	539474
29	Breadbass 74	278518	540083
		278518	540087
		278520	540080
		278517	540079
30	Exquisite Bus Stop	278469	540368
		278469	540375
		278472	540376
		278472	540368
31	New Road Bus Stop	278456	541040
		278457	541040
		278457	541035
		278455	541034
32	Guo Transport Co.	278487	541114
		278484	541113
		278485	541119
		278487	541120
33	Big Treat Bus Stop	278421	541331
		278423	541331
		278424	541325
		278422	541325
34		278421	541555
		278422	541550
		278419	541549
		278419	541555

35	*	277928	543699
		277928	543693
		277931	543693
		277931	543700

36		277914	544291
		277914	544225
		277917	544226
		277916	544220
38	Market Junction	281003	535098
		281002	535096
		281987	535092
		281985	535091
39	Market Junction 2	280976	535049
		280976	535050
		280985	535057
		280986	535055
40	Bridge	281699	535362
		281701	535359
		281711	535367
		281712	535363
41	Shell	283762	536275
		283763	536272
		283753	536267
		283752	536270
42	Rumuokwurusi	284060	536377
		284059	536381
		284072	536381
		284071	536377
43	Rumuokwurusi 2	284277	536343
		284289	536342
		284289	536338
		284277	536339

Table 4: Data Presentation for Built Bus Stops in Obio/Akpor LGA

Id	Road Name	Eastings	Northings	Shelter	Distance from Bus Stop Area to Road	Area of Bus Stops (M^2)	Environmental Status	Feature Type

1	Agip Bus Stop 1	276392	532520	Yes	3.17	18.698	Good	Polygon
		276393	532515					
		276389	532514					
		276389	532521					
2	Agip Bus Stop 2	276352	532513	Yes	2.89	18.035	Good	Polygon
		276356	532512					
		276358	532508					
		276357	532502					
3	Rivers State College of Health Bus Stop	276346	532727	Yes	3.91	12.514		POLYGON
		276347	532721				Good	
		276345	532721					
		276345	532727					
4	Union Bank / Ikwerr e Road Bus Stop	276119	533800	Yes	3.3	20.22		
		276116	533800				Bad	Polygon
		276120	533807					
		276119	533808					
5	Wimpe y	276294	534367	Yes	3.12	16.223		
		276292	537367				Good	Polygon
		276296	534371					
		276297	534309					
6	Rumuo kwuta	276824	534961	No	2.28	20.099	Good	Polygon
		276825	534960					
		276822	534953					
		276819	534954					
7	Rumui gbo	277219	536420	No	2.58	20.08	Good	Polygon
		277222	536420					
		277218	536416					
		277213	536417					
8	Rumiui gbo	277336	536861	No	2.72	15.678	Good	Polygon
		277338	536860					
		277339	536855					
		277333	536856					
9	Army Barrac	277563	537707	Yes	3.1	13.267	Good	Polygon
		277565	537705					
		277562	537701					
		277560	537701					
10	Rumuo	278080	538287	Yes	2.06	14.843	Good	Polygon

	koro							
		278077	538288					
		278073	538293					
		278081	538292					
11	Rumuo koro 2	277829	538307	Yes	1.78	19.078	Good	Polygon
		277829	538308					
		277826	538309					
		277824	538310					
12	Oil Mil 1	285334.61	536897.94	Yes	2.56	52.091	Good	Polygon
		285325.05	536890.41					
		285322.09	536893.36					
		285331.52	536900.47					
13	Oil Mil 2	285356.96	536882.15	Yes	2.25	52.052	Good	Polygon
		285359.21	536878.47					
		285350.12	536871.12					
		285347.62	536874.91					
14	Rumuo domay a	278108.62	538921.25	Yes	2.74	18.051	Bad	Polygon
		278112.54	538921.56					
		278111.45	538907.23					
		278108.88	538908.4					
15	Ikwerr e Road	278129	539128	Yes	3.23	15.506	Bad	Polygon
		278127	539130					
		278129	539137					
		278133	539135					
16	Presid ential Bus Stop - 1 Aba-Expres s Road	278669	533948	Yes	2.71	53.836	Good	Polygon
		278665	533946					
		278660	533955					
		278665	533959					
17	Presid ential Aba-Expres s Road 2	278675	534072	Yes	3.27	55.723	Good	Polygon
		278678	534071					
		278672	534085					
		278676	534088					
18	Rumuo la Bus Stop	278729.92	534382.66	Yes	2.44	53.585	Good	Polygon
		278733.78	534381.35					
		278727.44	534370.52					
		278724.19	534372.62					
19	Bori	279231	534746	Yes	2.5	51.067	Very Good	Polygon

	Camp 1							
		279229	534751					
		279240	534759					
		279242	534755					
20	Bori Camp 2	279246	534780	Yes	2.78	50.78	Very Good	Polygon
		279211	534774					
		279212	534777					
		279222	534785					
21	Pleasur e Park 1	279405	534895	Yes	2.83	27.987	Good	Polygon
		279402	534894					
		279412	534897					
		279413	534895					
22	Pleasur e Park 2	279497.4	534890.22	Yes	2.61	25.089	Good	Polygon
		279488.65	534888.02					
		279487.90	534889.42					
		279496.10	534891.83					
23	Air Force	279979	534874	Yes	3.27	53.062	Good	Polygon
		279994	534816					
		279999	534872					
		279980	534874					
24	Air Force 2	279986	534909	Yes	2.63	52.992	Very Good	Polygon
		279987	534910					
		280001	534908					
		280002	534907					
25	First Bank	280608	534892	Yes	2.77	55.094	Good	Polygon
		280604	534891					
		280620	534901					
		289062	534901					

26	Habitat Exclusi ve	278205	539181	Yes	2.36	20.65 6	Good	Polygon
		278206	539179					
		278203	539175					
		278200	539177					
27	Rumuo domay a	278418	539518	Yes	2.71	16.17 8	Good	Polygon
		278415	539518					
		278418	539521					
		278419	539520					
28	Adp Bus Stop	278423	539476	Yes	2.59	16.67 4	Good	Polygon
		278428	539480					
		278429	539479					
		278425	539474					
29	Breadb ass 74	278518	540083	Yes	3.12	18.20 2	Good	Polygon

		278518	540087					
		278520	540080					
		278517	540079					
30	Exquisite Bus Stop	278469	540368	Yes	2.61	19.592	Good	Polygon
		278469	540375					
		278472	540376					
		278472	540368					
31	New Road Bus Stop	278456	541040	Yes	2.89	16.631	Good	Polygon
		278457	541040					
		278457	541035					
		278455	541034					
32	Guo Transport Co.	278487	541114	Yes	3.23	15.815	Bad	Polygon
		278484	541113					
		278485	541119					
		278487	541120					
33	Big Treatbus Stop	278421	541331	Yes	3.51	16.294	Good	Polygon
		278423	541331					
		278424	541325					
		278422	541325					
34		278421	541555	Yes	3.57	15.967	Good	Polygon
		278422	541550					
		278419	541549					
		278419	541555					
35		277928	543699	Yes	2.98	19.091	Good	Polygon
		277928	543693					
		277931	543693					
		277931	543700					
36		277914	544291	Yes	3.24	18.283	Good	Polygon
		277914	544225					
		277917	544226					
		277916	544220					
38	Market Junction	281003	535098	Yes	3.24	15.506	Good	Polygon
		281002	535096					
		281987	535092					
		281985	535091					
39	Market Junction 2	280976	535049	Yes	3.15	51.674	Good	Polygon
		280976	535050					
		280985	535057					
		280986	535055					

40	Bridge	281699	535362	Yes	2.89	53.94	Good	Polygon

						3		
		281701	535359					
		281711	535367					
		281712	535363					
41	Shell	283762	536275	Yes	2.15	38.76 8	Very Good	Polygon
		283763	536272					
		283753	536267					
		283752	536270					
42	Rumuo kwuru si	284060	536377	Yes	2.15	53.33 8	Very Good	Polygon
		284059	536381					
		284072	536381					
		284071	536377					
43	Rumuo kwuru si 2	284277	536343	Yes	2.55	53.09 9	Good	Polygon
		284289	536342					
		284289	536338					
		284277	536339					

4.2 The environmental status of bus stop in study area

This term generally refers to the condition and surroundings of the bus stop, which impacts its functionality and passenger comfort (Transportation Research Board, 2013). Each status is defined as follows:

Very Good: The bus stop is in excellent condition—well-maintained, clean, and safe, with no litter or vandalism. It is easily accessible for all users, including those with disabilities (European Committee for Standardization, 2002).

Good: The bus stop is functional and in generally good condition. The surroundings are relatively safe and clean, with no significant accessibility or safety issues (Transportation Research Board, 2013).

Bad: The bus stop is poorly maintained and may be damaged. It could pose safety risks, such as a lack of lighting, signs of vandalism, or an unsafe or inaccessible location. The area may be unclean, with litter or other environmental hazards (Douglas & Jones, 2010).

Table 5: Environmental Status of Bus Stops in Obio Akpor LGA

Environmental Status	Data
Very Good	13.95
Good	76.74
Bad	9.3

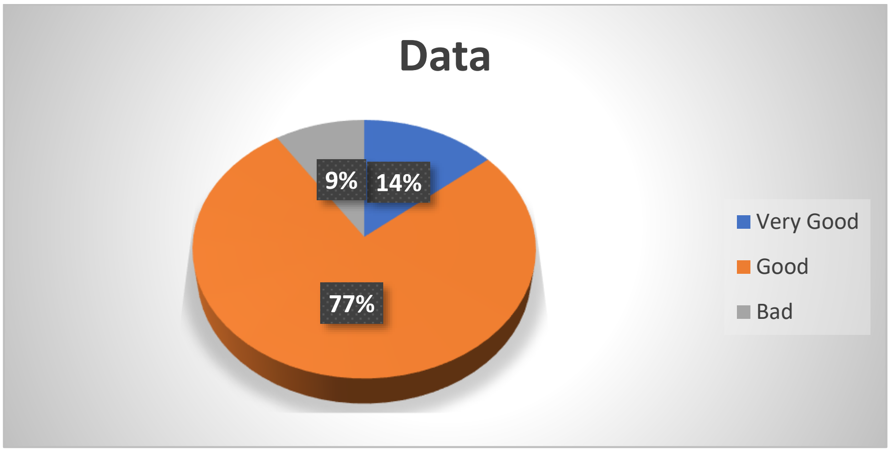

Figure 2: Pie Chat of the Environmental Status of Bus Stop in Obio/ Akpor LGA

4.3 Proximity Analysis of Bus Stops in Obio Akpor LGA

The proximity analysis of collection points was done using buffer of 100m and 200m in the study. The analysis revealed that a 100-meter buffer showed areas within a short walking distance (approximately a 1–2-minute walk). It indicated the immediate proximity to bus stops and was useful for identifying how many residents or destinations are very close to the public transport (Fig. 3). A 200-meter buffer represents a slightly longer walking distance (approximately a 4-5 minute walk). It captures a larger area around each bus stop and helps assess the total reach of each stop, showing how far people might need to walk to access public transportation.

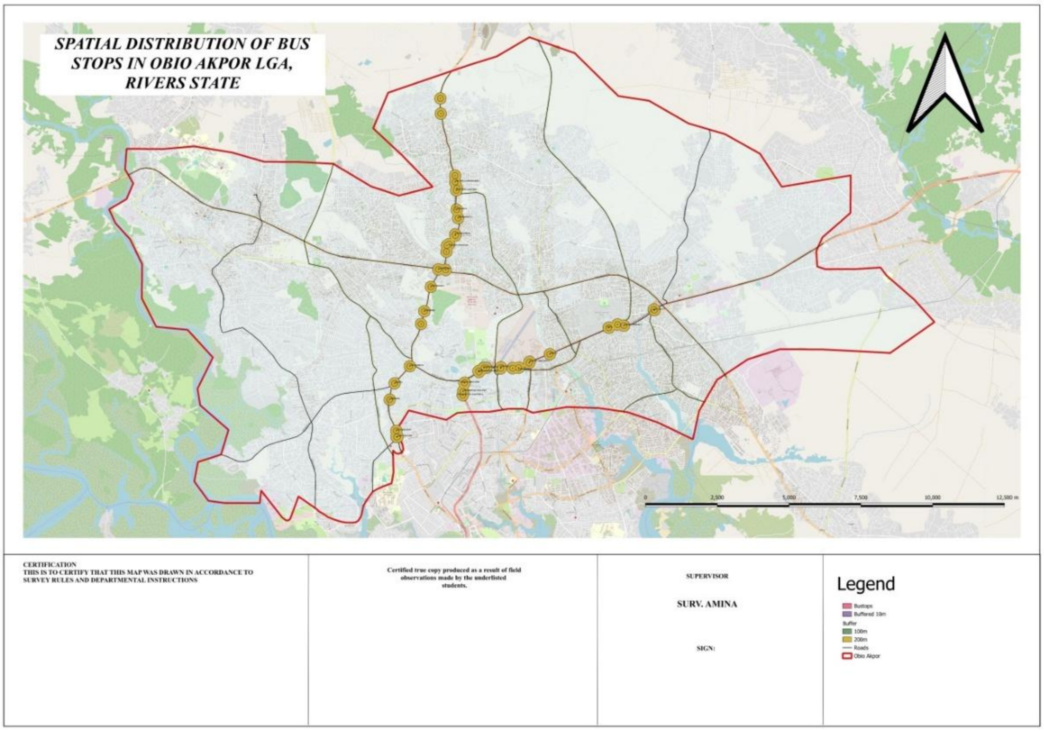

Figure 3: Proximity Analysis of Bus Stop using a 100m Buffer

4.3.2 Well-Served Areas

Areas where bus stops are close together and buffer overlap offer better public transport accessibility. The central part of the map has more overlapping buffers, suggesting this region is well-served by the bus system.

4.3.3 Under-served areas

Regions, especially on the outskirts of the LGA (northern and southern parts of the map), have little or no buffer coverage. These areas might face challenges in accessing bus services, and transport planning efforts should focus on these under-served zones.

5. Recommendations

5.1 Recommendations for Improvement

Underserved areas were identified as priorities for new bus stop construction, particularly in peri-urban and suburban regions, to address spatial gaps

5.2 Recommendations for Optimizing the Spatial Distribution of Bus Stops

1. Balanced Stop Spacing: Maintain an optimal distance between bus stops to minimize

walking distances without excessively increasing travel time. Generally, a spacing of 300–500 meters in urban areas and 500–800 meters in suburban regions ensures accessibility while maintaining efficiency.

2. Accessibility Considerations: Ensure bus stops are accessible to all users, including those with disabilities, by placing them near pedestrian crossings, ramps, and well-lit areas. Prioritize locations that minimize walking distance for vulnerable populations such as the elderly, children, and individuals with limited mobility.

3. Land Use Integration: Align bus stop placement with major land-use patterns, including residential, commercial, and institutional zones. This ensures stops are located near high-demand areas like schools, hospitals, shopping centers, and employment hubs.

4. Multimodal Connectivity: Position bus stops near key transport hubs, including train stations, bicycle-sharing docks, and major intersections, to facilitate seamless transfers between different modes of transportation.

5. Demand-Responsive Adjustments: Regularly assess ridership patterns and adjust bus stop locations based on actual demand, ensuring that high-demand areas are well-served while underutilized stops are reconsidered or relocated.

6. Equity in Access: Address disparities in public transportation access by ensuring bus stops are evenly distributed across socio-economically diverse neighborhoods, especially in underserved areas that lack reliable public transportation options.

7. Safety and Comfort Enhancements: Ensure that bus stops are placed in well-lit, safe areas, with shelters and seating to protect passengers from weather conditions. Stops should be located away from traffic hazards and designed to promote personal safety.

8. Integration of Smart Technologies: Incorporate real-time passenger information systems and smart technologies at bus stops to enhance rider experience and make public transport more attractive.

9. Collaborative Planning: Engage communities and stakeholders in the decision-making process to understand local needs and preferences, ensuring bus stop locations reflect user input and promote higher usage rates.

10. Environmental Considerations: Ensure bus stops are strategically placed to reduce congestion and minimize environmental impact by promoting public transit use over private vehicles.

6. Conclusion

This study examined the distribution and condition of bus stops within the study area, providing valuable insights into the current state of public transportation infrastructure. A total of 128 bus stops were identified, with spatial and attribute data recorded for each. The analysis highlighted a disparity in service distribution, with central areas being well-served while northern and southern regions are underserved.

Through a combination of primary and secondary data, including field surveys and GIS analysis, the study demonstrated the importance of accessible and strategically placed bus stops in enhancing connectivity and promoting efficient urban transportation. The findings emphasize the need to address gaps in bus stop locations by constructing additional stops in underserved areas, particularly in regions lacking built structures. This approach will contribute to a more balanced and effective transportation network, ultimately improving accessibility for residents and fostering sustainable urban mobility.

In conclusion, this research underscores the value of geospatial analysis in urban planning and provides recommendations to enhance public transit accessibility within the study area. The methods and findings from this study could serve as a foundation for future study aimed at improving transportation infrastructure and accessibility in other regions.

Declaration of Conflicting Interests

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APPENDIX 1: Rumuigbo Bus Stop

APPENDIX 2: Ikwerre Road

APPENDIX 3: Habitat Exclusive