Impact of Flooding on Road Transport Infrastructure in Port Harcourt Metropolis

Iheduru, J. O.[1*]; Gobo A. E. [1]; Iyama W.A. [1]; Okorji U.[1]
[1] Institute of Geosciences and Environmental Management,
Rivers State University, Port Harcourt, Rivers State, Nigeria
Joachim.iheduru@ust.edu.ng
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Abstract

Flooding has become a recurring phenomenon in Port Harcourt Metropolis. Flooding poses significant threats to road transport infrastructure and the overall socio-economic development of the region. This study investigated the Impact of Flooding on Road Transport Infrastructure in Port Harcourt Metropolis. It identified flood hotspots, causes, and effects of flooding, the frequency and severity of flooding events, considers the effectiveness of current flood management strategies in preserving the road transport infrastructure and proposes mitigation strategies. The methodology involved using a simple random sampling design in a cross-sectional survey. A total of 385 questionnaire copies were distributed to gather data. In addition, field studies and personal interviews were conducted. The sample size of the study was 385 motorists that ply the various routes that were considered. Sources of data included primary and secondary sources. Analytical methods involved the use of tables, charts and cross-tabulations etc. Findings revealed critical flood hotspots in the Metropolis which are in three categories such as highly flooded areas, moderately flooded areas and lowly flooded areas. The highly flooded areas include the following: Nkpolu Road 1, Rumuigbo, Eneka Town, NTA/Apara Link Road, Rotimi Amaechi Drive, GRA, Phase 11, Kenka Road, off Mgbuoba Road, Abacha Road, GRA Phase 11, Orubo Close, Peter Odili Road, and BluePearl Street, Peter Odili Road. Areas captured under moderately flooded areas are Omachi Road, Rumuodomaya, Salem Close, off Ada George Road, Obi Wali Road, Rumuigbo, Diamond Valley Estate, Zion street, Rumuodomaya, Odani Road, Elelenwo, Evelyn Close, GRA Phase 11, Horsefall Street, Old GRA, and Alibaba Road, Old GRA, while the following are lowly flooded areas: Abanna Street, Old GRA, Hon Atta Close, Peter Odili Road, L.K. Anga Road, Peter Odili Road, Hilltop Road, Amadi Kalagbo, Uyo Street, Rumuomasi, Omerelu Street, GRA Phase 11, Akwaka Street, Rumuodomaya and Peter Odili Road. The study identified heavy rainfall, inadequate drainage systems, urbanization, poor physical planning and climate change as primary causes of flooding. These resulted in physical damage to road infrastructure, increased travel times, and economic losses. The research recommended infrastructure improvement, effective drainage systems, installation of flood forecasting and early warning systems, effective urban planning, and emergency response plans to mitigate the impact of flooding. These findings and recommendations provide valuable insights for policy makers, urban planners, and stakeholders to develop proactive strategies for flood risk management and for a sustainable transportation infrastructure development in Port Harcourt Metropolis.

Keywords: *Flooding, Infrastructure, Hotspots, Mitigation, Urbanization*

1. Introduction

Flooding has been identified as a significant issue affecting road transport infrastructure in Port Harcourt Metropolis, Nigeria. According to a study by Nwilo & Badejo (2006), the city's topography, coupled with poor drainage systems, has led to recurrent flooding, causing severe damage to the road infrastructure. The study further highlights that the impact of these floods on the road transport infrastructure has led to increased traffic congestion, road degradation, and in some cases, complete road failure.

A more recent studies by Eze & Efiong (2017), Ugwu, *et al.,* (2022), corroborate these findings, emphasizing that the impact of flooding on road transport infrastructure in Port Harcourt Metropolis is a growing concern. The study found that during the rainy season, many roads become impassable due to flooding, leading to significant disruptions in the transport network. This not only affects the movement of people and goods but also has a negative impact on the local economy.

The impact of flooding on road transport infrastructure is not limited to physical damage. According to a study by Okoye & Ezezika (2013), flooding also has significant socio-economic implications. The study found that flooding often leads to increased travel times, higher vehicle operating costs, and reduced accessibility to certain areas of the city. This, in turn, affects the overall productivity of the city and the quality of life of its residents.

However, it's not all doom and gloom. A study by Achi *et al.,* (2019) suggests that there are potential solutions to mitigate the impact of flooding on road transport infrastructure in Port Harcourt Metropolis. The study recommends the implementation of proper urban planning and drainage systems, as well as the use of flood-resistant materials in road construction. The study also suggests that regular maintenance of existing road infrastructure can help reduce the impact of flooding.

Despite these potential solutions, a study by Ojeh *et al.,* (2020) argues that there is a lack of political will and funding to implement these measures. The study suggests that until these issues are addressed, the impact of flooding on road transport infrastructure in Port Harcourt Metropolis will continue to be a significant problem.

Flooding is among the most common and destructive natural hazards, resulting in considerable direct losses (e.g. personal injury and property damage) and increasing indirect impacts (e.g. interruption of public services and economic activities), especially in the urbanized areas around the world (Berezi & Nwankwoala, 2022; Hemmati, *et al.,* 2020; Park & Lee, 2019). Flooding can be caused by heavy rainfall which can be a regular pluvial flood by a short timescale, generally less than six hours. It is usually by their very fast evolution and occurs within minutes or a few hours of excessive rainfall (Naulin *et al.,* 2013; Nura & Alison, 2022). There exists a broad consensus that the combined effect of climate change and rapid urbanization is generally recognized as the primary cause for more frequent, heavier rainfall-runoff (Dube, *et al.,* 2018; IPCC, 2013). Furthermore, the lack of anticipation of flooding events such as the unavailability of short-term forecasting and warning, combined with insufficient, postponed adaption measures (e.g. inadequate drainage capacity) largely limit the efficiency of urban flood risk management, leading to the enhanced consequences of these events in most cities like Port Harcourt.

Over the past several decades, the significant disasters associated with street networks and flooding events have been frequently occurring in different urban environments such as New York and London in developed countries as well as Beijing and Bangkok in developing countries (Park & Lee, 2019). Road networks in Port Harcourt are particularly vulnerable to flooding events as the conflict between rapid urbanization and the lagging urban (infrastructure) planning is emerging unto the surface.

The impact of flooding on road transport infrastructure in Port Harcourt Metropolis is a multifaceted issue that requires a comprehensive approach. While there are potential solutions, their implementation is hindered by various challenges. Therefore, further research is needed to explore innovative and cost-effective strategies to mitigate the impact of flooding on road transport infrastructure in this region.

2. Methodology

This study employed a cross-sectional descriptive survey research design, utilizing both quantitative and qualitative methods to collect data. The simple random sampling technique was applied, focusing on the opinions and views of residents in Port Harcourt Metropolis. Data was gathered through a well-structured, detailed questionnaire administered to 385 respondents, mainly motorists. The questionnaire included 60 impact questions across six impact dimensions: flood hotspots, causes of flooding, damages, frequency and intensity of flooding, government interventions, and implications. A 5-Likert scale was used to assess respondents' perceptions. The sample size was drawn from a projected population of 3,637,000, considering factors like traffic flow and route capacity. Chi-Square statistics were used to test two formulated hypotheses. The study also categorized routes into major, minor, and local categories based on flooding vulnerability and traffic analysis.

Table 3.1: Some Selected Roads in Port Harcourt

Major routes	Minor routes	Local routes
Aba road	Abacha road	Obi Wali road
Ikwerre road	Creek road	Woji road
East/West road	Abuloma road	Elelenwo road
	Eneka road	SAS road
	Ada George road	Rukpokwu road
	Olu Obasanjo road	Tombia road
	TransAmadi/Slaughter road	Eleparanwo road
	Peter Odili road	Nkpolu road
		Uyo street, Rumuomasi

Source- Researcher's Compilation, 2024

The study selected 20 routes in Port Harcourt Metropolis, divided into three categories: 3 major routes, 8 minor routes, and 9 local routes, with 19 questionnaires administered on each route using a random sampling technique. The research utilized a combination of instruments, including reconnaissance surveys, roadside and in-car observations, questionnaires, and oral interviews. The road network was categorized into major arterial roads (e.g., Port Harcourt-Aba Expressway, East-West Road, and Ikwerre Road), feeder roads (state-maintained roads linking to major arterials), and minor roads (street-level roads connecting neighborhoods). To address the research objectives, the study employed Geographic Information Systems (GIS) and remote sensing data for identifying flood hotspots, analyzed factors like rainfall, drainage, and urban planning for causes of flooding, assessed road conditions for infrastructure damage, examined historical flood data for event frequency and severity, and evaluated the effectiveness of current flood management strategies through surveys and stakeholder interviews.

Population of the Study

According to Udoyen (2019), a study population is a group of elements or individuals as the case may be, who share similar characteristics. These similar features can include location, gender, age, sex or specific interest. The emphasis on study population is that it constitutes of individuals or elements that are homogeneous in description. This study will be carried out to examine the impact of flooding on road transport infrastructure in Port Harcourt Metropolis. For the purpose of this study, the target population consists of the motorists plying some selected roads in Port Harcourt Metropolis which is three hundred and eighty-five (385). This is a sample size of the projected population of the study area, which is three million, six hundred and thirty-seven thousand (3,637,000) people according to the current metro area population of Port Harcourt in 2024.

3.3 Sample and Sampling Technique

The sample of the study refers to that part of the population that was selected for closer study. To select the needed samples for this study with a projected population of three million, six hundred and thirty-seven thousand people (3,637,000) the researcher used a total of three hundred and eighty-five (385) motorists plying some selected roads in Port Harcourt Metropolis.

For a simple random sampling technique, the sample size (n) was calculated using the formula:

$$n = (Z^2 * \sigma^2) / E^2 \qquad 2.1$$

where:

Z=Z-score corresponding to the desired level of confidence (e.g., 95% confidence level = 1.96)

σ= estimated population standard deviation (or a rough estimate)

E= desired margin of error (e.g.,5%)

Assuming a 95% confidence level and a margin error of 5%, and using a rough estimate of σ= 0.5(which is a common value for social science research), we get:

$n= (1.96^2*0.5^2)/ 0.05^2$

n= 384.16

n= 385 approximately.

The researcher ensured that his sample was truly random and representative of the population. In order to ensure effective representation, the researcher ensured his sample is representative of the various types of motorists (e.g., private car owners, commercial drivers, motorcyclists) and roads in Port Harcourt Metropolis. And appropriate measures were taken to minimize bias and errors in the data collection and analysis.

3. Results

Table 3.1: Distribution of Questionnaire

Distribution	Frequency	Percentage
Returned	350	90.9
Unreturned	35	9.1
Total	385	100

Table 3.2: Distribution According to Gender

Gender	Frequency	Percentage
Male	215	61.4
Female	135	38.6
Total	350	100

Table 3.3: Distribution According to Age

Age	Frequency	Percentage
21 – 30 years	120	34.2
31 – 40 years	100	28.6
41 – 50 years	65	18.6
51 – 60 years	50	14.2
Above 60 years	15	4.4
Total	350	100.0

Table 3.4: Distribution According to Marital Status

Marital Status	Frequency	Percentage
Single	90	25.7
Married	120	34.3
Divorced	75	21.4
Widow	55	15.7
Widower	10	2.9
Total	350	100

Table 3.5: Distribution According to Level of Education

Level of Education	Frequency	Percentage
Primary	65	18.6%
Secondary	125	35.7%
Tertiary	110	31.4%
Vocational	40	11.4%
None	10	2.9%
Total	350	100

Table 3.6: Distribution According to Occupation

Occupation	Frequency	Percentage
Public Service	115	32.9
Self Employed	90	25.7
Unemployed	20	5.7
Retired	25	7.1
Business	100	28.6
Total	350	100

Testing of Hypotheses

Hypothesis 1

H_O: Flooding has no significant impact on Road Transport Infrastructure in Port Harcourt Metropolis.

Table 3.7: Relationship between Flooding and Road Transport Infrastructure

Structure	N	$\bar{X}$	SD	Df	Standard Error	t_{-cal}	t_{crit}	Decision
Flooding	350	3.59	0.883	172	0.177	2.813	1.96	H_0 Rejected
Road Transport Infrastructure	350	3.09	1.398					

0.5 level of significance

Hypothesis 2

Ho: Flooding has no negative impact on journey time on Port Harcourt Roads

Table 3.8: Flooding has no negative impact on journey time on Port Harcourt Roads

Response	Observed frequencies	Expected frequencies (E)	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
Yes	350	453.55	29.45	433.45	1.60
No	00	43.25	19.75	23.76	1.30
Undecided	00	65.15	29.85	87.56	5.24
					15.66

Degree of freedom = (row-1) (column-1)
= (3-1) (2-1)
= 2*1
=2

At 0.05 level of significance, given the above degree of freedom, table value of χ^2 (i.e χ^2_t) = 9.448.

To test our hypothesis, the decision rule is
Accept Ho if $\chi^2_t > \chi^2_{cal}$, and,
Reject Ho if $\chi^2_t < \chi^2_{cal}$

Thus, since the χ^2_t (9.448) < χ^2_{cal} (15.66), we reject Ho and accordingly accept Ha. We conclude by accepting the alternate hypothesis. This implies that Flooding has a Positive impact on journey time on Port Harcourt Roads.

Table 3.9: GPS Coordinates of Lowly Flooded Areas in Port Harcourt Metropolis

S/No	Name of Street/Area	Northings	Eastings
1	Abanna Street, Old GRA	4.785585	7.022028
2	Hon Attah Close, Peter Odili Road	4.793833	7.05075
3	L.K. Anga Road, off Peter Odili Road	4.801917	7.047389
4	Hilltop Road, Amadi-Kalagbo	4.823806	7.023444
5	Uyo Street, Rumumasi	4.838444	7.017583
6	Omerelu Street, GRA Phase 11	4.839583	7.005639
7	Akwaka Street, Rumuodomaya	4.880281	6.994285
8	Peter Odili Road	4.804861	7.045556

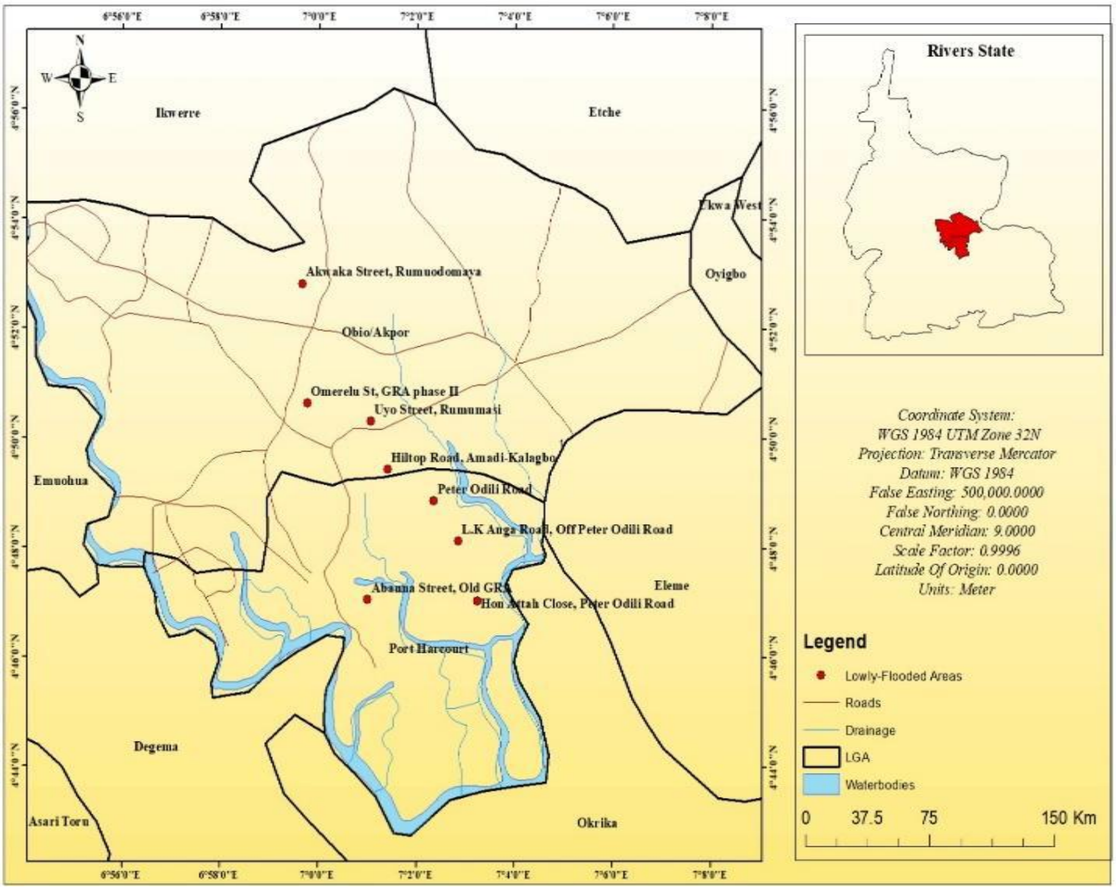

Figure 3.1: Lowly Flooded Area in Port Harcourt Metropolis

Table 5.3 shows the details of the geographic coordinates of the moderately flooded areas in Port Harcourt Metropolis. The result shows that nine (9) urban flood-prone areas in the metropolis fell into this category.

Table 3.10: GPS Coordinates of Moderately Flooded Areas in Port Harcourt Metropolis

S/No	Name of Street/Area	Northings	Eastings
1	Omachi Road Rumuodomaya	4.875247	6.999777
2	Salem Close, off Ada George Road	4.855444	6.979556
3	Obiwali Road Rumuigbo	4.858639	6.986944
4	Diamond Valley Estate	4.796222	7.046083
5	Zion Street Rumuodomaya	4.881607	6.993837
6	Odani Road Elelenwo	4.840208	7.073506
7	Evelyn Close, GRA Phase 11	4.8195	7.006917
8	Horsefall Street, Old GRA	4.786017	7.001000
9	Alalibo Road, Old GRA	4.794083	7.019917

Findings in this study as shown in Table 5.4 shows that there are eight (8) highly flooded areas in the metropolis.

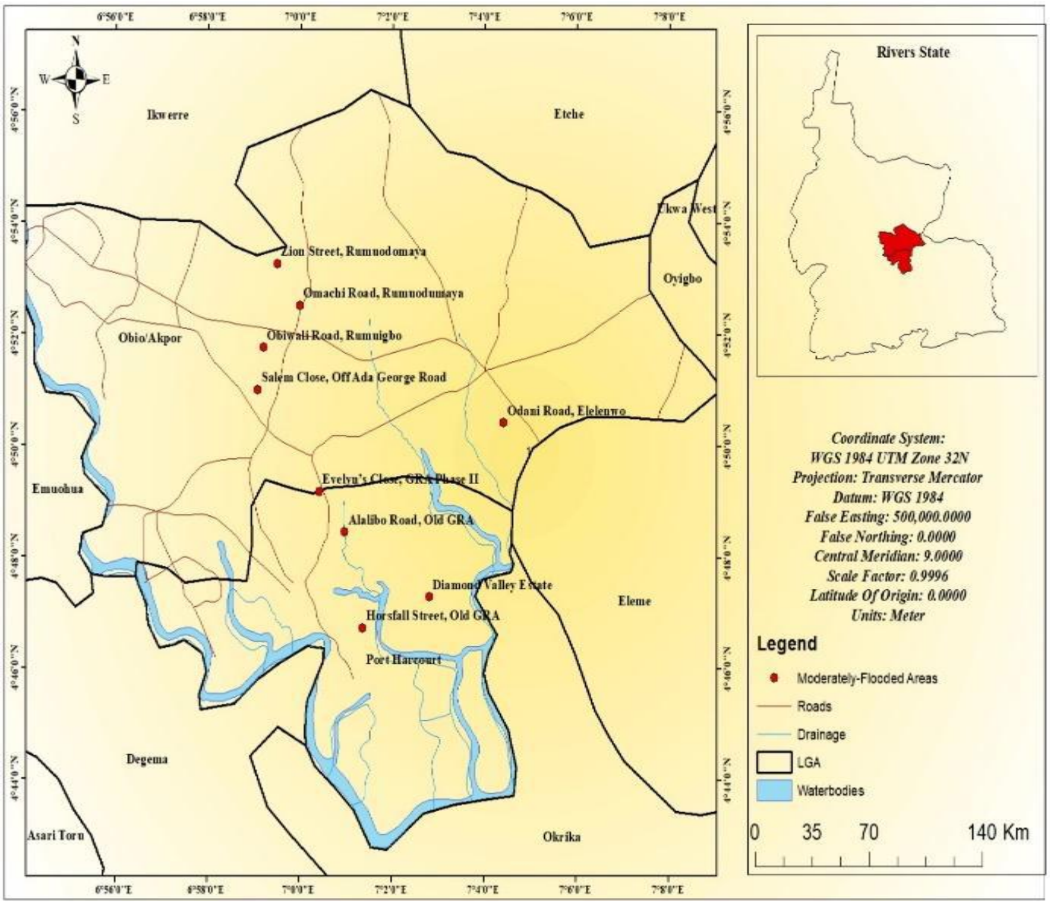

Figure 3.2: Moderately Flooded Areas in Port Harcourt Metropolis

Table 3.11: GPS coordinates of Highly Flooded Areas in Port Harcourt Metropolis

S/No	Name of Street/Area	Northings	Eastings
1	Nkpolu Road 1, Rumuigbo	4.853346	6.986527
2	Eneka Town	4.878167	7.029514
3	NTA/Apara Link Road	4.854637	6.983774
4	Rotimi Amaechi Drive, GRA Phase 11	4.821278	6.000972
5	Kenka Road, off Mgbuoba Road	4.856194	6.980361
6	Abacha Road, GRA Phase 11	4.823778	7. 003361
7	Orubo Close, Peter Odili Road	4.797111	7.052361
8	BluePearl Street, Peter Odili Road	4.794083	7.019917

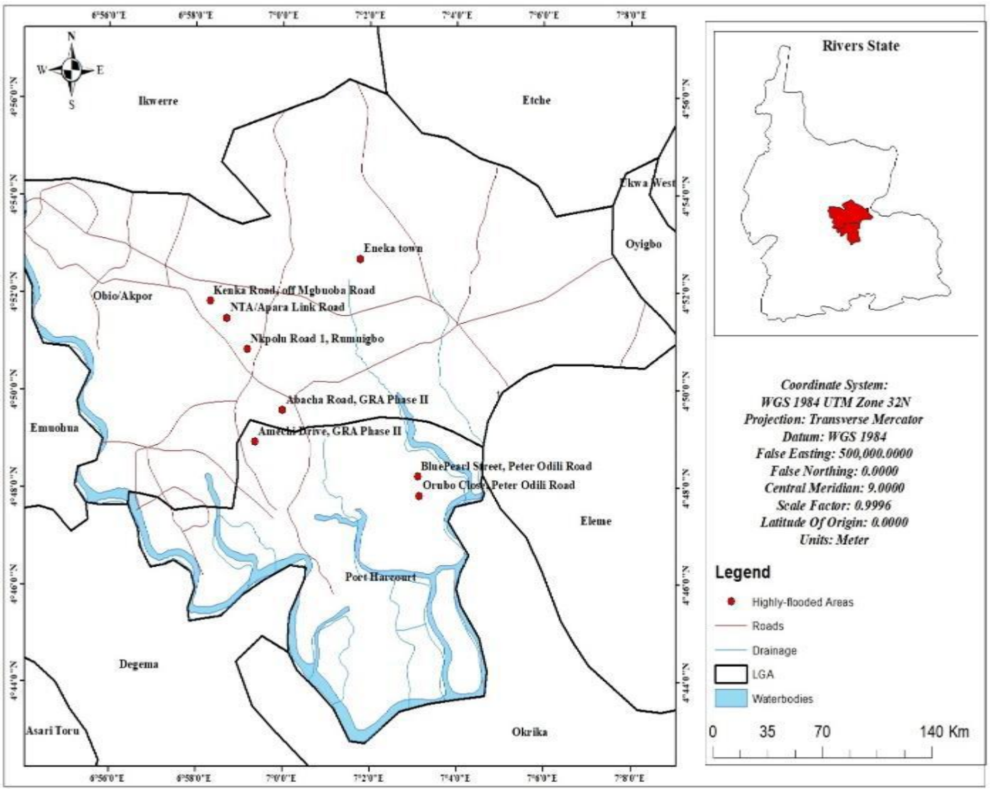

Figure 3.3: Highly Flooded Areas in Port Harcourt Metropolis

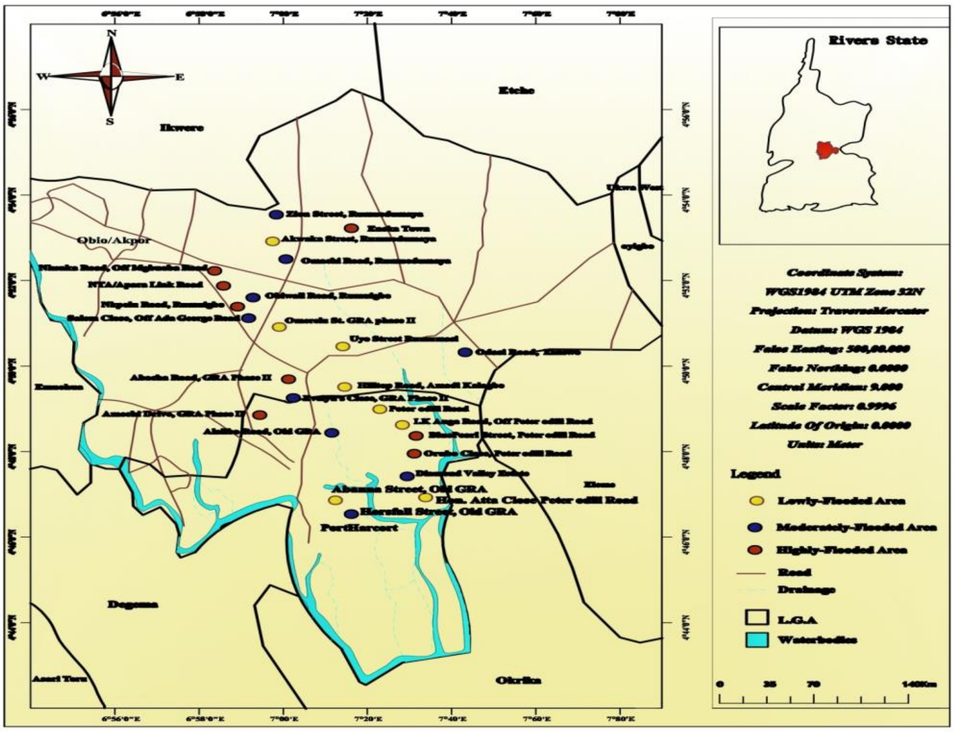

Figure 3.4: Flood Hotpots in Port Harcourt Metropolis

From the above study, the flood hotspots in Port Harcourt Metropolis include the following: Lowly Flooded Areas: Abanna Street, Old GRA, Hon Atta Close, Peter Odili Road, L.K. Anga Road, Peter Odili Road, Hilltop Road, Amadi- Kalagbo, Uyo Street, Rumumasi, Omerelu Street, GRA Phase 11, Akwaka Street, Rumuodomaya, and Peter Odili Road, Moderately Flooded Areas: Omachi Road, Rumuodomaya, Salem Close, off Ada George Road, Obiwali Road, Rumuigbo, Diamond Valley Estate, Zion Street, Rumuodomaya, Odani Road, Elelenwo, Evelyns Close, GRA Phase 11, Horse fall Street, Old GRA, and Alalibo Road, Old GRA, Highly Flooded Areas: Nkpolu Road 1, Rumuigbo, Eneka Town, NTA/Apara Link Road, Rotimi Amaechi Drive, GRA Phase 11, Kenka Road, off Mgbuoba Road, Abacha Road, GRA Phase 11, Orubo Close, Peter Odili Road and BluePearl Street, Peter Odili road.

This study employed Geographic Information Systems (GIS) and remote sensing techniques to identify flood-prone areas in Port Harcourt Metropolis. The result showed that:

a) Flood hotspots are concentrated in low-lying areas, particularly around Rivers State University, Rumuokuta, Eneka and Peter Road.
b) Areas with poor drainage systems, such as those with inadequate or clogged culverts, are more susceptible to flooding.
c) The most vulnerable neighborhoods are those near rivers, creeks, and canals, including Rumuokuta, Rumuodomaya and Eneka axes.

This finding agreed with the results of the studies carried out by Achi, *et al.*, (2015) and Adeaga, (2008).

Table 3.11: Factors That Cause Flooding

Factors of Flood	Frequency	Percentage
Building on water channels	28	8
Poor Physical Planning	52	14.9
Inadequate Drainage Channel	75	21.4
Heavy rainfall	135	38.6
Dumping of wastes on channels	60	17.1
Total	350	100

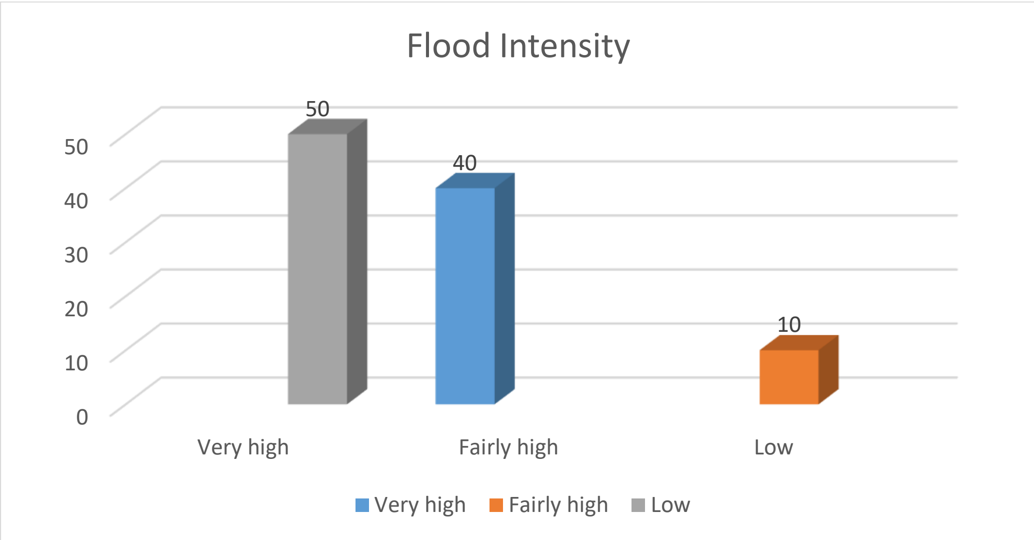

Figure 3.5: Flood Intensity in Port Harcourt Metropolis

4. Discussion

The study on the impact of flooding on road transport infrastructure in Port Harcourt Metropolis provides insights into the relationship between flooding and urban mobility challenges. Hypothesis 1, tested in Table 3.7: Relationship between Flooding and Road Transport Infrastructure, demonstrated that flooding has a significant impact on road infrastructure, as the t-calculated value (2.813) exceeded the critical threshold (1.96) at a 0.05 significance level. This aligns with findings by Ogundele *et al.,* (2023) and Adedeji *et al.,* (2022), who observed that frequent flooding deteriorates roads, causing erosion, potholes, and structural damage, thereby undermining the functionality of transport networks in Nigerian cities. Table 3.7 above shows that the calculated value of t-test $t_{cal} = 2.813$ which is greater than the critical value $t_{crit} = 1.96$ at 0.05 level of significance with degree of freedom df = 172; therefore, the null hypothesis is rejected in favour of the alternative hypothesis which states "Flooding has significant impact on Road Transport Infrastructure in Port Harcourt Metropolis.". This showed that Flooding has significant impact on Road Transport Infrastructure in Port Harcourt Metropolis.

Similarly, Hypothesis 2, analyzed in Table 3.8: Flooding and Journey Time, revealed that flooding significantly increases journey times, as indicated by a chi-square value of 15.66, greater than the critical value of 9.448. This result confirms that waterlogged streets and inadequate drainage systems exacerbate traffic congestion, delaying commutes and logistics. Bamigboye *et al.,* (2021) and Akinyemi & Olaniyan (2020) have similarly reported that inadequate drainage and unregulated urban development amplify the effects of flooding on transport delays.

The spatial analysis in Table 3.9: GPS Coordinates of Lowly Flooded Areas highlights less flood-affected regions in Port Harcourt, such as Peter Odili Road and Old GRA, which benefit from better drainage or higher elevation. These findings emphasize the need for targeted infrastructure upgrades in flood-prone areas to enhance resilience. Such interventions resonate with the recommendations of Adewole *et al.,* (2023), who advocate for adaptive infrastructure design in urban areas prone to climate-induced flooding.

On flood frequency and intensity as seen in Figure 4.5, , majority of the respondents agreed that flood events are often very high while other respondents said level of flood intensity in the city is fairly high and only few of the respondents agreed that flood intensity is often low in the city. It is imperative to note that these findings are similar to previous studies on flood menace in Nigeria. For instance, in a study by Daniel *et.al*. (2012), in Gombe State of Nigeria it was held that flood incidences have become a perennial problem in Gombe metropolis as the city experiences flood during the wet seasons. Even though the average annual rainfall figure (114.3cm) is low, yet every year there is a record of flood incidence. The authors attributed the high frequency and intensity of flood to poor drainage infrastructures. In a similar study by Abdulhamid and Ibrahim (2011) on episodic disaster events occurrence in Zaria urban area of Nigeria, it was reported that between 2007 and 2008, flood occurrence was the second highest disaster after fire outbreaks. The authors noted that floods occurred 28 times within the said period while 37 fire outbreak incidences were reported. The menace of flood respects no state irrespective of climatic features as the studies of Daniel, *et al.,* (2012) and Abdulhamid and Ibrahim (2011) have shown.

Analysis of historical flood data (2010-2022) and survey responses during the study showed that flooding occurs frequently, with an average of 5-7 events per year. Severity levels range from low to moderate to high and very high. Flooding events peak during the rainy season (June-September). These findings support the studies carried out by Eze and Effiong (2012), Nwilo and Badejo (2006).

5 Conclusion

The study on the impact of flooding on road transport infrastructure in Port Harcourt Metropolis highlights significant challenges faced by the city, particularly in its low-lying areas like Rumuokuta and Eneka. The research identifies flooding as a critical issue caused by a combination of heavy rainfall, poor urban planning, inadequate drainage systems, and human activities such as indiscriminate dumping of refuse. These factors exacerbate damage to road infrastructure, including erosion, the destruction of culverts, and disruption of traffic flow, leading to increased travel times, economic losses, and reduced productivity. The findings emphasize the high frequency of flooding events—occurring 5-7 times annually—with severe socio-economic impacts, especially on low-income communities. Despite existing flood management strategies, their inadequacy underscores the need for proactive and sustainable interventions to protect the city's road networks and mitigate future risks. Addressing these challenges requires a coordinated approach to urban planning, drainage improvement, and community awareness to ensure resilience against recurrent flooding.

To mitigate flooding in Port Harcourt Metropolis, the study recommends a multifaceted approach: improving road infrastructure using durable materials and designs that enhance water drainage, developing more effective and extensive drainage systems, and implementing advanced flood forecasting and early warning systems. Regular inspection and maintenance of roads and drainage infrastructure are essential to ensure functionality and resilience. Additionally, urban planning strategies should be revised to consider flood risks, avoiding construction in vulnerable areas or integrating flood mitigation measures. Finally, comprehensive emergency response plans should be developed to ensure swift and effective management of flood events, minimizing disruptions to road transport and reducing socio-economic impacts.

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