Determinants of Spatial Accessibility to Childhood Vaccination Uptake in A Zero-Dose Risk Perspective

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DOI: https://doi.org/10.5281/zenodo.22157806

Abstract

Childhood vaccination is one of the most effective public health strategies for lowering child morbidity and mortality. However, the persistence of poor access and zero-dose continues to pose health challenges in many parts of Nigeria. This study examined the spatial accessibility determinants of childhood vaccination uptake and zero-dose risk perspective in the Plateau Northern zone, Plateau State, Nigeria. A cross-sectional survey design was used. The study focused on women of childbearing age, 15-49 years, who had at least one child under the age of five. Taro Yamane's formula was used to select a sample size of 400 respondents. The study adopted a multistage random sampling technique, selecting sampling units sequentially at different stages to obtain a representative sample of the population, while data were collected through questionnaires and in-depth interviews. Descriptive statistics, Chi-square analysis, and binomial regression were employed for data analysis. The findings revealed that 82.0% of respondents had no vaccination centres within their communities, and 85.0% indicated that outreach teams did not visit their communities. Respondents who had difficulty reaching the vaccination site 68.5% reported long distance as a challenge. The Chi-square Test showed a significant relationship between childhood vaccination uptake and the number of vaccination centres ($\chi^2 = 64.83$, $p < 0.001$), outreach visits ($\chi^2 = 13.16$, $p = 0.001$), and difficulties in reaching vaccination sites ($\chi^2 = 12.19$, $p = 0.007$). Binary logistic regression further showed that the availability of vaccination centres significantly affected uptake ($p = 0.023$, COR = 2.255, 95% CI: 1.121–4.536), ease of locating vaccination sites was highly significant ($p < 0.000$, COR = 2.579, 95% CI: 1.786–3.725), and difficult access routes to vaccination centres were also significant ($p = 0.017$, COR = 1.380, 95% CI: 1.060–1.798). The study showed that spatial accessibility factors have a considerable impact on childhood immunization rates in the Plateau North Senatorial District. It suggests enhancing the spatial distribution of vaccination centres, improving transportation infrastructure, increasing outreach visits, and providing clear directional signposts to increase equitable access to routine childhood vaccination services and reduce low vaccination uptake in the study area.

Keywords: Spatial Accessibility, Zero-dose, Childhood vaccination, Vaccination uptake

1. INTRODUCTION

Globally, Childhood immunization is largely regarded as one of the most effective public health interventions. Nonetheless, discrepancies in vaccination access continue to leave millions of children unvaccinated. In 2024, 14.3 million children worldwide were categorized as zero-dose, meaning they had not received a single dose of any vaccine. Whereas the third dose of the diphtheria, tetanus, and pertussis vaccine (DTP3) accounted for 85% in 2024, a consistent number compared to the previous year but still short of universal coverage (World Health Organization – WHO, 2025) (WHO, 2025). This health intervention significantly protects against a wide range of

life-threatening diseases, including measles, polio, diphtheria, pertussis, and more recently, COVID-19 and the Human Papillomavirus (HPV) Vaccine (UNICEF, 2022). These benefits individual health, as they help establish herd immunity, thereby protecting vulnerable populations (Continental Hospitals, 2024). Zero-dose children, the focus of the study, are those who have not received the first dose of routine immunization against diphtheria, tetanus, and pertussis (DTP1) (WHO, 2023).

According to the 2025 WHO–UNICEF global immunization report, approximately 89% of infants worldwide (about 115 million children) received the first dose of the diphtheria–tetanus–pertussis vaccine (DTP1) in 2024, while 85% (about 109 million children) completed the third dose (DTP3), indicating a global dropout rate between the first and third doses of about 4 percentage points. In the WHO African Region, which mostly covers countries in Sub-Saharan Africa, immunization coverage remained below the world average, with persisting concentrations of zero-dose and under-immunized children in underserved and conflict-affected settings. Despite modest advances in coverage, an estimated 14.3 million children globally remained unvaccinated in 2024, underlining persisting discrepancies in access to routine vaccination treatments, notably across Sub-Saharan Africa (WHO & UNICEF, 2025). Despite considerable global immunization coverage, nearly 20 million children do not receive a full course of basic immunizations, among whom more than 14 million had "zero-dose" or did not receive any vaccines at all (WHO and UNICEF, 2023). The literature indicates that the disparities in access to the intervention related to zero-dose were largely among underserved, distant, or conflict-affected communities (Gavi, 2022). Moreover, Similar variations have been observed in conflict-affected areas, where interruptions in health services, population displacement, and insecurity severely reduced childhood vaccination coverage and increased the incidence of zero-dose children (Akseer *et al.,* 2023; UNICEF, 2023). The COVID-19 lockdowns have had a negative impact on childhood routine immunization, disrupting public health services. Postponement of mass vaccination campaigns across hotspot countries and diversion of resources in an already limited and underfunded health system further deprived access to immunization (Lai *et al.,* 2023). A global review of 204 countries found a significant decrease in routine childhood immunization during the COVID-19 pandemic due to disruptions in health services, migration limitations, and decreased healthcare consumption (Causey *et al.,* 2021). Similarly, Shet *et al.,* (2022) found that disruptions in vaccination programs in low- and middle-income countries dramatically increased the frequency of under-immunized and zero-dose children. As a result, parents delayed normal vaccination sessions for their children in fear of contracting the COVID-19 virus (Sharma, 2021). Similar trends were observed in Ethiopia, where fears of COVID-19 exposure reduced attendance at routine immunization sessions (Masresha *et al.,* 2020). According to empirical evidence, geographical constraints, uneven distribution of healthcare facilities, and restricted physical access to vaccination services continue to be key predictors of under-vaccination and zero-dose prevalence among children in vulnerable areas (Alegana *et al.,* 2024).

The situation significantly contributed to a decline in routine immunization coverage, resulting in zero-dose children. The “Big Catch-Up Programme” was introduced to assist countries in vaccinating children who missed immunization during the pandemic to recover from the impact of COVID-19 on routine immunization and strengthen health systems at the primary health-care for IA2030 trajectory (WHO, 2023), yet the post-COVID-19 interventions were not highly effective in some

countries. Despite the implementation of recovery programs following the pandemic, several countries still have gaps in routine vaccination coverage due to ongoing health-system inadequacies, vaccine reluctance, and insufficient outreach services (Shet *et al.,* 2022). Spatial disparities in access to immunization services continue to contribute to the concentration of zero-dose children in underserved and difficult-to-reach regions, where spatial barriers frequently limit access to routine vaccination programs (Shiferie *et al.,* 2024).

A close look at the vaccination exercise in Nigeria, children between the ages of 12 and 23 years old have now had their basic vaccination in the last two decades. This increased from 23% in 2008 to 44% in 2021, with a significant milestone in 2020 when the country was confirmed and declared polio-free (WHO & UNICEF, 2022). Nigeria continues to face a disproportionate amount of the global burden for zero-dose children. According to recent estimates, roughly 2.1 million Nigerian children have not received a single dose of standard immunizations, making Nigeria the country with the highest proportion of zero-dose children worldwide. Immunization coverage varies greatly across the country, with the lowest rates found in northern Nigeria, where armed conflict, population relocation, poverty, and restricted access to health care continue to impede vaccine uptake. Developing effective techniques for locating, tracking, and reaching these children is critical to ensuring equitable vaccination coverage and lowering vaccine-preventable diseases. Furthermore, despite significant progress in child survival, Nigeria continues to have the highest number of under-five deaths in the world, with an estimated 768,000 deaths in 2023, many of which were preventable, such as vaccine-preventable diseases and inadequate access to essential healthcare services (UN IGME, 2025). A spatio-temporal study of childhood vaccination uptake in Nigeria revealed a considerable geographical inequality in immunization coverage. Lower uptake concentrated in some northern states is associated with differences in healthcare accessibility, socioeconomic settings, and community-level characteristics that significantly influenced childhood vaccination uptake (Lawal *et al.,* 2023).

In Plateau State, 62.2% of the population travel over a 5-kilometer distance to the nearest Primary Health Centres, indicating a significant difference in healthcare access (Damashi *et al.,* 2020). This has continued to contribute to low access and utilization of important health services, such as children's vaccination. Poor geographical access to healthcare facilities is a major barrier to the use of key maternal and child health treatments, such as routine childhood immunization, especially among Nigeria's rural and underserved communities (Hassan *et al.,* 2024). However, despite the growing evidence at the national and state levels, evidence-based studies on Plateau Northern Zones remain scarce. This highlights the need to investigate the Spatial factors of childhood vaccination uptake and zero-dose perspectives in the Northern Zone of Plateau State.

LITERATURE REVIEW

The Study Content

Spatial accessibility refers to how easily people may access and use healthcare services based on their geographical location relative to service delivery places. It considers the physical distance to health services, travel time, transit availability, road network characteristics, and the spatial distribution of healthcare resources. In healthcare research, spatial accessibility is seen as an important factor of healthcare access because it impacts how easily communities may acquire essential health treatments, particularly preventive measures like childhood immunization. Areas with poor spatial accessibility frequently have lower utilization of health care due to increased

travel loads, transportation expenses, and topographical constraints (Khazanchi *et al.,* 2024). Childhood immunization uptake is the rate at which children receive recommended immunizations in accordance with national or international immunization schedules. It is typically defined as the percentage of eligible children who receive specified vaccination doses or complete the entire routine immunization schedule within the prescribed age range. High immunization coverage is critical for preventing vaccine-preventable diseases, lowering childhood morbidity and mortality, and developing herd immunity in communities. However, various factors influence vaccine uptake, including socioeconomic status, parental understanding, health system conditions, and access to vaccination services (Olaniyan *et al.,* 2021). The relationship between spatial accessibility and childhood immunization uptake is predicated on the idea that the availability and closeness of vaccination facilities influence caregivers' ability to provide immunization for their children. Caregivers may delay, miss, or entirely skip vaccination appointments if vaccination centers are remote from communities, travel times are long, transportation alternatives are limited, or outreach services are insufficient. In contrast, communities with well-distributed health facilities, functioning outreach programs, and shorter travel distances have higher vaccination coverage and a lower proportion of zero-dose children. As a result, spatial accessibility is an important factor in equitable immunization coverage and can help identify individuals at risk of under-vaccination and zero-dose status. Spatial accessibility is especially essential in the Plateau North Senatorial District due to the uneven distribution of healthcare institutions, distant rural settlements, transportation constraints, and differences in healthcare infrastructure between areas. Understanding how factors such as the number of vaccination centers, outreach visits, travel time, ease of locating vaccination sites, and accessibility to health facilities influence childhood immunization uptake is critical for developing targeted interventions to reduce zero-dose prevalence and improve equitable access to routine immunization services.

Spatial accessibility and temporal barriers to routine childhood vaccination

Inadequate vaccine information and misunderstandings continue to be significant obstacles to vaccination uptake, particularly in vulnerable areas. Other factors such as an increase in vaccination sites, outreach visits, time taken to reach the vaccination centre, ease of locating the vaccination site, and difficulties in reaching the vaccination site were investigated to close the gaps.

In Africa, children on zero-dose in rural Democratic Republic of Congo were related to quantitative household-to-facility travel times, where children living more than 60 minutes from the nearest health facility had a slightly higher chance of being zero-dosed compared to those living within less than <5 minutes. While geographic access is important, caregiver demand and attitudes were far more effective in driving vaccine uptake (Mbunga *et al.,* 2024). This suggests that reducing zero-dose prevalence needs to address both the physical access and behavioural demand constraints. Similarly, a spatio-temporal analysis of immunization coverage in Ethiopia reported that distance to health facilities and travel time to the nearest city were consistently associated with lower vaccination uptake across all years (Atalell *et al.,* 2022). This further emphasized that locations further from health centres exhibited clustering of low vaccination and variolation in the uptakes. A spatial analysis of vaccination coverage in Ethiopia revealed large regional differences, with low coverage areas clustered in distant and underserved locations (Atalell *et al.,* 2022). In Nigeria, poor road conditions, damaged infrastructure, and seasonal accessibility constraints significantly influenced under-five immunization utilization

in Plateau State's Northern Senatorial District (Oladejo *et al.,* 2025). A study undertaken in a multi-country Human-Centred Design (HCD) and qualitative participatory action research study in the Democratic Republic of Congo, Mozambique, and Nigeria identified geographic inaccessibility and restricted functionality of outreach programs as key structural issues. Caregivers mentioned long travel distances, a lack of functional nearby primary health care Centre (PHC) facilities, and negative service experiences as causes for absence during vaccinations (Shearer *et al.,* 2023). Vaccination services sometimes fail to reach vulnerable populations due to ineffective implementation of pro-equity methods such as outreach and mobile clinics. Evidence from Gavi-supported countries indicates that well-coordinated outreach services and mobile vaccination strategies substantially improve vaccine access among underserved and hard-to-reach populations (Gavi, 2023).

In Nigeria, Utazi *et al.,* (2024) investigate the distribution of zero-dose and under-immunized children. Their findings revealed distinct spatial clusters of zero-dose children, especially in underserved and hard-to-reach areas, and showed that geographical accessibility to health services remains a major determinant of vaccination outcomes.

Furthermore, in Plateau, David *et al.,* (2020) did a hospital-based study in Jos, Plateau State, to assess factors influencing the timing of birth vaccines and found 53.8% of neonates received their at-birth vaccines within 24 hours, due to weekend deliveries, non-vaccination days, public holidays, and vaccine stockouts. The type of health facility for delivery being a private hospital predicted delayed vaccination, signifying health-care disparities in timely vaccine access. Spatio-temporal parameters such as delivery schedule, location (private/public facility), and operational days have a substantial impact on the timeliness of routine vaccination David *et al.,* (2020). This study emphasizes the need for better institutional scheduling, stock management, and 24-hour

According to the reviewed literature, spatial accessibility remains a significant predictor of childhood immunization uptake, particularly in underserved and difficult-to-reach communities where distance to health facilities, inadequate outreach services, and transportation barriers contribute to low vaccine coverage and the persistence of zero-dose children (Alegana *et al.,* 2024; Shiferie *et al.,* 2024). However, empirical research into how these spatial characteristics influence childhood vaccine uptake and zero-dose prevalence in the Plateau North Senatorial District is limited. Given the area's mix of urban, peri-urban, and rural inhabitants, as well as known inequities in healthcare accessibility, this study is necessary to provide context-specific data for improving equitable access to routine immunization treatments. The study also contributes to achieving Sustainable Development Goals 3 (Good Health and Well-being) and 10 (Reduced Inequalities) by encouraging equitable vaccination coverage and improving child health outcomes (United Nations, 2024).

MATERIALS AND METHODS

Study Area

The Northern Zone is a political delineation of one of three Senatorial Districts in Plateau State. Plateau North Senatorial District is a unique location for studying geographic accessibility and childhood vaccination uptake since it includes urban, peri-urban, and rural populations with diverse levels of access to healthcare facilities. While the zone contains important referral and tertiary health institutions inside Jos, many towns like Barkin Ladi, Riyom, Bassa, and Jos East are still physically remote from healthcare facilities and crucial vaccination programs. Evidence suggests that geographical constraints, long travel durations, and unequal distribution of health services all play a role in under-

vaccination and the persistence of zero-dose children in underserved groups (Alegana *et al.,* 2024; Shiferie *et al.,* 2024). These spatial disparities may exacerbate differences in childhood vaccination uptake across communities in the research area. Given the growing concern about equal access to routine immunization in Nigeria, the Plateau North Senatorial District provides a crucial backdrop for evaluating how spatial accessibility affects vaccination uptake and zero-dose prevalence among children. As a result, the area is ideal for gathering evidence to support targeted interventions aimed at increasing vaccination coverage and decreasing geographical disparities in child health outcomes. The study area is made up of six (6) LGAs: Jos North, Jos East, Jos South, Barkin Ladi, Riyom and Bassa. The Zone lies between Latitudes 8^0 24' and 10^0 30' N and Longitudes 8^0 32' and 10^0 38' E (GVP, 2021). The study area shares boundaries with Bauchi State to the North through Toro, Bogoro, and Ningi LGAs to Kaduna State to the West through Kaura, Jema'a, and Zangon Kataf LGAs. It has a total land area of about 9,400 square kilometers, with an average elevation of about 1,250 meters above mean sea level.

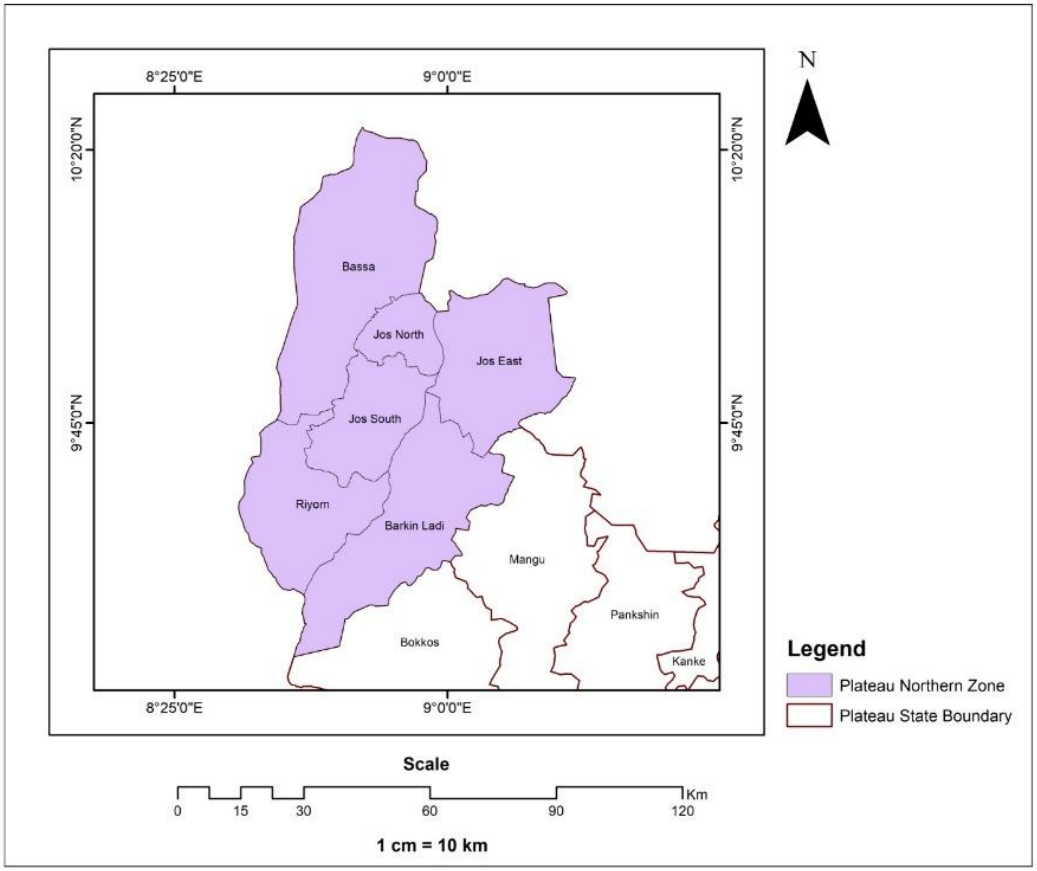

Figure 1: Plateau State showing Plateau North Senatorial District

The distribution of healthcare facilities within the Plateau North Senatorial District is very important to this study because health facilities are the key sites for routine pediatric immunization program delivery. Although the zone has various primary, secondary, and tertiary healthcare facilities, including major referral hospitals in Jos, access to these services is not uniformly dispersed across all areas. According to Alegana *et al.,* (2024), regional

disparities in the distribution and accessibility of health-care facilities contribute considerably to under-vaccination and the persistence of zero-dose children, particularly in underprivileged communities. As a result, rural and geographically isolated populations in sections of Barkin Ladi, Riyom, Bassa, and Jos East may face longer travel distances, higher transportation expenses, and less access to vaccination services than urban towns. The World Health Organization and the United Nations Children's Fund (WHO & UNICEF, 2025) also emphasized that inequitable access to vaccination services continues to be a major contributor to the global prevalence of zero-dose children. Understanding how the location and accessibility of healthcare facilities affect childhood vaccination uptake is critical for achieving equitable immunization coverage and lowering the prevalence of zero-dose children in the Plateau North Senatorial District. Nevertheless, the population size in the zone makes a case for the establishment of more healthcare facilities (Shaba *et al.,* 2023).

Methods

Research Design

This study used a mixed methods design (MMD), specifically a convergent parallel design. The design was deemed appropriate because quantitative and qualitative data were collected during the same phase of the study, analyzed separately, and integrated during interpretation to provide a comprehensive understanding of the spatial accessibility determinants of childhood vaccination uptake from a zero-dose risk perspective in Plateau North Senatorial District. The quantitative component produced measurable evidence on spatial accessibility criteria that influence vaccine uptake, whilst the qualitative component gave deeper insights into caregivers' experiences, views, and issues with access to immunization services.

Quantitative Method

The quantitative component used a cross-sectional survey design with women of reproductive age (15–49 years) who had at least one child under the age of five. The strategy allowed for the collection of data on vaccine uptake and spatial accessibility factors at a single point in time.

Qualitative Method

The qualitative component conducted In-Depth Interviews (IDIs) with women of childbearing age, community leaders, and religious leaders to investigate their experiences and perceptions of vaccination accessibility, barriers to utilization, and factors contributing to zero-dose children in the study area.

Study Population

The study population included women of reproductive age (15-49 years old) with at least one child under the age of five who lived in the Plateau North Senatorial District. According to the National Population Commission (NPC, 2024), the district had an estimated 504,972 women of childbearing age.

Sample Size Determination

The sample size for the quantitative survey was determined using the Yamane Taro (1967) formula:

$$n = \frac{N}{1 + Ne^2}$$

Where
n= Sample size

N= Population size: 504,972 (women of childbearing age 15-49 years))

e= Level of Precision or Sampling of Error, which is $\pm$5%

$$n = \frac{504{,}972}{1+504{,}972\ (0.05)^2}$$

$$n = \frac{504972}{1{,}262.43} = 400$$

Sampling Procedure

Political boundaries were used as the operational spatial framework because immunization planning, health-service administration, data collection, and resource allocation are mostly organized through administrative units. However, the boundaries were not treated as causal factors. Within those boundaries, I examined the actual spatial determinants that may influence childhood vaccination uptake.

A multistage stratified random sampling technique was employed for the study. At the first stage, Plateau North Senatorial District was stratified into six strata based on local government areas, thus, Barkin Ladi, Bassa, Jos East, Jos North, Jos South, and Riyom LGAs. At the second stage, wards were then clustered and randomly selected to give representation across the study area. Furthermore, at the third stage, polling units were then selected by simple random sampling. Fourthly, the 400 women of childbearing age (15-49 years) were distributed across the selected polling units proportionately to size. For the qualitative component, purposive sampling was used to select participants for in-depth interviews. Approximately 10 communities and religious leaders were purposively selected based on their leadership positions, knowledge of community health practices, and experience with childhood immunization activities. In addition, 50-60 mothers were purposively selected for interviews based on their experience with childhood vaccination services and having at least one child eligible for routine immunization. Participants were identified within the selected communities and approached based on the predetermined inclusion criteria. The interviews were conducted with participants who consented to take part in the study.

Data Collection Methods

Structured questionnaires were distributed to qualified respondents in order to collect quantitative data. The qualitative data were gathered through In-Depth Interviews (IDIs). Interviews were audio-recorded with the participants' permission and supplemented with field notes.

Data Analysis

The quantitative data were analyzed using IBM SPSS Statistics Version 25. Descriptive statistics, such as frequencies and percentages, were employed to characterize respondents' characteristics and factors influencing geographical accessibility. The Chi-Square Test of Association was conducted to evaluate whether there were any significant associations between children's vaccination uptake and spatial accessibility characteristics.

1. Chi-Square Formula:

$\chi^2 = \Sigma[(O - E)^2/E]$

Where: χ^2 = Chi-square statistic O = Observed frequency E = Expected frequency

2. Binomial Logistic Regression was employed to determine the determinants of childhood vaccination uptake because the dependent variable was binary (uptake versus non-uptake).

Logistic Regression Model:

$$\ln \frac{p}{1-p} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_n X_n$$

Where:

p = probability of childhood vaccination uptake

β_0 = intercept

$\beta_1 \ldots \beta_n$ = regression coefficients

$X_1 \ldots X_n$ = spatial accessibility variables

Ethical clearance

Ethical approval for this study on spatial accessibility determinants of childhood vaccination uptake was obtained from the Ministry of Health Headquarters. Informed consent was secured from all respondents, and confidentiality and anonymity were strictly maintained. Participation was strictly maintained. Participation was voluntary, and data collected were used solely for academic purposes.

RESULTS AND DISCUSSION

The study findings are reported on the Characteristics of Spatial Accessibility to Childhood Vaccination Uptake, Determinants of Children Vaccination Uptake, and the zero-dose perspective.

Table 1 shows that 13.8% of the respondent had 1 (one) vaccination centre in their area, 2.5% reported having 3 (three), and only 1.8% had 2 (two). The majority of respondents, 82.0%, had no vaccination centres close to or in their area and had to travel very long distances for the routine vaccination of their children.

Table 1: Characteristics of Spatial Accessibility to Childhood Vaccination Uptake

Spatial Accessibility Factors	Frequency	Percentage (%)
Number of Vaccination sites in our Area		
1	55	13.7
2	7	1.8
>3	10	2.5
None	328	82.0
Outreach Team Ever Visit		
Yes	41	10.2
No	340	85.0
Only nearby village	19	4.8
Time Taken to Vaccination Centre		
< 15 min.	42	10.0
15–30 min.	123	31.0
31–60 min.	53	13.0
> 1 hour	182	46.0
Signpost Condition		
Very clear	53	13.2
Confusing	102	25.5
No signpost	245	61.3
Ease of New Person Locating Site		
Cannot locate	258	64.5
Easy, but need to ask	5	1.2
Easy, no need to ask	6	1.5
Difficult to locate	131	32.8
Challenges with Reaching Vaccination Site		
Long distance	274	68.5
Lack of transport	61	15.2
Security/conflict zones	57	14.3
No difficulties	8	2.0
Total	**400**	**100.0**

In an interview conducted with respondents, 82% of whom said none to the question about the number of vaccination centres in their area, it was asserted that:

> *"We don't have any vaccination* centre *in my area. If I want to immunize my children, I have to travel to another community, which is costly and time-consuming. Because of this, I sometimes delay or miss my children's routine vaccinations."* (IDI, Kimakpa, Bassa LGC, 2024).

In one of the interviews conducted, 13.8% reported having one vaccination centre in their area; it was asserted that:

> *"We have only one vaccination* centre *in our area, and it is always*

> *crowded. Sometimes the vaccine finishes before it gets to my turn, and I have to come back another day. This makes it hard to keep up with my children's routine vaccinations".* (IDI, Kimakpa, Bassa LGC, 2024).

Visits to vaccination outreach sites were reported among 10.3% of respondents, and 4.8% visited. However, a large proportion (85.0%) of the respondents have not visited vaccination outreach sites.

Regarding the time taken to reach the nearest vaccination centre, about half (46.0%) of the respondents reported that it took them more than 1hour; 13% and 31% had between 31-60 minutes, and only 10% took less than 15 minutes to the closest vaccination centre. Signposts or directions to the site that help locate vaccination centres. The result reveals that 61.3% of the respondents had no signpost and, 25.5% had a signpost that was not clear enough to direct to the vaccination site in their community. Only 13.3% had one that was very clear for direction to the centre.

In an interview conducted with respondents, 25.5% said yes, but that they were confused; it was asserted that:

> *"Yes, we have a vaccination* centre*, but the signpost and directions are confusing. Many people don't know exactly where to go, and I have gotten lost before."* (IDI, Jol/Kwi, Riyom LGC, 2024).

Furthermore, regarding the ease with which a new visitor can locate vaccination centres, 64.5% of the respondents indicated they cannot easily locate them, and 32.8% stated it was difficult to locate. Only 1.3% indicated it can be easily located with signs and 1.5% stated it was easy, without asking.

The respondents mentioned challenges with accessing the vaccination site. Nearly seven in every ten of the study participants (68.5%) indicated long distance as the difficulty to accessing vaccination sites, 15.3% reported lack of transportation, and 14.3% had security concerns. Only a few respondents (2.0%) had no difficulty accessing vaccination sites.

Table 2 shows that the number of Vaccination sites has a significant association with the nature of children's vaccination uptake (χ^2:64.83;3, p=0.0001). The households with no vaccination site available nearby dominate the non-immunized group, while areas with more available sites (one, two, or three and above) are far more associated with uptake. This means vaccination uptake is heavily influenced by service availability and spatial coverage of health facilities. In simple terms, where vaccination sites are few or absent, uptake drops sharply, while increased facility presence improves uptake significantly.

Outreach visits were found to be significantly (χ^2:13.16;2, p=0.0014 associated with vaccination uptake. The data show that respondents who reported that health workers visited their communities had higher vaccination uptake compared to those who said no outreach visits occurred. This indicates that community outreach services play a critical role in improving immunization coverage, especially in hard-to-reach areas. Where outreach is absent, many children remain unvaccinated due to distance, poor awareness, or access barriers.

Table 2: Predictors of Spatial Accessibility to Children's Vaccination Uptake

Spatial Accessibility Variable	**Nature Children Vaccination Uptake**						(χ^2) **P-value**
	Uptake		**No Uptake**		**Total**		
No. of Vaccination Sites	**No.**	**%**	**No.**	**%**	**F**	**%**	
	(188)	(47.0)	(212)	(53.0)	(400)	(100)	
One	3	0.75	52	13.00	55	13.75	**(64.83) 0.0001**
Two	0	0.00	7	1.75	7	1.75	
Three or more	0	0.00	10	2.50	10	2.50	
None	185	46.25	143	35.75	328	82.00	
Outreach Visit							
Yes, they have visited	30	7.50	11	2.75	41	10.25	
No, they have not visited	148	37.00	192	48.00	340	85.00	**(13.16) 0.0014**
Only visited nearby village	10	2.50	9	2.55	19	4.75	
Time Taken to Reach Vaccination Centre							
< 15 minutes	25	6.25	17	4.25	42	10.50	
15–30 minutes	52	13.00	71	17.75	123	30.75	**(3.86) 0.277**
31–60 minutes	24	6.00	29	7.25	53	13.25	
> 1 hour	87	21.75	95	23.75	182	45.50	
Signpost Condition							
Very clear	30	7.50	23	5.75	53	13.25	
Confusing	47	11.75	55	13.75	102	25.50	**(2.28) 0.320**
No signpost	111	27.75	134	33.50	245	61.25	
New Person's Ease of Locating Site							
Cannot locate	121	30.25	137	34.25	258	64.50	
Easy, with signs	3	0.75	2	0.50	5	1.25	**(0.37) 0.946**
Easy, no need to ask	3	0.75	3	0.75	6	1.50	
Difficult to locate	61	15.25	70	17.50	131	32.75	
Difficulties in Reaching Vaccination Site							
Long distance	129	32.25	145	36.25	274	68.50	
Lack of transport	32	8.00	20	7.25	61	15.25	**12.19(3) p=0.007**
Security/conflict zones	27	6.75	30	7.50	57	14.25	
No difficulties	0	0.00	8	2.00	8	2.00	

P-value = <0.01
(χ^2) = Chi–square test

Finally, Difficulties in Reaching Vaccination Sites show (χ^2:12.19;3, p=0.007 significant affects vaccination uptake. Those who face long distances or lack transportation to vaccination sites are less likely to immunize their children. Improving transportation infrastructure and healthcare accessibility is critical to increasing vaccination rates.

Table 3: Results of the Binomial regression analysis of Spatial accessibility determinants and childhood vaccination uptake in Plateau North Senatorial District.

							95% C.I.	
	B	**S.E.**	**Wald**	**df**	**Sig.**	**COR**	**Lower**	**Upper**
No. of Vaccination centres	.813	.357	5.199	1	.023	2.255	1.121	4.536
Outreach frequency	-.076	.150	.256	1	.613	.927	.691	1.244
Time taken	.051	.172	.087	1	.769	1.052	.751	1.474
Direction sign to site	-.028	.076	.137	1	.712	.972	.837	1.129
Easy Location	.947	.188	25.5	1	.000	2.579	1.786	3.725
Difficulty accessing vaccination centres	.322	.135	5.718	1	.017	1.380	1.060	1.798
Constant	-3.044	.733	17.256	1	.000	.048		

*P-value = <0.01
COR = Crude Odd Ratio

Table 3 presents the results of the binomial logistic regression analysis of spatial accessibility factors and childhood vaccination uptake in Plateau North Senatorial District. The findings revealed that the number of vaccination centres significantly influenced childhood vaccination uptake (COR = 2.255, 95% CI = 1.121–4.536, p = 0.023). Ease of locating vaccination centres was also found to be a significant predictor of vaccination uptake (COR = 2.579, 95% CI = 1.786–3.725, p < 0.001). Similarly, difficulties in reaching vaccination centres showed a statistically significant association with childhood vaccination uptake (COR = 1.380, 95% CI = 1.060–1.798, p = 0.017). This study investigated the impact of spatial accessibility determinants on childhood vaccination uptake and zero-dose risk in the Plateau North Senatorial District. The study found that the number of vaccination centers, the ease of finding vaccination centers, and the difficulty of getting to vaccination centers were all significant predictors of childhood vaccination uptake, whereas outreach frequency, travel time, and directional signposts were not.

Discussion

The study looked at the impact of spatial accessibility determinants on childhood immunization rates in the Plateau North Senatorial District. The data demonstrated that the number of vaccination centers, the convenience of identifying vaccination centers, and the difficulty in reaching vaccination centers were all significant predictors of childhood vaccination uptake. The substantial relationship between the number of vaccination centers and vaccination uptake shows that increasing the availability of vaccination service points may improve access to routine immunization services while lowering obstacles related to distance and travel. This finding is aligned with that of Alegana *et al.* (2024), who found that limited geographical access to health services contributes to under-vaccination and the persistence of zero-dose children in underserved groups. Similarly, the significant influence of ease of locating vaccination centres indicates that the visibility and accessibility of vaccination service points may affect caregivers' utilization of immunization services. Communities where vaccination centres are easily identifiable are more likely to achieve higher immunization uptake than those where caregivers experience challenges in locating service points. The finding further supports evidence from Shiferie *et al.,* (2024), who observed that spatial inequalities in access to immunization services contribute to disparities in vaccination

coverage and the concentration of zero-dose children.

The study also discovered that problems in accessing vaccination centers had a substantial impact on childhood vaccine uptake. This research implies that physical impediments, such as poor road networks, transportation constraints, and geographical distance, may hinder caregivers' ability to provide routine immunization services to their children. The results support previous research that identified spatial accessibility as a key driver of healthcare utilization and childhood vaccine uptake, particularly among rural and hard-to-reach populations (Shiferie *et al.,* 2024). However, outreach visit frequency, time taken to reach vaccination centres, and the availability of directional signposts did not demonstrate statistically significant associations with childhood vaccination uptake. The non-significant effect of these variables may indicate that their influence is mediated by other factors such as caregivers' awareness, perceived benefits of immunization, availability of vaccines, and overall functionality of healthcare services. Overall, the findings underscore the importance of spatial accessibility in shaping childhood vaccination uptake and suggest that improving the distribution, visibility, and physical accessibility of vaccination centres may contribute to reducing the prevalence of zero-dose children and enhancing equitable immunization coverage in Plateau North Senatorial District. These findings are particularly relevant to the achievement of Sustainable Development Goal 3 on Good Health and Well-being and Sustainable Development Goal 10 on Reduced Inequalities through improved access to essential healthcare services.

CONCLUSION

The study concludes that spatial accessibility is a critical factor influencing childhood vaccination uptake in Plateau North Senatorial District. The significant effects of the number of vaccination centres, ease of locating vaccination centres, and difficulties encountered in reaching vaccination facilities indicate that physical access to immunization services remains a major challenge for some communities within the study area. These findings highlight the role of geographical inequalities in shaping vaccination outcomes and underscore the need for strategies that improve equitable access to routine immunization services. By providing empirical evidence on the spatial determinants of childhood vaccination uptake, the study contributes to efforts aimed at reducing the burden of zero-dose children, strengthening routine immunization systems, and advancing the achievement of equitable child health outcomes. The findings further provide a basis for evidence-informed planning and resource allocation to improve vaccination coverage among underserved populations in Plateau State and Nigeria as a whole.

References

Akseer, N., Wright, J., Tasic, H., Everett, K., Scudder, E., Amsalu, R., Bhutta, Z. A., & Bendavid, E. (2023). The impact of conflict and displacement on childhood vaccination coverage in low- and middle-income countries: A systematic review. *The Lancet Global Health,* 11(4), e567–e578.

Alegana, V. A., Ticha, J. M., Mwenda, J. M., Katsande, R., Gacic-Dobo, M., Danovaro-Holliday, M. C., Shey, C. W., Akpaka, K. A., Kazembe, L. N., & Impouma, B. (2024). Modelling the spatial variability and uncertainty for under-vaccinated and zero-dose children in fragile settings. *Scientific Reports,* 14, 24405. https://doi.org/10.1038/s41598-024-74982-5

Atalell, K. A., Tekile, A. K., Demissie, G. D., & Fenta, T. G. (2022). Mapping BCG

vaccination coverage in Ethiopia using geospatial analysis of Demographic and Health Survey data. *BMC Infectious Diseases*, 22, 569. https://doi.org/10.1186/s12879-022-07547-4

Causey, K., Fullman, N., Sorensen, R. J. D., Galles, N. C., Zheng, P., Aravkin, A., Danovaro-Holliday, M. C., Martinez-Piedra, R., Sodha, S. V., Velandia-González, M. P., Gacic-Dobo, M., Castro, E., He, J., Schipp, M., Deen, A., Hay, S. I., Lim, S. S., & Mosser, J. F. (2021). Estimating global and regional disruptions to routine childhood vaccine coverage during the COVID-19 pandemic in 2020: A modelling study. *The Lancet,* 398(10299), 522–534. https://doi.org/10.1016/S0140-6736(21)01337-4

Continental Hospitals. (2024). *Importance of Childhood Immunizations.* Retrieved from https://continentalhospitals.com/blog/importance-of-childhood-immunizations

Damashi, M.T., Adedeji, O.I., Mai Bukar, A., Babamaaji, R., & Dakul, D.A. (2021). Accessibility to Primary Health Centre Facilities Using Geospatial Techniques in Southern Plateau, Nigeria. *Nigerian Journal of Parasitology,* 41(2). https://doi.org/10.4314/njpar.v41i2.3

Damashi, S. A., Yusuf, A. L., & Mallo, D. M. (2020). Geospatial Analysis of Accessibility to Primary Health Care Facilities in Southern Plateau State, Nigeria. *International Journal of Scientific and Research Publications,* 10(8), 563–571.

Gavi, the Vaccine Alliance. (2022). *Reaching Zero-Dose Children: A Pathway to Equity.* Retrieved from https://www.gavi.org

Geological Survey of Nigeria (2019). Geology of Plateau State.

Global Volcanism Program. (2021). *Smithsonian Institution.* Jos Plateau Retrieved 2021-06-24

Hassan, I. A., Adeleke, I. T., & Musa, A. A. (2024). Enhancing birth vaccination coverage via health facility geospatial mapping in Nigeria. *Discover Public Health,* 21(1), 89–102. https://doi.org/10.1186/s12982-024-00289-5

Khazanchi, R., Rader, B., Cantor, J., McManus, K. A., Bravata, D. M., Weintraub, R., Whaley, C., & Brownstein, J. S. (2024). Spatial accessibility and uptake of pediatric COVID-19 vaccinations by social vulnerability. *Pediatrics,* 154(2), e2024065938. https://doi.org/10.1542/peds.2024-065938

Lai, X.; Zhang, H.; Pouwels, K.B.; Patenaude, B.; Jit, M.; Fang, H. (2023). Estimating global and regional between-country inequality in routine childhood vaccine coverage in 195 countries and territories from 2019 to 2021*:* A longitudinal study. E Clinical Medicine 2023, 60, 102042. *[CrossRef] [PubMed]*

Lawal, T. V., Atoloye, K. A., Adebowale, A. S., & Fagbamigbe, A. F. (2023). Spatio-temporal analysis of childhood vaccine uptake in Nigeria: A hierarchical Bayesian Zero-inflated Poisson approach. *BMC Pediatrics*, 23, 493.

Masresha, B. G., Luce, R., Shibeshi, M. E., Ntsama, B., N'Diaye, A., Chakauya, J., Poy, A., & Mihigo, R. (2020). The performance of routine immunization in selected African countries during the first six months of the COVID-19 pandemic. *Pan African Medical Journal,* 37(Suppl. 1), 12. https://doi.org/10.11604/pamj.supp.2020.37.1.26107

Mbunga, B.K., Liu, P.Y., Bangelesa, F., Mafuta, E., Dalau, N.M., Egbende, L.,

Hoff, N.A., Kasonga, J.B., Lulebo, A., Manirakiza, D., Mudipanu, A., Mvuama, N., Ouma, P., Wong, K., Lusamba, P., & Burstein, R. (2024*).* Zero-dose childhood vaccination status in rural Democratic Republic of Congo: quantifying the relative impact of geographic accessibility and attitudes toward vaccination. Vaccines, 12(6), 617.

National Population Commission (NPC) [Nigeria] & ICF. (2024*). Nigeria Demographic and Health Survey 2024*, Plateau State, Nigeria

Oladejo, A. J., Akanbi, A. O., & Mundi, R. (2025). Environmental predictors of under-five immunization utilization among women of childbearing age in Plateau North Senatorial District of Plateau State, Nigeria. *FUDMA Journal of Sciences,* 9(12), 690–697. https://doi.org/10.33003/fjs-2025-0912-4477

Olaniyan, A., Isiguzo, C., & Hawk, M. (2021). The socioecological model as a framework for exploring factors influencing childhood immunization uptake in Lagos State, Nigeria. *BMC Public Health,* 21(1), 867. https://doi.org/10.1186/s12889-021-10922-6

Sambayuka, B., Mwendo, E., Babyebonela, L., Kisanga, J. A., Marandu, S., *et al.,* (2023). Improving Urban Immunization and Reducing the Zero-dose Children: Results from Implementation Study in Dar es-Salaam, Tanzania. Advances in Preventive Medicine and Health Care, 6:1042. https://doi.org/10.29011/2688-996X.001042

Shaba, H. A. Omomoh, E., Nannim, S., Danlami, G.R.R., Omirinde, M.O., Davou, G.Y., Mairiga, B., & Gwamzhi, E.P. (2023). Cluster and buffer analysis of the distribution of healthcare facilities in Plateau state. International Journal of Medical Science and Clinical Research Studies, 3(10), 2420-2431. https://doi.or/10.47191/ijmscrs/v3-i10-58

Sharma, M.; Singh, S.K.; Sharma, L.; Dwiwedi, M.K.; Agarwal, D.; Gupta, G.K.; Dhiman, R. (2021) Magnitude and causes of routine immunization disruptions during COVID-19 pandemic in developing countries. J. Fam. Med. Prim. Care, 10, 3991. *[CrossRef] [PubMed]*

Shet, A., Carr, K., Danovaro-Holliday, M. C., Sodha, S. V., Prosperi, C., Wunderlich, J., Wonodi, C., Reynolds, H. W., Mirza, I., Gacic-Dobo, M., O'Brien, K. L., & Lindstrand, A. (2022). Impact of the SARS-CoV-2 pandemic on routine immunisation services: Evidence of disruption and recovery from 170 countries and territories. *The Lancet Global Health,* 10(2), e186–e194. https://doi.org/10.1016/S2214-109X(21)00512-X

Shiferie, F., Gebremedhin, T., Andargie, G., DelPizzo, J., Belete, H., & Fenta, S. M. (2024). Spatial distribution of zero-dose children in Ethiopia: Evidence for a targeted intervention from a large-scale cross-sectional evaluation survey. *Frontiers in Pediatrics,* 12, 1337922. https://doi.org/10.3389/fped.2024.1337922

Siddiqi, D. A., Siddiqui, M., Nisar, M. I., Khan, A. A., & Ahmed, J. (2021). The impact of COVID-19 on routine immunization services in Pakistan. Vaccine, 39(37), 5463–5469. https://doi.org/10.1016/j.vaccine.2021.07.056

UNICEF. (2022). Immunization: Giving Every Child a Fair Chance. Retrieved from https://www.unicef.org/immunization

UNICEF. (2023). *The state of the world's children 2023: For every child,*

vaccination. United Nations Children's Fund. https://www.unicef.org

United Nations Inter-agency Group for Child Mortality Estimation (UN IGME). (2025). *Levels and trends in child mortality:* Report 2025. United Nations Children's Fund, World Health Organization, World Bank Group, and United Nations Population Division.

Utazi, C. E., Thorley, J., Alegana, V. A., Ferrari, M. J., Takahashi, S., Metcalf, C. J. E., Tatem, A. J., & Oteri, J. (2024). High-Resolution Geospatial Mapping of Zero-Dose and Underimmunized Children Following Nigeria's 2021 Multiple Indicator Cluster Survey/National Immunization Coverage Survey. *The Journal of Infectious Diseases,* 230(Supplement 2), S470–S479.

World Health Organization (2023). *Immunization coverage*. https://www.who.int/news-room/fact-sheets/detail/immunization-coverage

World Health Organization (WHO), & United Nations Children's Fund (UNICEF). (2025*). Global childhood vaccination coverage holds steady, yet over 14 million infants remain unvaccinated.*WHO.https://www.who.int/news/item/15-07-2025-global-childhood-vaccination-coverage-holds-steady-yet-over-14-million-infants-remain-unvaccinated-who-unicef

World Health Organization, & United Nations Children's Fund. (2025). *Global childhood vaccination coverage holds steady, yet over 14 million infants remain unvaccinated.* World Health-Organization.https://www.who.int/news/item/15-07-2025-global-childhood-vaccination-coverage-holds-steady-yet-over-14-million-infants-remain-unvaccinated-who-unicef

World Health Organization, & United Nations Children's Fund. (2025). *Global childhood vaccination coverage holds steady, yet over 14 million infants remain unvaccinated.* World Health-Organization.https://www.who.int/news/item/15-07-2025-global-childhood-vaccination-coverage-holds-steady-yet-over-14-million-infants-remain-unvaccinated-who-unicef

World Health Organization. (2022). "*Child Mortality*(*under 5 Years) Fact Sheet,"* https://www.who.int/news-room/fact-sheets/detail/levels-and-trends-in-child-under-5-mortality.

World Health Organization. (2025). *Global immunization coverage 2024 - Key facts and data.* https://www.who.int/news-room/fact-sheets/detail/immunization-coverage

World Health Organization. (2025). Immunization Agenda 2030: *A global strategy to leave no one behind.* https://www.immunizationagenda2030.org/