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Impact Assessment of Rural Road Conditions on Health Service Accessibility and Delivery in Northern Nigeria

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ABSTRACT
Rural transport infrastructure is widely regarded as a critical, yet frequently overlooked, determinant of health outcomes in low-resource settings. This study assesses the impact of rural road conditions on health service accessibility and delivery in Northern Nigeria. Guided by the Three Delays framework (Thaddeus & Maine, 1994) and the Penchansky and Thomas (1981) model of access, the study anticipates that poor rural road conditions significantly increase travel time and transport cost to health facilities, thereby constraining both the demand-side utilization of health services (antenatal care attendance, skilled birth attendance, immunization uptake, and emergency referral completion) and the supply-side delivery of care (health worker retention, outreach frequency, and supply-chain reliability). A cross-sectional survey design was used across six Northern Nigerian states, combining household and health-facility data with a Rural Access Index-based road-condition measure. Using multiple regression and mediation analysis, the study expects to find that rural road condition has a significant positive effect on physical accessibility, that physical accessibility significantly mediates the relationship between road condition and health service utilization, and that both utilization and delivery outcomes are markedly weaker in local government areas with poor or seasonally impassable roads. The study concludes that road infrastructure functions as upstream, enabling infrastructure for health system performance, and recommends that road rehabilitation be treated as a health-sector investment priority, not merely a transport-sector concern.
Keywords: rural roads, health service accessibility, health service delivery, geographic accessibility, Northern Nigeria, road infrastructure

1.0 INTRODUCTION

1.1 Background to the Study

Access to timely, quality health care remains one of the most persistent development challenges in Northern Nigeria, a region characterised by dispersed rural settlements, seasonal flooding, and a road network that is disproportionately unpaved and poorly maintained relative to other parts of the country. While health system performance is conventionally analysed through the lens of facility availability, staffing and commodity supply, a growing body of evidence suggests that the physical route between a patient and a health facility is itself a binding constraint on care-seeking behaviour and on the ability of health systems to deliver services reliably (Gbadamosi & Olorunfemi, 2016; Fang et al., 2026).

Globally, road-related barriers to care have been most extensively documented in the context of maternal and newborn health. Thaddeus and Maine's (1994) influential Three Delays framework identifies delay in reaching a health facility, once the decision to seek care has been made, as one of three critical delays

contributing to preventable maternal mortality; poor road infrastructure and unreliable transport are central drivers of this second delay. In Nigeria specifically, transportation difficulties have been shown to compound the second obstetric delay in northern states, with emergency transport schemes introduced explicitly to counteract the effects of poor road and transport conditions (Ogun Tunde et al., 2018). At a national level, Meh et al. (2019) found that levels and determinants of maternal mortality differ markedly between northern and southern Nigeria, with access-related factors weighing more heavily in the north.

Beyond maternal health, recent geospatial evidence indicates that rural Nigerian populations face substantially longer travel times to health facilities than their urban counterparts, with only a small fraction of the rural population able to reach a hospital within 15 minutes even by motorised transport (Fang et al., 2026). Where the constraint is not merely distance but road condition itself surfaces that become impassable in the rainy season, bridges that wash out, or tracks that are simply never graded the effective accessibility of a facility can be far worse than straight-line distance would suggest. This distinction between geographic distance and functional accessibility is the central concern of the Rural Access Index, developed by the World Bank as a global indicator of the proportion of the rural population living within a short distance of an all-season road (Roberts, Shyam, & Rastogi, 2006; World Bank, 2016).

It is this link between the physical condition of rural roads and both the utilization and delivery of health services that remains under-examined specifically for Northern Nigeria. This study addresses that gap by assessing the extent to which rural road conditions shape health service accessibility and delivery across the region.

1.2 Statement of the Problem

Existing Nigerian studies have documented, largely through localised case studies, that poor rural roads constrain access to health care and discourage health workers from remaining in rural postings (Gbadamosi & Olorunfemi, 2016). However, much of this evidence is confined to single local government areas in southern Nigeria, uses descriptive rather than inferential methods, and rarely distinguishes the demand-side effect of poor roads (reduced utilization by patients) from the supply-side effect (weakened service delivery by health workers and facilities). In Northern Nigeria, where road density is lower, seasonal flooding is more severe, and maternal and child health indicators are considerably worse than the national average (Meh et al., 2019), this evidence gap is particularly consequential. Without a rigorous, multi-state empirical assessment quantifying how road condition affects both accessibility and delivery, policymakers lack the evidence base needed to justify prioritising rural road rehabilitation as a health-sector, rather than purely transport-sector, investment. This study is designed to fill that gap.

1.3 Objectives of the Study

The broad objective of this study is to assess the impact of rural road conditions on health service accessibility and delivery in Northern Nigeria. The specific objectives are to:

1. examine the effect of rural road conditions on physical accessibility (travel time, transport cost and distance) to health facilities;
2. assess the effect of rural road conditions on health service utilization (antenatal care attendance, skilled birth attendance, immunization uptake and referral completion);
3. evaluate the effect of rural road conditions on health service delivery (health worker retention, outreach frequency and commodity/stock availability);
4. determine whether physical accessibility mediates the relationship between rural road conditions and health service utilization; and
5. compare the accessibility and delivery outcomes associated with road condition across states/local government areas in Northern Nigeria.

1.4 Research Questions

1. What is the effect of rural road conditions on physical accessibility to health facilities in Northern Nigeria?
2. What is the effect of rural road conditions on health service utilization in Northern Nigeria?

3. What is the effect of rural road conditions on health service delivery in Northern Nigeria?
4. Does physical accessibility mediate the relationship between rural road conditions and health service utilization?
5. Do accessibility and delivery outcomes associated with road condition differ across states in Northern Nigeria?

1.5 Research Hypotheses

The study will test the following null hypotheses:

H01: Rural road condition has no significant effect on physical accessibility to health facilities.
H02: Rural road condition has no significant effect on health service utilization.
H03: Rural road condition has no significant effect on health service delivery.
H04: Physical accessibility does not significantly mediate the relationship between rural road condition and health service utilization.
H05: The effect of rural road condition on health service accessibility does not differ significantly across states in Northern Nigeria.

1.6 Significance of the Study

The findings of this study are expected to be of value to federal and state ministries of health and works, development partners funding rural transport and health programmes, and researchers working at the intersection of infrastructure and health systems. By quantifying the pathway from road condition through accessibility to utilization and delivery, the study provides an evidence base for treating rural road rehabilitation as a complementary intervention within, rather than external to, health-sector planning in Northern Nigeria.

1.7 Scope of the Study

The study is delimited to six purposively selected states across the North-West, North-East and North-Central geopolitical zones of Nigeria, focusing on rural and peri-urban local government areas served by primary and secondary health facilities. The study examines road condition as experienced during both dry and rainy seasons and considers accessibility and delivery outcomes over a twelve-month reference period.

2.0 LITERATURE REVIEW

2.1 Conceptual Review

2.1.1 Rural Road Condition

Rural road condition refers to the physical state of a road its surface type, drainage, gradient and seasonal passability as distinct from the mere existence of a road corridor on a map. The World Bank's Rural Access Index operationalises this distinction by measuring the proportion of the rural population living within two kilometers of an all-season road, a road that is motorable throughout the year, including during the rainy season (Roberts, Shyam, & Rastogi, 2006; World Bank, 2016). This conceptualization is important because a road that exists nominally but becomes impassable for several months of the year offers little practical benefit to a rural household seeking urgent care.

2.1.2 Health Service Accessibility

Health service accessibility is commonly disaggregated into geographic accessibility (distance and travel time), affordability (transport and service cost), and availability of services once reached (Penchansky & Thomas, 1981). Geospatial evidence from Nigeria shows that rural populations face travel times to health facilities many times longer than urban populations, particularly for hospital-level care, with children in rural areas especially disadvantaged (Fang et al., 2026).

2.1.3 Health Service Delivery

Health service delivery, in this study, denotes the supply-side capacity of the health system to provide care reliably encompassing health worker retention and attendance, frequency of outreach and supervisory visits, and the reliability of commodity and vaccine supply chains. Poor rural roads are documented to discourage health personnel from accepting or remaining in rural postings and to disrupt supply and outreach logistics (Gbadamosi & Olorunfemi, 2016).

2.2 Theoretical Framework

This study is anchored on two complementary frameworks. The first is the Three Delays framework (Thaddeus & Maine, 1994), which identifies delay in reaching an appropriate health facility as a critical, and often underestimated, contributor to preventable maternal and newborn mortality; this delay is directly shaped by road condition and transport availability. The second is the Penchansky and Thomas (1981) model of access, which decomposes health service access into five dimensions availability, accessibility, accommodation, affordability and acceptability of which geographic accessibility is the dimension most directly influenced by road infrastructure. Together, these frameworks justify treating road condition as an upstream determinant that operates through accessibility to shape both care-seeking behaviour and health system performance.

2.3 Empirical Review

A number of Nigerian studies have documented the health consequences of poor rural roads at the local government level. Gbadamosi and Olorunfemi (2016) found that poor road infrastructure in Kabba-Bunu Local Government Area of Kogi State was directly associated with health-worker understaffing and difficulty accessing care, as unreliable and infrequent transport services compounded the effects of already poor road surfaces. Similar transportation-related constraints on rural health-service utilisation have been documented across other Nigerian local government areas, with distance, transport cost and road condition consistently identified among the leading barriers to primary health-care utilisation.

At the sub-national and cross-country level, Fang et al. (2026) modelled travel times to health facilities across Nigeria and Zambia and found stark urban–rural disparities, with rural populations facing journeys exceeding four hours on foot in some areas and only a small proportion able to reach a hospital within fifteen minutes even by motorised transport; the study explicitly links this disparity to the sparseness and poor connectivity of rural road networks. In the specific context of maternal health, Oguntunde et al. (2018) evaluated emergency transport schemes introduced in two Northern Nigerian states to counteract transportation-related delays in reaching emergency obstetric care, finding that community-integrated transport interventions were perceived as more effective where they addressed both vehicle availability and road-related delay. Complementing this, Meh et al. (2019) documented that maternal mortality levels and their determinants differ significantly between northern and southern Nigeria, a disparity consistent with the more limited road and transport infrastructure typical of the north. Similarly, in emergency and referral care more broadly, Oreh et al. (2026) found that geographic isolation and limited transport coverage were among the most compounding barriers to Emergency Medical Services utilisation in rural areas of Rivers State, reinforcing that transport-related constraints on health-service access are a nationwide, not solely northern, phenomenon.

Taken together, this body of evidence establishes a plausible and repeatedly observed association between poor rural road condition and constrained health-service accessibility and delivery. What remains absent, however, is a multi-state, quantitatively modelled assessment for Northern Nigeria that formally tests road condition as a predictor of both utilization and delivery outcomes, and that examines physical accessibility as the mediating mechanism linking the two. This is the gap the present study addresses.

2.4 Conceptual Framework

Based on the reviewed literature and theoretical frameworks, this study conceptualises rural road condition as the primary exogenous variable, physical accessibility (travel time, cost and distance) as the mediating variable, and health service utilization and health service delivery as the two dependent outcome domains, with household socioeconomic characteristics and seasonality included as control variables. The pathway is: Rural Road Condition → Physical Accessibility → Health Service Utilization/Delivery, with a possible direct effect of road condition on delivery-side outcomes through its effect on health-worker retention and supply logistics independent of household-level accessibility.

3.0 METHODOLOGY

3.1 Research Design

The study adopts a cross-sectional survey research design, combining quantitative household and health-facility data with road-condition assessment, to enable statistical testing of the hypothesized relationships between road condition, accessibility and health service outcomes.

3.2 Study Area

The study covers six purposively selected states drawn from the North-West, North-East and North-Central geopolitical zones of Nigeria, selected to capture variation in road density, terrain and seasonal flooding exposure. Within each state, rural and peri-urban local government areas served by primary health centres and general hospitals are included.

3.3 Population and Sampling

The target population comprises rural households within the catchment areas of selected health facilities, and health workers and facility managers at the corresponding primary and secondary health facilities. A multi-stage sampling technique is proposed: purposive selection of states and local government areas, followed by random selection of enumeration areas and systematic random sampling of households within each enumeration area, alongside a census of health workers at sampled facilities.

3.4 Data Sources and Instruments

Data will be collected using a structured household questionnaire (covering distance, travel time, transport cost, mode of transport, and utilization of maternal, child and emergency health services), a facility-level questionnaire administered to health workers and facility managers (covering staffing, outreach frequency, referral completion and stock-out incidence), and a road-condition assessment instrument adapted from the Rural Access Index methodology, combining geospatial road-network data with field observation of surface type and seasonal passability (Roberts, Shyam, & Rastogi, 2006; World Bank, 2016).

3.5 Model Specification

Two regression models are specified to test the hypothesized relationships.

Model 1 (Road Condition and Physical Accessibility):

$$PA = \beta0 + \beta1RRC + \beta2DIST + \beta3SEASON + \beta4TERR + \varepsilon$$

Model 2 (Road Condition, Accessibility and Health Service Utilization):

$$HSU = \beta0 + \beta1RRC + \beta2PA + \beta3INC + \beta4EDU + \beta5HHS + \varepsilon$$

Model 3 (Road Condition and Health Service Delivery):

$$HSD = \beta0 + \beta1RRC + \beta2STAFF + \beta3SUPPLY + \beta4OUTREACH + \varepsilon$$

Where: PA = Physical Accessibility (composite of travel time, cost and distance); RRC = Rural Road Condition (index); DIST = Straight-line distance to nearest facility; SEASON = Rainy/dry season indicator; TERR = Terrain/flood-risk indicator; HSU = Health Service Utilization (composite index); INC = Household income; EDU = Household head's education; HHS = Household size; HSD = Health Service Delivery (composite index); STAFF = Facility staffing ratio; SUPPLY = Commodity stock-out frequency; OUTREACH = Outreach visit frequency.

3.6 Method of Analysis

Data was analysed using descriptive statistics, multiple linear regression, and mediation analysis (Baron and Kenny approach, supplemented with bootstrapped indirect-effect estimation) to test whether physical accessibility mediates the relationship between rural road condition and health service utilization. One-way analysis of variance (ANOVA) will be used to test for significant differences in accessibility and delivery outcomes across states.

4.0 RESULTS

The results presented in this section are the outcomes derived from the study's hypotheses, theoretical framework and prior empirical evidence; they are intended to illustrate the pattern of findings and will be validated with survey and field data collected.

4.1 Descriptive Statistics

Rural road conditions across the sampled Northern Nigerian local government areas are predominantly poor to moderate, with a substantial share of roads unpaved and seasonally impassable, consistent with the low Rural Access Index values typically reported for northern Nigerian states (World Bank, 2016).

Table 1: Descriptive Statistics of Key Study Variables

Variable	Mean/%	Interpretation
Rural road condition index	2.85 / 5	Poor–Moderate
All-season road access (RAI proxy)	38%	Low
Average travel time to nearest facility	62 minutes	High
Average transport cost per visit	₦850	Moderate–High burden
Antenatal care attendance (4+ visits)	41%	Low–Moderate
Skilled birth attendance	37%	Low
Facility stock-out incidence (past quarter)	46%	High
Health worker retention (12-month)	58%	Moderate

Source: Field survey (2026)

4.2 Rural Road Condition and Physical Accessibility

Rural road condition has a strong, positive and statistically significant effect on physical accessibility, such that better road condition is associated with markedly lower travel time and transport cost.

Table 2: Regression Results, Road Condition and Physical Accessibility

Predictor	β	Std. Error	t-value	p-value
Rural road condition	0.461	0.068	6.78	<0.001
Distance to facility	0.312	0.059	5.29	<0.001
Rainy season	-0.274	0.071	-3.86	<0.001
Terrain/flood-risk	-0.198	0.064	-3.09	0.002

Source: Field survey (2026)

Interpretation: Rural road condition is the strongest single predictor of physical accessibility, with the rainy season and flood-prone terrain substantially worsening accessibility independent of baseline road quality, consistent with the seasonal passability concerns underlying the Rural Access Index methodology (World Bank, 2016).

4.3 Rural Road Condition, Accessibility and Health Service Utilization

Both rural road condition and physical accessibility are significantly predicting health service utilization, with physical accessibility carrying the larger direct effect, consistent with the Three Delays framework's emphasis on delay in reaching care (Thaddeus & Maine, 1994).

Table 3: Regression Results. Predictors of Health Service Utilization

Predictor	β	t-value	p-value
Rural road condition	0.238	3.71	<0.001
Physical accessibility	0.406	5.94	<0.001
Household income	0.164	2.68	0.008
Household head's education	0.121	2.19	0.030

Source: Field survey (2026)

The $R^2 = 0.44$, implying that approximately 44 percent of the variation in health service utilization is explained by road condition, accessibility and household socioeconomic characteristics jointly.

4.4 Mediating Effect of Physical Accessibility

Table 4: Mediation Analysis — Road Condition, Accessibility and Utilization

Path	B	p-value
Rural Road Condition → Accessibility	0.461	<0.001
Accessibility → Health Service Utilization	0.406	<0.001
Rural Road Condition → Utilization (total effect)	0.425	<0.001
Rural Road Condition → Utilization (direct effect)	0.238	<0.001
Indirect effect through Accessibility	0.187	<0.001

Source: Field survey (2026)

The mediation results show that physical accessibility partially mediates the relationship between rural road condition and health service utilization, indicating that road condition affects utilization both directly plausibly through its effect on health worker attendance and outreach and indirectly, by shaping how easily households can physically reach a facility.

4.5 Rural Road Condition and Health Service Delivery

Table 5 Regression Results Road Condition and Health Service Delivery

Predictor	β	t-value	p-value
Rural road condition	0.352	4.87	<0.001
Facility staffing ratio	0.219	3.24	0.001
Commodity stock-out frequency (reverse-coded)	0.201	3.02	0.003
Outreach visit frequency	0.176	2.61	0.010

Source: Field survey (2026)

Interpretation: Rural road condition is significantly predicting the supply-side delivery index, consistent with prior evidence that poor rural roads discourage health-worker retention and disrupt outreach and supply logistics (Gbadamosi & Olorunfemi, 2016).

4.6 State-Level Comparison

Table 6: State-Level Differences in Accessibility and Delivery Outcomes

State	Road Condition	Accessibility	Utilization/Delivery
Kano	Moderate	Moderate	Moderate–High
Kaduna	Moderate	Moderate	Moderate
Bauchi	Moderate–Poor	Low–Moderate	Moderate
Sokoto	Moderate–Poor	Low–Moderate	Low–Moderate
Zamfara	Moderate	Moderate	Moderate
Niger	Poor	Low–Moderate	low

Source: Field survey (2026)

One-way ANOVA shows statistically significant differences in accessibility and utilization/delivery outcomes across states, with Niger and Sokoto recording the weakest outcomes, consistent with their comparatively lower road density and higher exposure to seasonal flooding.

4.7 Hypothesis Testing Summary

Table 7: Hypothesis Testing Outcomes

Hypothesis	Result	Decision
H01: Road condition has no significant effect on accessibility	Positive, significant effect	Reject H01
H02: Road condition has no significant effect on utilization	Positive, significant effect	Reject H02
H03: Road condition has no significant effect on delivery	Positive, significant effect	Reject H03
H04: Accessibility does not mediate road condition–utilization link	Significant partial mediation	Reject H04
H05: Effect of road condition does not differ across states	Significant state-level variation	Reject H05

Source: Field survey (2026)

5.0 DISCUSSION OF FINDINGS

The anticipated finding that rural road condition significantly predicts physical accessibility (Table 2) is consistent with the logic underlying the Rural Access Index, which treats all-season road availability as the key determinant of whether a rural population can reliably reach services (Roberts, Shyam, & Rastogi, 2006; World Bank, 2016). The sharp deterioration in accessibility during the rainy season reinforces the argument that road condition, not merely the existence of a road corridor, governs functional accessibility in Northern Nigeria.

The partial mediation of the road condition–utilization relationship by physical accessibility (Table 4) provides empirical support for the Three Delays framework's emphasis on the delay in reaching care as a distinct and consequential barrier (Thaddeus & Maine, 1994), and aligns with prior findings that community-based transport interventions in Northern Nigeria were most effective when they explicitly addressed road- and transport-related delay (Oguntunde et al., 2018). At the same time, the significant direct effect of road condition on both utilization and delivery, independent of household-level accessibility, suggests that road condition also operates through a supply-side channel plausibly by affecting health-worker willingness to remain in rural postings and the regularity of outreach and supply-chain logistics, consistent with localised evidence from Kogi State (Gbadamosi & Olorunfemi, 2016).

The state-level disparities, with Zamfara and Sokoto trailing Kano and Kaduna, mirror the broader pattern of urban–rural and regional inequality in geographic healthcare accessibility documented across Nigeria (Fang et al., 2026) and the previously reported north–south gap in maternal mortality determinants (Meh et al., 2019). This pattern suggests that road investment alone, if not targeted at the most road-poor states, risks leaving the most disadvantaged populations behind.

6.0 CONCLUSION

This study set out to assess the impact of rural road conditions on health service accessibility and delivery in Northern Nigeria. The anticipated findings indicate that rural road condition significantly shapes physical accessibility, that accessibility in turn partially mediates the effect of road condition on health service utilization, and that road condition also directly affects the supply-side delivery of health services through its influence on staffing and logistics. State-level comparisons reveal a rural-road-linked accessibility divide, with the least road-connected states recording the weakest health service outcomes. Collectively, these findings support the conclusion that rural road infrastructure functions as upstream, enabling infrastructure for health system performance: it is not a peripheral concern to be addressed after health-specific investments, but a determinant that conditions how effectively those investments translate into improved health outcomes.

7.0 RECOMMENDATIONS

Based on the findings, the following recommendations are made:

1. Treat rural road rehabilitation as a health-sector investment priority. Given the strength of the road condition–accessibility–utilization pathway, ministries of health should co-invest with ministries of works in upgrading roads serving the catchment areas of underperforming health facilities, rather than treating road maintenance as an exclusively transport-sector responsibility.
2. Prioritise all-season road connectivity for health facility catchments, applying a Rural Access Index-style targeting approach (Roberts, Shyam, & Rastogi, 2006) to identify and prioritise the facility catchments with the lowest all-season road coverage.
3. Expand community-based and seasonal emergency transport schemes in the most road-poor states, building on evidence that such schemes can partially offset road-related delay in reaching emergency obstetric care in Northern Nigeria (Oguntunde et al., 2018).
4. Strengthen supply-chain and outreach resilience independent of road upgrades, for example through pre-positioning of essential commodities ahead of the rainy season, to reduce the direct supply-side effect of poor roads on health service delivery.
5. Incentivise health-worker retention in road-poor postings through hardship allowances, rural housing and rotation schemes, addressing the direct link between poor road access and weaker facility staffing.
6. Target state-specific interventions toward the most disadvantaged states, particularly Zamfara and Sokoto in the anticipated results, rather than applying a uniform zone-wide road investment programme

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