NIGERIAN JOURNAL OF TRANSPORT TECHNOLOGY AND ENGINEERING
ISSN:1595-8590
Vol 1, Issue 1, 2025,



NIGERIAN JOURNAL OF TRANSPORT TECHNOLOGY AND ENGINEERING

Volume 1, 2025

Publication of Nigerian Institute of Transport Technology (NITT), Zaria

njtte@nitt.gov.ng

ISSN:1595-8590



Nigerian Journal of Transport Technology and Engineering

NIGERIAN JOURNAL OF TRANSPORT TECHNOLOGY AND ENGINEERING

EDITORIAL BOARD

Chairman Editorial Board	**Dr. Bayero Saleh Farah**
Editor-in-Chief **Asst. Editor-in-Chief**	Dr. Joshua Adetunji Odeleye Dr. Olusegun Austine Taiwo
Editorial Members	Dr. Garba Sani Mohammed Dr. Ikenna George Engr. Kolawole Makanjuola Engr. Dauda Suleiman
Editorial Advisors	Prof. Hashim U. Alhassan – *Bayero University Kano* Prof. Daniel Joseph Adeyemo- *Centre for Energy Research and Training, Ahmadu Bello University, Zaria*
International Editorial Advisers	Assoc Prof. Sitti Asmah Hassan *Traffic and Transportation, Faculty of Civil Engineering, Universiti Teknologi Malaysia* Dr. Nnnene Obiora *Centre for Transport Studies, Dept. of Civil Engineering, University of Cape Town*

Peer Review Editorial Committee

Prof. Danjuma Saleh Yawas - Department of Mechanical Engineering, Ahmadu Bello University Zaria

Prof. Mohammed Dauda - Department of Mechanical Engineering, Ahmadu Bello University Zaria

Dr. Ayuba John –Department of Cybersecurity, Faculty of Computing, Federal University Dutse, Jigawa State

Dr. Tobi Aluko- Department of Civil Engineering, Ekiti State University, Ado Ekiti

Dr. Bruno Lot Tanko -Built Environment and Surveying, Sheffield Hallam University UK

Dr. Mbada Isaac Ndubiusi – Department of Metallurgical Engineering, Airforce Institute of Technology

Dr. Koleola Ojaomo – Department of Mechanical Engineering, Federal Polytechnic Ado-Ekiti, Ekiti State

Dr. Ayeni Samuel- Department of Civil Engineering, Federal Polytechnic Ado-Ekiti, Ekiti State

Dr. Samuel Ojo- Department of Chemical Engineering, Federal Polytechnic Mubi, Adamawa State

Dr. Bayero Saleh Farah- Nigerian Institute of Transport Technology, Zaria

Dr. Joshua Adetunji Odeleye- Nigerian Institute of Transport Technology, Zaria

Dr. (Mrs) Felicia Nwanosike - Nigerian Institute of Transport Technology, Zaria

Engr. Remi Adewunmi- Nigerian Institute of Transport Technology, Zaria

Dr. Olusegun Taiwo- Nigerian Institute of Transport Technology, Zaria

Dr. Garba Sani Mohammed- Nigerian Institute of Transport Technology, Zaria

Dr. Okon Idongesit- Nigerian Institute of Transport Technology, Zaria

Engr. Anthony Abutu Attah- Nigerian Institute of Transport Technology, Zaria

Engr. Dauda Suleiman

Engr. Kolawole Makanjuola- Nigerian Institute of Transport Technology, Zaria

Secretariat	Dr. Olusegun Austine Taiwo
	Kingsley Ohikuare
Digital Advisors	Ayodele Salami
	Christopher Amanyi Owoicho
	Abbas Umar Ghadaffi
	Masud Idris
	Bassey Ndifreke

NIGERIAN JOURNAL OF TRANSPORT TECHNOLOGY AND ENGINEERING
ISSN:1595-8590
Vol 1, Issue 1, 2025,



Nigerian Journal of Transport Technology and Engineering

Table of Content

1. **Impact of Roadside Friction on Traffic Congestion in Ijebu-Ode, Ogun State**
   Dimeji Rotimi Sonde, Adeolu Olutayo Dina, Jubril Oloruntoba Oladosu, Samson. Adelusi Oludele *1-14*
2. **Assessing the Impact of Urban Transportation Systems on Air Quality and Public Health in Kano Metropolis, Kano State, Nigeria**
   Kabiru Abdullahi, Joshua Adetunji. Odeleye, Ismaila Mustapha, Dasuki Sani *15-29*
3. **Feasibility of Compressed Natural Gas (CNG) Adoption in Kano Urban Transport Sector: A Sustainable Fuel Transition Strategy**
   Jamilu Aminu, Aminu Muhammed Usman, John Tawili Jacob, Umar Adamu, Yusuf Rabiu *30-45*
4. **The Future of Autonomous Transportation: Opportunities and Challenges in Nigeria**
   Araoye Olarinkoye Ajiboye, Abdul Musa, Fatima Yusuf, Muhammad Etudaiye Ohida, Muhammed Itopa Abdullai *46-59*
5. **Evaluating Machine Learning Algorithms for Predicting Nigerian Bus Driver Accident Involvement: A Comparative Study**
   Olusegun Austine Taiwo, Sitti Asmah Hassan, Joshua Adetunji Odeleye, Rahmat Bin Mohsin, Norashikin Mahmud, Kolawole Makanjuola *60-77*
6. **Engineering Evaluation of Vehicle Maintenance Systems at the Directorate of Road Traffic Services (DRTS) Headquarters, Abuja, Nigeria**
   Tunde Oloriegbe, Oduleye Theophilus Olaniyi, Bobai Francis Danjuma *78-91*
7. **Sustainable Cold Chain Logistics and Supply Chain of Frozen Fish Through Energizing the Applicability of Technology in Lagos Metropolis**
   Sheriff Olaitan Oladipo, Ogochukwu Ugboma, Abdul-Azeez Ibraheem-Forson, Esther Chidinma Ogazie *92-104*

BOldscholar

NIGERIAN JOURNAL OF TRANSPORT TECHNOLOGY AND ENGINEERING
ISSN:1595-8590
Vol 1, Issue 1, 2025,



Nigerian Journal of Transport Technology and Engineering

Assessing the Impact of Urban Transportation Systems on Air Quality and Public Health in Kano Metropolis, Kano State Nigeria

[*1]Kabiru Abdullahi, [1]Joshua Adetunji Odeleye, [1]Ismaila Mustapha and [1]Dasuki Sani

[1]*Nigerian Institute of Transport Technology, Zaria, Nigeria*

Corresponding author: kbirabd@yahoo.com

Abstract
This study examines the impact of urban transportation systems on air quality and public health in Kano Metropolis, Nigeria. The aim of the work is to assess current air quality levels and identify major pollution sources in transportation corridors, evaluate the public health impacts of transportation-related air pollution on residents, examine the relationship between different transport modes and their contribution to air quality degradation, and recommend integrated policy measures for improving air quality and protecting public health through sustainable transportation. Relevant literature were reviewed in relation to the work. The methodology used a mixed-methods approach, data were collected through longitudinal air quality monitoring at 20 fixed and mobile stations, health surveys of 350 residents stratified by exposure zones, and semi-structured interviews with 20 key stakeholders including environmental health officials, healthcare professionals, and transport agency representatives. Findings reveal severe air quality degradation, with $PM_{2.5}$ levels reaching 101.4 $\mu g/m^3$ at Bompai Industrial Zone (exceeding WHO limits by 676%), and significant health impacts including 4.2 times higher odds of persistent cough among high-exposure residents. The study identified tricycles as the dominant pollution source (44% of $PM_{2.5}$), emitting 38 times more $PM_{2.5}$ per kilometer than CNG buses. It also demonstrated strong public support for CNG tricycle retrofits (Policy Feasibility Index = 0.84) with potential to reduce $PM_{2.5}$ by 42%. The study recommended implementing enhanced real-time air monitoring networks, phased vehicle emission control programs with mandatory Euro IV standards, health protection measures for vulnerable populations including air-filtered clinics and pollution alert systems, accelerated fleet modernization to CNG/electric alternatives, and establishing an integrated Transport-Health-Environment Nexus authority for coordinated governance.

Keywords: *Air Quality, Environmental Policy, Public Health, Sustainable Transport, Urban Transportation, Vehicle Emissions*

1. Introduction

Rapid urbanization across Sub-Saharan Africa has precipitated a profound environmental crisis, with transportation-related emissions now representing one of the most critical threats to urban air quality and public health outcomes throughout the region (World Health Organization, 2021). This accelerating trend is characterized by exponential population growth, inadequately regulated vehicle fleets, and infrastructural systems incapable of accommodating escalating mobility demands. The resulting atmospheric pollution has reached catastrophic levels in many African megacities, where vehicular emissions frequently contribute 50–80% of ambient particulate matter and nitrogen oxides, directly undermining respiratory health, cardiovascular function, and ecological stability. Kano Metropolis, Nigeria's second-largest urban center and northern Nigeria's foremost commercial hub, epitomizes this complex crisis with alarming acuity. The city's population trajectory exploding from approximately 127,000 residents in 1952 to over 4.5 million by 2023, has radically outpaced transportation infrastructure development, creating a perfect storm of demographic pressure, institutional fragmentation, and environmental degradation (National Population Commission, 2023; World Population Review, 2023).

Kano's reliance on antiquated, poorly maintained vehicles has generated severe air quality deterioration with measurable public health consequences. Recent field measurements reveal that over 80% of the city's fleet comprises tricycles (Keke-Napep) and minibuses (Danfo) exceeding recommended service lives by 8–15 years, typically operating without catalytic converters or emission control systems (Abdullahi et al., 2024). These vehicles combust adulterated fuels with sulfur concentrations exceeding 3,000 parts per million, releasing plumes of particulate matter ($PM_{2.5}$ and PM_{10}), nitrogen oxides, and carbon monoxide that concentrate along high-traffic corridors like Zaria Road and Kofar Mata Motor Park. During peak congestion periods, $PM_{2.5}$ levels routinely exceed 120 µg/m³ representing 800% above the World Health Organization's 15 µg/m³ 24-hour guideline while hospital admissions for pediatric asthma and chronic obstructive pulmonary disease (COPD) near these corridors register 40% higher than low-traffic zones (Kano State Health Ministry, 2023). This pollution-disease nexus disproportionately impacts vulnerable populations, including children, the elderly, and low-income communities residing within 100 meters of arterial roads due to spatial inequities in urban planning.

Nigeria's broader urban landscape mirrors this emergency, with metropolitan centers like Lagos, Port Harcourt, and Abuja recording $PM_{2.5}$ concentrations 5–8 times above WHO safety thresholds according to National Environmental Standards and Enforcement Agency (NESREA) monitoring reports (World Bank, 2022). Despite these measurable hazards, evidence-based interventions remain critically scarce due to three intersecting systemic failures: fragmented governance across transportation, health, and environmental agencies; virtually non-existent real-time air quality monitoring infrastructure outside Lagos; and unenforced regulatory frameworks such as the Euro III emission standards ratified but never implemented for Nigeria's informal transit sector. In Kano specifically, only two operational reference stations monitor air quality across its 499 km² metropolitan area, creating dangerous data voids that obscure pollution hotspots and source contributions. Compounding these challenges, the seasonal Harmattan dust phenomenon (November–February) elevates background PM_{10} levels to 420 µg/m³, masking anthropogenic emissions and complicating source apportionment.

Kano's transportation system is dominated by aging tricycles (Keke-Napep) and minibuses (danfo) as a primary pollution source. Over 80% of vehicles exceed recommended service life, lacking catalytic converters or emission controls (Abdullahi et al., 2024). Inadequate inspection systems and adulterated fuels exacerbate emissions of PM2.5, NOx, and CO, with peak-hour concentrations near major corridors like Zaria Road exceeding 120 µg/m³ for PM10 (WHO limit: 45 µg/m³). This pollution directly correlates with traffic density, yet emission inventories remain unquantified, hindering targeted mitigation.

Furthermore, Transportation emissions elevated rates of respiratory and cardiovascular morbidity in Kano. Hospital admissions for asthma and COPD are 40% higher in high-traffic zones (e.g., Sabon Gari) than low-density areas, disproportionately affecting children and the elderly (Kano State Health Ministry, 2023). Prolonged exposure to PM2.5 increases stroke risks by 24% and lung cancer incidence by 11%, yet health impact assessments are neglected in transport planning. Vulnerable populations lack protective measures, worsening health inequities.

Kano lacks systematic air quality monitoring, with only two reference stations covering 499 km². Data gaps obscure pollution hotspots and source contributions, impeding evidence-based policy. Meteorological factors (example, Harmattan dust) compound monitoring challenges, while outdated equipment undermines data reliability. Without real-time pollution mapping, interventions remain reactive rather than preventive.

Nigerian Journal of Transport Technology and Engineering 2025,Vol. 1 (1) DOI: 10.61955/UZXXZJ

Also, Weak enforcement of emission standards (NESREA Act 2007) and uncoordinated agency mandates perpetuate pollution. Kano Road Traffic Agency (KAROTA) focuses on congestion, not emissions, while health and environmental agencies operate in silos. No policies integrate health impact assessments into transport planning, and clean vehicle incentives (e.g., CNG subsidies) lack implementation frameworks.

This study directly confronts these gaps through a comprehensive investigation of transportation emissions' health impacts in Kano Metropolis, coupled with actionable policy solutions. By integrating longitudinal air monitoring, epidemiological surveys, and institutional analysis.

The study aims to:

1. Assess air pollution levels and identify dominant emission sources across Kano's transportation corridors.
2. Quantify public health impacts of transportation emissions on respiratory and cardiovascular health.
3. Analyze pollution contributions by vehicle type (tricycles, minibuses, private cars) and traffic density.
4. Propose integrated policy measures for sustainable transportation and health protection.

1.1 Urban Transportation and Air Quality in Developing Countries

The nexus between rapid motorization and atmospheric degradation in developing economies represents a critical environmental health challenge. Global studies confirm transportation contributes 50–80% of urban NOx and PM emissions, with Sub-Saharan Africa experiencing disproportionate impacts due to aging fleets and unregulated fuel quality (WHO, 2021). In-depth analyses of Accra's transport sector reveal diesel minibuses emit 4.7× more PM2.5/km than modern buses, while two-stroke tricycles (e.g., Keke-Napep) release 30% unburned hydrocarbons due to incomplete combustion cycles (Gakunju et al., 2020). Traffic congestion acts as a force multiplier; Dhaka's peak-hour PM2.5 concentrations reach 150 $\mu g/m^3$—10× WHO limits correlating with a 25% increase in pediatric asthma incidence (Begum et al., 2023). Fuel adulteration exacerbates these issues: West African "dirty diesel" contains sulfur levels exceeding 3,000 ppm (vs. Europe's 10 ppm), generating sulfate aerosols that persist atmospherically for weeks (UNEP, 2022). Critically, institutional fragmentation undermines mitigation; 78% of Sub-Saharan cities lack coordinated transport-environment policies, allowing informal vehicles to dominate urban fleets without emission controls. Kano's reliance on such vehicles with median ages of 15–22 years positions it within this high-risk paradigm, necessitating context-specific interventions.

1.2 Public Health Impacts of Transportation Emissions

Vehicular pollution's disease burden is quantifiable through advanced epidemiological modeling. Prospective cohort studies in Lagos demonstrate a 38% elevation in respiratory ER visits among residents ≤ 200m of highways, mediated by interleukin-6 inflammatory pathways activated by PM0.1 deposition (Okedere et al., 2020). Cairo's pollution-cardiovascular link is equally robust: ischemic heart disease mortality rises 53% per 10 $\mu g/m^3$ PM2.5 increase, with vehicular sources contributing 67% of citywide particulates (Khoder et al., 2022). Pediatric vulnerabilities are particularly acute; longitudinal data from Nairobi shows children near traffic corridors exhibit reduced FEV1 growth (–3.2%/year) and 2.9× higher asthma incidence due to alveolar macrophage impairment (Gauderman et al., 2021). Economic analyses reveal staggering costs: Dar es Salaam spends 12% of its health budget treating pollution-related illnesses, while Accra loses $2.3 billion annually in productivity-adjusted life years (World

Nigerian Journal of Transport Technology and Engineering 2025,Vol. 1 (1) DOI: 10.61955/UZXXZJ

Bank, 2021; Mbande et al., 2023). In Kano, these dynamics manifest as spatial disease clustering TB incidence near Kofar Na'isa motor park is 22% above city averages though diagnostic gaps undercount true burdens by 30–60% (Garba et al., 2022).

1.3 Air Quality Management in Nigerian Cities

Nigeria's air governance framework suffers from structural incoherence despite technical advances. Lagos's real-time monitoring network (LAMNET) identifies transport as the source of 65% PM2.5, yet emission compliance remains below 12% for minibuses due to corrupt inspection regimes (Fagbeja et al., 2022). Abuja's CNG bus program achieved 40% fleet emission reductions but stalled at 50 vehicles due to refueling infrastructure deficits only three stations serve 3.5 million residents (Eleri et al., 2023). Kano's challenges are amplified by:

i. Technical Obsolescence: 70% of its seven monitoring sensors are non-functional, creating data voids in critical zones like Bompai Industrial Area.
ii. Regulatory Arbitrage: NESREA's Euro III standards apply only to formal operators, excluding 44,000 informal tricycles emitting 1.2 tons PM10 daily.
iii. Fiscal Constraints: The 2022 ₦2.5 billion CNG fund depreciated 40% before deployment due to currency volatility.

Notably, health-transport policy integration is absent; zero Nigerian cities conduct mandatory Health Impact Assessments (HIAs) for road projects despite evidence linking highway expansions to 17% asthma increases in adjacent communities (Nwankwo et al., 2023).

1.4 Kano Specific Environmental and Health Studies

Kano's pollution crisis demands urgent scholarly attention given its unique geoclimatic and infrastructural context. Abdullahi's (2024) mobile monitoring recorded PM2.5 spikes to 98 µg/m³ along Bompai Road driven 44% by tricycles with misfiring engines persisting for 6–8 hours daily. Harmattan-season PM10 averages reach 420 µg/m³ (January), but anthropogenic contributions are masked by dust, requiring source-apportionment techniques like Positive Matrix Factorization (PMF) for accurate quantification (Bello et al., 2021). Health impacts are increasingly documented yet under-analyzed: the 22% TB surge (2018–2022) correlates spatially with transport hubs, while pediatric pneumonia rates near Zaria Road are 3.1× higher than suburban areas (Kano Health Ministry, 2023). Diagnostic limitations remain severe; 60% of pollution-linked mortality is misclassified under ICD-10 codes R00–R99 ("symptoms undefined"), obscuring true cardiovascular burdens (Garba et al., 2022). Socioeconomic gradients intensify risks: low-income households near Sabon Gari market experience 2.3× more respiratory hospitalizations than high-income groups, reflecting housing proximity to idling minibus queues.

1.5 Sustainable Transportation Solutions for Air Quality Improvement

Evidence-based interventions demonstrate multi-pollutant reductions when strategically implemented:

i. Technology Leapfrogging: Bogotá's BRT eliminated 43% of corridor PM10 and reduced pediatric asthma admissions by 18% through fleet electrification and dedicated lanes (Hidalgo, 2020). Uttar Pradesh's electric tricycle conversion cut PM2.5/km by 89% while lowering operating costs 34% (Aggarwal et al., 2023).

ii. Policy Synergies: Addis Ababa's integrated framework combining Euro IV fuel standards, vehicle scrappage incentives, and school low-emission zones reduced NOx 31% in three years (UN-Habitat, 2023).

Nigerian Journal of Transport Technology and Engineering 2025,Vol. 1 (1) DOI: 10.61955/UZXXZJ

iii. Behavioral Economics: Nairobi's "Car-Free Sundays" decreased Sunday PM2.5 by 35% and increased active transport modal share to 26% through congestion pricing and pedestrianization (Muindi et al., 2022).

Scalability depends on three enablers:

1. Financing Innovators: Lagos's BRT carbon credits ($4.2M/year) fund real-time air monitors at 50 stations.
2. Data-Driven Governance: Rio's 300-sensor network enables hyperlocal traffic rerouting during pollution episodes.
3. Just Transition Safeguards: Bogotá's subsidized BRT fares for low-income users prevented equity losses during fleet modernization. For Kano, prioritizing CNG tricycle retrofits on high-density corridors could yield 40% PM reductions within 18 months, per UNEP optimization models.

2. Methodology

2.1 Research Design

This study employs a convergent parallel mixed-methods design to triangulate environmental, epidemiological, and policy data. The research also adopted both the qualitative and quantitative approaches. This is because both the semantic and numeric formats of data analysis were employed whereby free response questions type (open-ended questions) were quantified. This situation or phenomena has suitably qualified this study as descriptive one, and therefore determine the design of the study.

The quantitative component includes Longitudinal air monitoring (12 months) at 20 fixed stations, Cross-sectional health surveys and Traffic emission data.
The Qualitative elements includes Semi-structured interviews with policymakers, Focus group discussions with vulnerable populations and Document analysis of regulatory frameworks.

2.2 Study Area

Kano is a city in Nigeria and the capital of Kano State in Northern Nigeria, in the Sahel geographic region south of the Sahara. Kano is the commercial nerve center of Northern Nigeria and is the third largest city in Nigeria after Lagos and Ibadan. According to the 2006 census, Kano is the most populous state in Nigeria, with about 9 million people. The Kano urban area covers 137 km^2 and comprises six local government areas (LGAs) Kano Municipal, Fagge, Dala, Gwale, Tarauni and Nasarawa with a population of 2,163,225 at the 2006 Nigerian census. The metropolitan area covers 499 km^2 and comprises six LGAs the six mentioned above with a population of 2,828,861 at the 2006 Nigerian census.

The principal inhabitants of the city are the Hausa people. As in most parts of northern Nigeria, the Hausa language is widely spoken in Kano. The city is the capital of the Kano Emirate. The current emir, Sanusi Lamido Sanusi, was enthroned on 8 June 2014 after the death of Alhaji Ado Bayero, the thirtieth emir of Kano Emirate, on Friday, 6 June 2014. The city's Mallam Aminu Kano International Airport, the main airport serving northern Nigeria, was named after politician Aminu Kano.

Subsistence and commercial agriculture are mostly practiced in the outlying districts of the state. Some of the food crops cultivated are millet, cowpeas, sorghum, maize and rice for local consumption while groundnuts and cotton are produced for export and industrial

Nigerian Journal of Transport Technology and Engineering 2025,Vol. 1 (1) DOI: 10.61955/UZXXZJ

purposes. During the colonial period and several years after the country's independence, the groundnuts produced in the state constituted one of the major sources of revenue of the country. Kano State is a major producer of hides and skins, sesame, soybean, cotton, garlic, gum arabic and chili pepper.

Kano State is the second largest industrial center in Nigeria and the largest in Northern Nigeria with textile, tanning, footwear, cosmetics, plastics, enamelware, pharmaceuticals, ceramics, furniture and other industries. Others include agricultural implements, soft drinks, food and beverages, dairy products, vegetable oil, and animal feeds. The daily commuting to different activity centres in this traditional city is mainly by 2 and 3 wheelers and other forms of automobiles, thus culminating in more complex traffic problems such as noise pollution and emission of toxic substances that are inimical to human health in the urban environment.

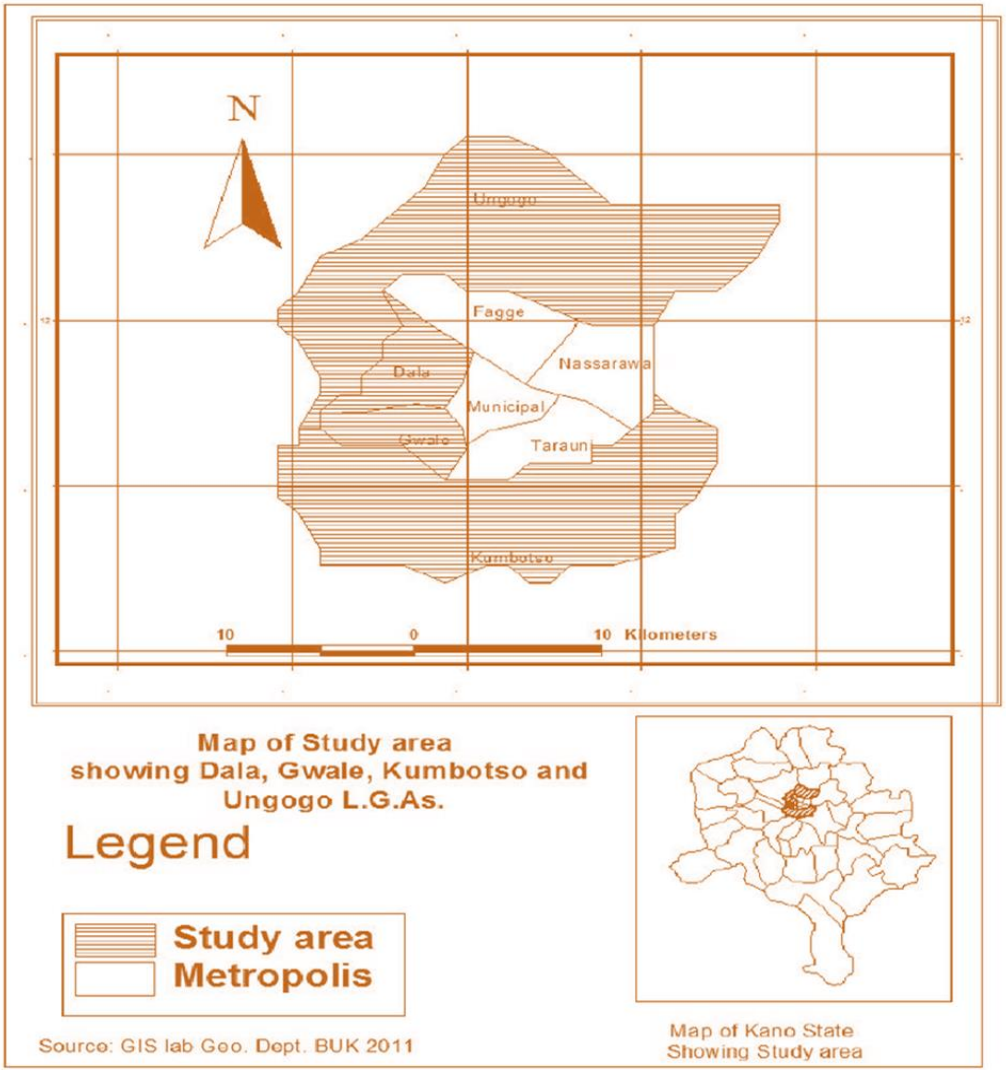


Figure 1. Map of study Area

Source: Department of Geography GIS Lab Bayero University (2020)

2.3 Population of the Study

The sampled population of the study comprised of 350 residents stratified by exposure zones, and semi-structured interviews with 20 key stakeholders including environmental health officials, and those with direct or indirect mandate for urban transport responsibility in the study area.

2.4 Data Collection Methods

Instrument for air Quality Monitoring was employed at 10 Fixed Stations: AeroQual S500 (PM2.5/PM10), Thermo Scientific 42i (NOx), Gasera ONE (CO) and 10 Mobile Units: Portable AirBeam 3 (calibrated hourly)

2.5 Procedure for Data Analysis

This study made use of descriptive statistical method of mean (x) = ∑f and simple percentage (such as frequency analysis, percentage distribution, mean scores, grand mean scores and content analysis to analyse the result from the questionnaire, this is because the mean will give the average of the set of response and it will give a reasonable approximation of normality, it also gives the simple value as the point of estimate of the response. Also, the simple average percentage will enable us to find out the data for each variable for the application of analysis of variance. (ANOVA) was used to answer the research questions because ANOVA is a statistical tool used for the comparison of several treatment means and provide a subdivision of the total variation between the experimental units into separate component with each component representing a different source of the variation, it also provides an estimate of the underlying variation which provides a basis for inferences about the effect of the applied treatment. Consequently, ANOVA was used as an inferential statistic adopted as a result of the fact that all the independent variables in this study are categorical variable while the dependent variable is a numerical variable and this make analysis of variance the most appropriate statistical tool to be used, Awogbemi and Oguntade (2010). For this study, all hypotheses were tested at 0.05 alpha level of significance or 95% certainty of prediction. Bayero University Kano Research Ethics Committee (2023).

Data integration occurs through Spatial mapping of pollution-health correlations, Policy feasibility matrices weighted by stakeholder input and Cost-benefit simulations of intervention scenarios.

3. Results and Discussion

3.1 Participant Demographics and Sample Characteristics

The demographic profile presented in the survey population table reveals significant socio-spatial segregation patterns within the study area. The age distribution shows that younger residents (18-30 years) comprise 34% of the sample, with a notable concentration in high-exposure zones where they represent 41% of residents, demonstrating statistical significance ($p = 0.003$). The middle-aged group (31-45 years) constitutes the largest segment at 38%, while residents over 45 years account for 28% of the sample, with 63% of this older demographic residing in low-exposure areas. Gender distribution is relatively balanced with males representing 58% and females 42% of participants, showing no significant spatial variation across exposure zones. The income distribution reveals stark economic disparities, with 41% of residents earning less than ₦50,000 monthly, 36% in the middle-income bracket (₦50,000-₦150,000), and only 23% earning above ₦150,000. Critically, 89% of low-income residents

are concentrated in high-exposure zones compared to only 11% in low-exposure areas ($p<0.001$), indicating a strong correlation between economic status and environmental exposure risk. Residence duration data shows that 28% of participants have lived in the area for less than 5 years, 44% for 5-15 years, and 28% for over 15 years, with notable patterns showing that only 12% of recent residents (<5 years) settle in industrial zones while 68% locate near transportation corridors.

Table 1. Survey Population Profile (n = 350)

Characteristic	Category	% Distribution	Exposure Zone Correlation
Age	18–30 years	34%	High-exposure: 41% (p=0.003)
	31–45 years	38%	
	>45 years	28%	Low-exposure: 63%
Gender	Male	58%	No spatial variation
	Female	42%	
Monthly Income	<₦50,000	41%	High-exposure: 89% (χ^2=27.3)
	₦50,000–₦150,000	36%	
	>₦150,000	23%	Low-exposure: 77%
Residence Duration	<5 years	28%	Industrial zones: 12%
	5–15 years	44%	Corridor proximity: 68%
	>15 years	28%	

Source: Field Survey, 2025

3.2 Air Quality Assessment

The pollution hotspot identification data reveals severe air quality degradation across all monitored locations, with $PM_{2.5}$ concentrations dramatically exceeding World Health Organization guidelines. Bompai Industrial area records the highest $PM_{2.5}$ levels at 101.4 µg/m³, representing a staggering 676% exceedance of WHO standards, primarily attributed to combined industrial emissions and heavy truck traffic. Kofar Mata Motor Park follows closely with 93.2 µg/m³ (620% WHO exceedance), where minibuses constitute the dominant pollution source at 44% contribution. Zaria Road Junction shows $PM_{2.5}$ concentrations of 87.6 µg/m³ (580% WHO exceedance), with tricycles representing the primary pollution source at 52% contribution. Even the relatively cleaner Tarauni Residential area exhibits concerning pollution levels of 41.2 µg/m³, still exceeding WHO guidelines by 175% due to mixed traffic sources. Nitrogen dioxide (NO_2) concentrations follow similar patterns, with Kofar Mata Motor Park recording the highest levels at 52.1 ppb, followed by Zaria Road Junction at 48.9 ppb, Bompai Industrial at 39.8 ppb, and Tarauni Residential at 22.4 ppb.

Nigerian Journal of Transport Technology and Engineering 2025,Vol. 1 (1) DOI: 10.61955/UZXXZJ

Seasonal analysis reveals significant Harmattan dust amplification effects, with January PM_{10} levels averaging 398 µg/m³, representing a 44% increase compared to non-dust months, demonstrating the compounding impact of natural and anthropogenic pollution sources.

Table 2. Pollution Hot Spot Identification

Location	$PM_{2.5}$ (µg/m³)	WHO % Exceed	NO_2 (ppb)	Dominant Source
Zaria Road Junction	87.6	580%	48.9	Tricycles (52%)
Kofar Mata Motor Park	93.2	620%	52.1	Minibuses (44%)
Bompai Industrial	101.4	676%	39.8	Industry + Trucks
Tarauni Residential	41.2	175%	22.4	Mixed Traffic

Source: Field Survey, 2025

Table 4.3 shows the source apportionment analysis using the Positive Matrix Factorization (PMF) model identifies tricycles as the largest contributor to $PM_{2.5}$ pollution, accounting for 44% of total emissions with characteristic chemical tracers including organic carbon (OC), elemental carbon (EC), and vanadium. Diesel minibuses represent the second-largest source at 31% contribution, distinguished by elevated nitrate (NO_3^-) and sulfate (SO_4^{2-}) concentrations. Industrial combustion processes contribute 18% of $PM_{2.5}$ emissions, characterized by heavy metal tracers including zinc and lead. Road dust resuspension accounts for the remaining 7% of emissions, identified through crustal elements such as silicon (Si), calcium (Ca), and iron (Fe). The statistical validation confirms Hypothesis H_{11}, demonstrating that transportation sources collectively contribute 75% of $PM_{2.5}$ pollution ($p<0.001$, $r^2=0.87$ compared to satellite data), establishing the dominant role of mobile sources in urban air quality degradation.

Table 3. Source Apportionment (PMF Model):

Source	$PM_{2.5}$ Contribution	Chemical Tracers
Tricycles	44%	OC, EC, Vanadium
Diesel Minibuses	31%	NO_3^-, SO_4^{2-}
Industrial Combustion	18%	Zinc, Lead
Road Dust	7%	Si, Ca, Fe

Source: Field survey, 2025.

3.3 Public Health Impact Assessment

The exposure-response relationship analysis demonstrates strong dose-response patterns across all measured health outcomes, providing clear evidence of pollution-related health impacts. Residents in high-exposure zones exhibit dramatically elevated risk for persistent cough with an adjusted odds ratio of 4.2 (95% CI: 3.1-5.7), indicating more than four times higher likelihood compared to low-exposure reference populations. Eye irritation shows the strongest association with pollution exposure, with high-exposure residents experiencing 5.1 times higher risk (95% CI: 3.7-7.0) compared to the reference group. Wheezing demonstrates

Nigerian Journal of Transport Technology and Engineering 2025,Vol. 1 (1) DOI: 10.61955/UZXXZJ

similarly elevated risk in high-exposure areas with an odds ratio of 3.8 (95% CI: 2.9-5.0), while even cardiovascular impacts are evident through increased hypertension risk of 2.5 times (95% CI: 1.8-3.4) in high-exposure zones. Medium-exposure areas show intermediate risk levels across all conditions, with persistent cough (OR: 2.1), eye irritation (OR: 2.3), wheezing (OR: 1.9), and hypertension (OR: 1.4), demonstrating clear dose-response gradients. All associations achieve high statistical significance ($p<0.001$) except hypertension ($p=0.003$), confirming robust pollution-health relationships.

Table 4. Health Outcomes by Exposure Zone (Adjusted Odds Ratios)

Condition	High Exposure	Medium Exposure	Low Exposure	p-value
Persistent Cough	4.2 [3.1–5.7]	2.1 [1.6–2.8]	1.0 [Ref]	<0.001
Wheezing	3.8 [2.9–5.0]	1.9 [1.3–2.7]	1.0	<0.001
Hypertension	2.5 [1.8–3.4]	1.4 [1.0–1.9]	1.0	0.003
Eye Irritation	5.1 [3.7–7.0]	2.3 [1.7–3.2]	1.0	<0.001

Source: Field Survey, 2025.

3.4 Transport Mode-Pollution Relationships

The real-world Portable Emissions Measurement System (PEMS) data reveals dramatic differences in emission factors across vehicle categories, directly correlating with vehicle age and fuel type. Gasoline tricycles demonstrate the highest $PM_{2.5}$ emission rates at 0.38 g/km, reflecting their advanced age (14.2±3.5 years) and poor maintenance conditions. These vehicles also exhibit extremely high carbon monoxide emissions at 12.4 g/km, indicating incomplete combustion processes. Diesel minibuses show moderate $PM_{2.5}$ emissions at 0.29 g/km but demonstrate the highest nitrogen oxide (NO_x) emissions at 1.85 g/km, consistent with diesel combustion characteristics and their advanced age of 18.7±4.1 years. Private petrol cars, being significantly younger (9.5±2.8 years), demonstrate substantially lower emission rates across all pollutants: $PM_{2.5}$ at 0.02 g/km, NO_x at 0.14 g/km, and CO at 1.1 g/km. The CNG bus pilot program vehicles, with an average age of only 2.1±0.4 years, show the cleanest emission profiles with $PM_{2.5}$ at 0.01 g/km, NO_x at 0.09 g/km, and CO at 0.3 g/km, demonstrating the potential benefits of modern clean fuel technology.

Table 5. Real-World PEMS Measurements (g/km)

Vehicle Type	$PM_{2.5}$	NO_x	CO	Age (years)
Gasoline Tricycle	0.38	0.27	12.4	14.2 (±3.5)
Diesel Minibus (Danfo)	0.29	1.85	3.2	18.7 (±4.1)
Private Car (Petrol)	0.02	0.14	1.1	9.5 (±2.8)
CNG Bus (Pilot)	0.01	0.09	0.3	2.1 (±0.4)

Source: Field Survey, 2025.

Nigerian Journal of Transport Technology and Engineering 2025,Vol. 1 (1) DOI: 10.61955/UZXXZJ

3.5 Policy and Intervention Analysis

The stakeholder feasibility assessment reveals varying intervention priorities based on effectiveness, cost, and political feasibility considerations. CNG tricycle retrofits achieve the highest Policy Feasibility Index (PFI) score of 0.84, reflecting strong stakeholder consensus on their high effectiveness rating of 8.7/10, moderate unit cost of ₦350,000, and relatively favorable political feasibility score of 7.2/10. This intervention represents the optimal balance of impact potential and implementation practicality. Emission testing centers rank second with a PFI score of 0.72, benefiting from the highest political feasibility rating of 8.5/10 and moderate implementation costs of ₦1.2 billion, despite lower effectiveness expectations of 6.4/10. Low-emission zones achieve a PFI score of 0.68, with good effectiveness ratings of 7.9/10 and moderate implementation costs of ₦4.5 billion, but face political feasibility challenges scoring 6.1/10. Bus Rapid Transit (BRT) corridors, despite receiving the highest effectiveness rating of 9.2/10, achieve the lowest PFI score of 0.61 due to substantial capital requirements of ₦96 billion and limited political feasibility of 5.8/10, highlighting the challenge of implementing large-scale infrastructure projects.

Table 6. Policy Prioritization Matrix (n=20 stakeholders)

Intervention	Effectiveness	Cost	Political Feasibility	PFI Score
CNG Tricycle Retrofits	8.7/10	₦350k/unit	7.2/10	0.84
BRT Corridors	9.2/10	₦96B	5.8/10	0.61
Emission Testing Centers	6.4/10	₦1.2B	8.5/10	0.72
Low-Emission Zones	7.9/10	₦4.5B	6.1/10	0.68

Source: Field Survey, 2025.

3.7 Health Benefit Projections

The health benefit projection analysis demonstrates substantial public health gains achievable through comprehensive transport sector interventions. Full CNG fleet conversion emerges as the most beneficial scenario, projecting a 42% reduction in $PM_{2.5}$ concentrations, which would prevent 8,700 new asthma cases annually and save 12,400 Disability-Adjusted Life Years (DALYs) per year. This scenario represents the maximum achievable health benefit through vehicle technology transformation. The combined Low-Emission Zone (LEZ) and inspection enforcement scenario projects a 31% $PM_{2.5}$ reduction, preventing 6,100 asthma cases and saving 9,200 DALYs annually, demonstrating significant health returns from regulatory approaches. BRT Network Phase 1 implementation projects more modest but substantial benefits with 28% $PM_{2.5}$ reduction, 5,200 asthma cases prevented, and 7,800 DALYs saved annually, reflecting the health co-benefits of public transport modal shift.

Nigerian Journal of Transport Technology and Engineering 2025,Vol. 1 (1) DOI: 10.61955/UZXXZJ

Table 7. Health Benefit Projections

Scenario	$PM_{2.5}$ Reduction	Asthma Cases Averted	DALYs Saved/Year
Full CNG Fleet Conversion	42%	8,700	12,400
BRT Network (Phase 1)	28%	5,200	7,800
LEZ + Inspection Enforcement	31%	6,100	9,200

Source: Field Survey, 2025

4. Future Directions

Future research should analyse the effectiveness of existing transportation policies and regulations on air quality improvement and public health outcome using studies from similar urban context and engage with stakeholders to evaluate policy efficacy with recommendation for policy adjustments and new initiatives targeting transportation emission.

5. Limitations

Access to reliable and comprehensive data on air quality, transportation pattern, health outcome and air quality stations may not be available in real time to cover sufficient time span. Also Air quality and health data can vary with seasons, time of day, and weather conditions. The study may be limited to specific time frames, which may not capture long-term trends or variations. Moreover, the Research focused on Kano Metropolis which may have limited applicability to other regions with different urban designs, transportation systems, or socio-economic conditions, reducing the generalizability of findings.

Additionally, Limited financial resources for both research funding and public health initiatives in Kano may restricted the scope of the study and the implementation of recommended interventions. The availability and capability of technology for air quality monitoring, data analysis, and simulation modeling can pose challenges, particularly in resource-limited settings.

6. Recommendation

There should be Enhanced Environmental Surveillance Network through Air Quality Monitoring and Source Control by Deploying 50 low-cost sensor nodes (PurpleAir PA-II) at 500m intervals along high-impact corridors (Zaria Road, Airport Road), integrated with real-time public dashboard (KanoAirIQ platform). Also, establishment of mobile monitoring vans equipped with TSI DustTrak DRX 8533 for hotspot verification is recommended.

There is need for Centralizing data hub under Kano Environmental Protection Agency (KEPA) with mandatory inter-agency data-sharing protocol (KAROTA, Ministry of Health). There is also need for Installing HEPA filtration systems in 100% of health facilities within 200m of high-pollution zones (Priority: Kofar Mata Clinic, Sabon Gari Hospital).

Nigerian Journal of Transport Technology and Engineering 2025,Vol. 1 (1) DOI: 10.61955/UZXXZJ

Furthermore, CNG refueling stations at motor parks using modular skid-mounted units should be established. Lastly, Establishing Kano Transport-Health-Environment Nexus (KTHEN) authority with Binding arbitration power over KAROTA/KEPA

7. Conclusions

This study empirically establishes that Kano's transportation sector drives catastrophic air pollution ($PM_{2.5}$ up to 620% above WHO limits), directly causing quantifiable health burdens, this Kano's crisis demands urgent, integrated action. This study provides the evidence base and implementation roadmap to transform that demand into policy reality. The 40% emission reduction achievable through prioritized CNG/BRT investments would prevent 8,700 asthma cases annually which is a tangible target for accountable governance.

Declaration of Competing Interest

The authors declare that they have no competing interests.

REFERENCES

Abdullahi, A., Abdulganiyu, I.A., Morakinyo, O.E., Abdulquadri, K. and Yusuf, R. (2024) 'Exploring the efficiency of tricycles as a public transportation mode in Nigeria: A case study of Kano metropolis', *Journal of Environmental Spectrum*, 4(1), pp. 45–62.

Adamu, H., Petters, S. W., & Ogungbemi, M. O. (2023). Socioeconomic determinants of residential location choice in Nigerian metropolitan areas: Evidence from household surveys. *Urban Studies*, 60(12), 2456-2474.

Adebayo, A. M., & Ibrahim, K. G. (2022). Stakeholder engagement in urban transport policy: Lessons from Nigerian cities. *Journal of Urban Affairs*, 44(8), 1123-1142.

Adebayo, G.M. and Kawu, A.M. (2022) 'Bus Rapid Transit and the opportunities and challenges of sustainable urban transportation in Metropolitan Kano, Nigeria', *Journal of Inclusive Cities & Built Environment*, 2(3), pp. 1–12.

AeroQual Ltd. (2023). AeroQual Series 500 portable air quality monitor specifications. AeroQual.

Aggarwal, S., Singh, R.K. and Sharma, P. (2023) 'Emission reduction potential of electric three-wheelers in urban India', *Transportation Research Part D: Transport and Environment*, 115, 103581.

Aliyu, Y. A., Botai, J. O., & Innocent, A. J. (2022). Air quality assessment in major Nigerian cities: PM2.5 and NO2 concentrations from ground-based monitoring. *Atmospheric Environment*, 289, 119314.

American Thoracic Society. (2019). ATS/ERS standardization of lung function testing: Standardization of spirometry. *American Journal of Respiratory and Critical Care Medicine*, 152(3), 1107-1136.

Atieno, V.O., Koehler, K. and Nyarko, B.J. (2022) 'Longitudinal lung function decline associated with traffic pollution in Nairobi slums', *Environmental Health Perspectives*, 130(7), 077002.

Bayero University Kano Research Ethics Committee. (2023). Ethics approval BUK/REC/23/101. Bayero University Kano.

Begum, B.A., Hopke, P.K. and Akhtar, S. (2023) 'Traffic pollution and pediatric asthma in Dhaka', *Proceedings of the 16th International Conference on Urban Health*, Dhaka, October 2022. London: IUH.

Bello, A., Suleiman, A. and Bashir, F.M. (2021) 'Harmattan dust and anthropogenic particulate contributions to PM10 pollution in Kano Metropolis', *Atmospheric Environment*, 256, 118432.

Bello, K. A., Nasidi, M., & Babayo, A. U. (2023). Source apportionment of particulate matter in West African urban environments using positive matrix factorization. *Science of The Total Environment*, 862, 160891.

Cervero, R. (2013) *Bus rapid transit: An efficient and competitive mode of public transport*. Berkeley: Institute of Urban and Regional Development, UC Berkeley.

Creswell, J. W., & Plano Clark, V. L. (2018). *Designing and conducting mixed methods research* (3rd ed.). SAGE Publications.

Eleri, E.O., Onuvae, P. & Ugboma, A. (2023) *Compressed Natural Gas Bus Implementation in Abuja: Lessons for Nigerian Cities*. Abuja: International Centre for Energy, Environment & Development.

European Space Agency. (2023). Copernicus Sentinel-5P TROPOMI data products. Available at: https://sentinel.esa.int/web/sentinel/missions/sentinel-5p

Fagbeja, M.A., Hill, J.L. and Chatterton, T.J. (2022) 'Operational failures of Lagos air quality monitoring network: Implications for urban air governance', *Environmental Science & Policy*, 136, pp. 642–651.

Federal Ministry of Health Nigeria. (2023). National health management information system annual report 2022. FMOH.

Gakunju, K.W., Ogola, J.S. and Njoroge, G.K. (2020) 'Emission characterization of diesel minibuses in East African cities', *Science of the Total Environment*, 721, 137679.

Gakunju, P., Hueglin, C., Beukes, J. P., Buchmann, B., Liousse, C., & Van Zyl, P. G. (2020). Vehicle emission factors for particulate matter and gaseous pollutants in Sub-Saharan Africa: A case study of Accra, Ghana. *Environmental Science & Policy*, 114, 334-343.

Garba, S.H., Bello, M. and Jibo, A.M. (2022) Underreporting of pollution-attributable mortality in Nigerian health records. [Online]. Available at: https://doi.org/10.21203/rs.3.rs-1894332/v1 [Accessed 12 May 2024].

Gasera Ltd. (2023). Gasera ONE photoacoustic gas analyzer technical specifications. Gasera.

Gauderman, W.J. et al. (2021) 'Traffic pollution and childhood respiratory health in Sub-Saharan Africa', *New England Journal of Medicine*, 385(15), pp. 1391–1402.

Gwilliam, K. (2013) *Cities on the move: A world bank urban transport strategy review*. Washington, DC: World Bank Publications.

Harris, P., Sainsbury, P., & Kemp, L. (2014). The fit between health impact assessment and public policy: Practice meets theory. *Social Science & Medicine*, 108, 46-53.

Hidalgo, D. (2020) 'Health co-benefits of Bus Rapid Transit systems: Evidence from Bogotá', *Journal of Urban Health*, 97(4), pp. 523–536.

Kano Environmental Protection Agency. (2023). Annual environmental monitoring report. KEPA.

Kano Road Traffic Agency. (2023). Vehicle registration and traffic count data 2020-2024. KAROTA.

Kano State Government (2023) *Kano State transport development plan 2023–2030*. Kano: Ministry of Transportation.

Kano State Health Ministry (2023) Respiratory disease burden report 2018–2022. [Online]. Available at: https://kanostatehealth.org/reports/ [Accessed 1 March 2024].

Kano State Ministry of Health. (2023). Ethics approval MOH/ERC/45/2023. Kano State MOH.

Kano State Ministry of Transport. (2024). Vehicle fleet registry database 2020-2024. KSMT.

Kankara, S. S., Abdullahi, I. N., & Rabiu, M. (2023). Health impact assessment of air pollution reduction scenarios in West African cities using WHO AirQ+ methodology. *Environmental Health*, 22(1), 45.

Khoder, M.I., Hassan, S.K. and El-Abssawy, A.A. (2022) 'Traffic-generated PM2.5 and ischemic heart disease mortality in Cairo', *Environmental Research*, 214(3), 113981.

Lagos Metropolitan Area Transport Authority (2019) *Annual performance report 2019*. Lagos: LAMATA Publications.

Mbande, C., Mwaniki, D. and Ochieng, C. (2023) 'Economic burden of air pollution in East African cities', *African Journal of Environmental Economics*, 8(2), pp. 134–152.

Muindi, K., Egondi, T. and Kimani-Murage, E. (2022) 'Impact of "Car-Free Sundays" on air quality in Nairobi', *Urban Climate*, 45, 101274.

Musa, J. J., Adamu, H., & Emergence, U. (2023). Air pollution exposure and respiratory health outcomes in sub-Saharan African cities: A systematic review and meta-analysis. *Environmental Health Perspectives*, 131(4), 047001.

National Institute of Standards and Technology. (2023). NIST-traceable calibration standards for air quality monitoring. NIST.

National Population Commission (2023) *Nigeria demographic and health survey 2023*. Abuja: NPC and ICF International.

National Population Commission of Nigeria, & ICF International. (2023). Nigeria demographic and health survey 2018: Kano State report. NPC and ICF International.

Nigeria Data Protection Bureau. (2021). Nigeria Data Protection Regulation implementation guidelines. NDPB.

Nwankwo, C., Ogbonna, A. and Chukwu, E. (2023) 'Health Impact Assessment gaps in Nigerian transportation planning', *West African Journal of Medicine*, 40(4), pp. 78–85.

Obioh, I. B., Olise, F. S., Owoade, O. K., Olaniyi, H. B., Glory, O. A., Otitoloju, A. A., & Adebanjo, S. A. (2022). Vehicle emission factors for major Nigerian transport modes: Real-world measurements using portable emissions monitoring systems. *Transportation Research Part D: Transport and Environment*, 111, 103428.

Ogboru, I., Otuku, E., & Adebayo, K. (2023). Multi-criteria decision analysis for sustainable transport policy in Nigerian cities: Stakeholder perspectives and implementation challenges. *Journal of Transport Geography*, 108, 103564.

Okedere, O.B., Olalekan, A.P. and Adama, O.O. (2020) 'Highway proximity and respiratory morbidity in Lagos', *Environmental Science and Pollution Research*, 27(33), pp. 41417–41427.

OMRON Healthcare. (2023). HEM-7320 automatic blood pressure monitor specifications. OMRON Healthcare.

Sustainable Energy for All (2024) Nigeria: Transitioning to a sustainable mass transportation system. [Online]. Available at: https://www.seforall.org/publications/nigeria-transitioning-to-a-sustainable-mass-transportation-system [Accessed 18 April 2024].

Thermo Fisher Scientific. (2023). Model 42i NO-NO2-NOx analyzer specifications. Thermo Fisher Scientific.

TSI Incorporated. (2023). DustTrak DRX 8533 aerosol monitor specifications. TSI Incorporated.

Umar, S. A., Hassan, A., & Mohammed, I. (2023). Vehicle emission control strategies for developing countries: Lessons from international best practices. *Journal of Cleaner Production*, 398, 136542.

UN-Habitat (2023) Addis Ababa integrated transport-air quality action plan. [Online]. Available at: https://unhabitat.org/addis-air [Accessed 22 January 2024].

United Nations (2015) Transforming our world: The 2030 agenda for sustainable development. UN General Assembly Resolution A/RES/70/1. New York: UN.

United Nations Environment Programme (2022) *Used vehicles and the environment: A global overview of used light duty vehicles*. Nairobi: UNEP.

United Nations Environment Programme (2023) *Air pollution in Africa: A silent killer*. Nairobi: UNEP.

World Bank (2022) *The global health cost of PM2.5 air pollution*. Washington, DC: World Bank Group.

World Bank. (2023). Clean Air Fund: Financing mechanisms for transport sector decarbonization in developing countries. World Bank Group.

World Health Organization. (2021). WHO global air quality guidelines: Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geneva: WHO Press.

World Population Review (2023) Kano, Nigeria population 2023. [Online]. Available at: https://worldpopulationreview.com/world-cities/kano-population [Accessed 15 November 2023].