



Cost-Benefit Analysis of Pollution from Transportation and the Economic Justification for Green Transport Policies in Zaria LGA Kaduna State, Nigeria

¹Kasimu Abdullahi, ^{*2}Khalid Abubakar, ²Koshe Umar-Farouk Musa,
²Kabiru Mohammed Barau and ²Aminu Alhassan Umar

¹Department of General Studies, Nuhu Bamalli Polytechnic Zaria, Kaduna State.

²Transport Research and Intelligence Department, Nigerian Institute of Transport Technology, Zaria Kaduna State.

*Corresponding authors' email: akhaleed23@gmail.com

ABSTRACT

This study examines the cost-benefit implications of transportation-related pollution and evaluates the economic justification for green transport policies in Zaria local government area, Kaduna state. Anchored in Pigouvian externality theory, welfare economics, and the cost-benefit analysis (CBA) framework, the study employed a cross sectional survey design with data collected from 121 respondents. Descriptive statistics, Chi-Square, and binary logistic regression were used for analysis. Findings reveal that transportation activities in Zaria generate substantial environmental and welfare costs, with 89.3% of respondents identifying pollution as a major challenge and 67.8% reporting increased healthcare expenditure attributable to transport emissions. The dominance of motorcycles and tricycles signals structural inefficiencies and deep fossil fuel dependence within the urban transport system. Despite high environmental awareness, adoption of green transport alternatives remains constrained by inadequate infrastructure, cost barriers, and weak policy support. Environmental awareness ($\beta=1.842$, $p<0.01$), fuel price impact ($\beta=1.204$, $p<0.05$), and pollution-related health effects ($\beta=1.410$, $p<0.01$) significantly predict willingness to adopt sustainable alternatives. The Cost-Benefit Analysis projects a positive NBS of ₦48,100 per capita annually from year 5, confirming the long-term economic viability of green transport investment. The study concludes that transitioning sustainable transport system is economically justified and recommends a coordinated policy approach encompassing financial incentives, infrastructure development, public awareness campaigns, and regulatory reforms to accelerate Nigeria's urban mobility transition.

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INTRODUCTION

Transportation infrastructure is a fundamental driver of economic development, facilitating the movement of people, goods, and services essential for trade, commerce, and access to opportunities (Njoh, 2012). Efficient transport systems are particularly critical in urban environments, where mobility constraints can significantly impede productivity and restrict social and economic interactions. In Nigeria, the transport sector has historically faced challenges, including inadequate road and railway infrastructure, which have constrained economic efficiency. However, post-independence national development plans have increasingly prioritized transportation infrastructure improvements to foster social and economic growth (Doi, 2015; Uche, 2019). Globally, the transportation sector remains one of the largest contributors to greenhouse gas emissions and urban air pollution, accounting for substantial environmental and public health costs. In developing economies, rapid urbanization, dependence on fossil fuel-powered mobility systems, weak public transportation infrastructure, and inefficient regulatory mechanisms have intensified transportation-induced environmental degradation. In Nigeria, road transportation dominates the mobility system and contributes significantly to carbon emissions, fuel consumption, urban congestion, and declining air quality (Akujor et al., 2022).

Zaria, a prominent urban center in Kaduna state, exemplifies this resilience on transportation n for its daily economic and social fabric. The city's major educational institutions,

markets, and commercial hubs attract substantial commuter traffic. Road transportation, dominated by private vehicles, commercial buses, motorcycles, and tricycles, serves as the primary mode of movement. While this has enhanced accessibility and connectivity, the escalating number of vehicles has concurrently exacerbated traffic congestion and contributed to rising levels of air pollution within the urban environment (Akujor et al., 2022). The pervasive use of petrol and diesel-powered vehicles in Zaria leads to the emission of greenhouse gases and other pollutants, significantly impacting air quality, public health, and environmental sustainability (Ogunlowo et al., 2020; Oluwakoya, 2023; Yusuf et al., 2020).

Despite growing concerns regarding the environmental and public health ramifications of transportation pollution, the widespread adoption of sustainable transport initiatives, such as cleaner fuels, enhanced public transport systems, and low-emission vehicles, although several studies have examined transportation emissions and environmental sustainability in Nigeria, limited empirical attention has been given to the localized economic costs of transportation pollution and the welfare implications of transitioning toward green transport system, in medium-sized urban centers such as Zaria. Existing studies largely focus on national emissions trends, energy consumption, or climate-related implications without explicitly evaluating the economic justification for the investment at the household and urban mobility levels (Akujor et al., 2022). Notwithstanding, efforts have been

made to promote cleaner alternatives, including compressed natural gas (CNG) and improvements in public transportation (Associated press, 2024; Oyebode, 2022), their uptake is hampered by inadequate infrastructure, financial constraints, and insufficient public awareness (Ajao et al., 2024). While studies suggest that expanding public transport and integrating cleaner vehicle technologies can yield reductions in emissions and fuel costs (Gujba et al., 2013), there is a notable dearth of localized evidence comprehensively assessing the economic implications of such measures in Zaria.

The study addresses this critical gap by examining the cost-benefit implications of transportation-related pollution and providing an economic justification for green transport in Zaria. A significant concern is the limited application of robust economic evaluation tools, such as cost-benefit analysis, in local transportation planning and policy decisions. Current policies often prioritize short-term interventions, such as fuel price adjustments, over strategic, long-term investments in environmentally sustainable transport systems (Associated Press, 2024). Consequently, the economic benefits associated with adopting greener options including CNG vehicles, electric vehicles, and improved public transport systems have not been adequately quantified. The absence of such rigorous analysis impedes policymakers and stakeholders from justifying necessary investments in sustainable transport infrastructure, thereby hindering the adoption of cleaner transport technologies and progress toward environmentally sustainable urban mobility (Ajao et al., 2024; Onubi et al., 2021). Therefore, the study contributes to the literature in three important ways. First, it provides localized empirical evidence on transportation-related pollution and its welfare implications in Zaria, Kaduna state. Second, it applies an economic cost-benefit perspective to evaluate the justification for green transportation policies within an urban Nigerian context. Third, the study contributes to the growing discourse on sustainable urban mobility and environmental policy in developing economies by highlighting the economic rationale for public investment in environmentally sustainable transport systems.

The study is anchored on the theory of externalities developed by Arthur Cecil Pigou, welfare economics, and the cost-benefit analysis (CBA) framework (Pigou, 1920). The theory of negative externalities explains situations where economic activities impose uncompensated costs on third parties that are not reflected in market prices. In transportation economics, vehicle emissions generate environmental pollution, health challenges, congestion, and productivity losses that are not directly borne out by transport users. This results in market failure and socially inefficient outcomes. From welfare economics perspective, government intervention becomes necessary to internalize external costs through policy instrument such as Pigouvian taxes, environmental regulations, subsidies for cleaner technologies, and investment in sustainable public transportation systems. The framework of CBA provides an economic basis for evaluating whether the expected social benefits of the policies exceed the associated implementation and adjustment costs.

Empirical literature on transportation pollution and sustainable mobility increasingly demonstrates that conventional transportation systems generate substantial environmental and economic externalities, especially in developing economies characterized by rapid urbanization, weak regulatory institutions, and inadequate public transport infrastructure. However, while the literature generally agrees on the adverse environmental implications of fossil fuel-dependent systems, findings differ regarding the magnitude of

economic costs, the effectiveness of green policies, and the major constraints to sustainable mobility transitions. These differences largely reflect variations in methodological approaches, institutional contexts, infrastructural conditions, and levels of economic development across countries and cities.

A dominant strand of the literature argues that transportation-related pollution imposes significant social and economic costs through carbon emissions, declining air quality, public health deterioration, and productivity losses. Ogunlowo, Bristow, and Sohail (202), using the Long-range Energy Alternatives Planning (LEAP) model for Lagos state, found that continued dependence on fossil fuel-powered systems would substantially increase greenhouse gas emissions and particulate pollution in the absence of effective environmental policy intervention. Similarly, Akujor et al. (2022) contends that Nigeria's transportation sector remains one of the major contributors to environmental degradation due to excessive reliance on petrol and diesel-powered vehicles. Their studies emphasize that decarbonization of the sector through cleaner fuels and low-emission technologies is necessary for achieving environmental sustainability and reducing urban pollution costs. In the same direction, Oluwakoya (2023) links transportation emissions in Nigeria to respiratory illnesses, increasing healthcare expenditure, and declining urban environmental quality. These studies collectively support the argument that this sector's activities generate substantial negative externalities that extend beyond private transport users to society at large.

Evidence further suggests that transportation pollution generates measurable welfare losses through increased healthcare costs and reduced labor productivity. Miller (2019) demonstrates that reducing diesel emissions produces substantial net social benefits through lower mortality rates, improved health outcomes, and reduced hospital admissions. The implication of this finding is that environmental pollution should not merely be viewed as an ecological issue but also as a major economic burden capable of reducing productivity and increasing public and private healthcare expenditures. Similarly, International Council on Clean Transportation (2021) estimates the transitioning to soot-free transportation systems in Nigeria would significantly reduce fuel consumption, environmental damage costs, and pollution-induced health risks. Collectively, these findings strengthen the welfare economics argument that it creates market failures by imposing uncompensated social costs that are not reflected in market prices. Although the literature generally agrees that it generates substantial economic and environmental costs, studies differ regarding the most effective mechanisms for achieving sustainable transitions. One group of studies emphasizes infrastructure investment and technological transition as the primary solution. For instance, Nwokedi et al. (2020) found that investments in rail freight transportation in Nigeria generated benefit-cost ratios greater than unity, indicating that sustainable infrastructure in the sector can produce positive long-term economic returns through reduced logistics costs, low emissions, and improved efficiency. Likewise, Alogdianakis and Dimitriou (2024) argue that investment in sustainable urban bus systems yields substantial welfare gains by improving mobility efficiency and reducing environmental externalities. Similarly, the Rocky Mountain Institute (2022) identifies electric mobility systems and alternative fuel technologies as critical pathways for achieving low-carbon transportation systems in Nigeria. These studies collectively argue that sustainable transportation investment generates long-term social and economic benefits capable of outweighing initial adjustment

and implementation costs.

In contrast, another strand of the literature argues that the success of green transportation policies depends less on technological availability and more on institutional quality, affordability, infrastructure accessibility, and policy coordination. Ajao, Sadeeq and Sodiq (2024), using an extended Unified Theory of Acceptance and Use of Technology (UTAUT) framework, found that infrastructure deficits, affordability challenges, weak policy support, and low public awareness significantly constrain electric vehicle adoption in Nigeria. Their findings suggest that willingness to adopt green transportation alternatives may exist, but structural barriers prevent actual behavioral transition. Similarly, Onubi et al. (2021) argue that weak environmental regulation and inconsistent policy implementation reduce the effectiveness of sustainability initiatives in Nigeria. Unlike studies that primarily emphasize technological solutions, these studies maintain that sustainable transitions require institutional reforms, coordinated environmental governance, and supportive regulatory frameworks capable of reducing uncertainty and encouraging long-term investment in green mobility systems.

The literature also differs regarding the extent to which public awareness influences environmental sustainability outcomes. Some studies argue that environmental awareness significantly improves willingness to adopt sustainable practices. Agboola et al. (2023) identify poor environmental awareness and weak institutional coordination a major barrier to sustainable environmental practices in Nigeria. The study argues that public sensitization and policy coordination are critical for achieving environmental sustainability objectives. Similarly, Yunusa et al. (2025) found that weak environmental management practices and low public compliance significantly increase environmental and health risks in Kaduna metropolis. Their findings imply that improving environmental awareness can positively influence environmental behavior and reduce pollution-related risks. However, other studies suggest that awareness alone may be insufficient to induce substantial behavioral change in the absence of supportive infrastructure and economic incentives. Ajao et al. (2024) found that although many individuals demonstrate willingness to adopt environmentally sustainable alternatives, adoption remains constrained by high transition costs, inadequate charging infrastructure, and weak government incentives, but effective transition requires coordinated economic and institutional support systems. Consequently, the literature increasingly recognizes that sustainable mobility transitions require a combination of environmental awareness, financial incentives, technological accessibility, and infrastructural development rather than reliance on a single policy mechanism.

Another important dimension within the literature concerns the relationship between urbanization, transportation pressure, and environmental sustainability. Tadama, Monday, and Garba (2022) found that rapid population growth and urban expansion in Kaduna state have significantly increased

pressure on transportation facilities and urban infrastructure, thereby intensifying congestion and environmental stress with urban areas. This supports the argument that unplanned urban growth contributes to inefficiencies, rising mobility costs, and environmental degradation. Similarly, Venables, Laird, and Overman (2014) argue that inadequate transportation infrastructure constrains productivity and economic efficiency by increasing costs and reducing mobility efficiency. These studies collectively suggest that sustainability in the sector cannot be separated from broader issues of urban planning, infrastructure provision, and economic development.

Despite growing empirical evidence, there remains limited localized evidence on the economic justification for green transportation policies within medium-sized urban centres in Nigeria such as Zaria. Existing studies have largely concentrated on national emissions trend, climate change implications, or transportation infrastructure challenges without explicitly examining the welfare costs associated with transportation pollution and the potential net social benefits of transitioning toward green transport systems at the urban level. Furthermore, while some studies focus primarily on technological transition and others emphasize institutional constraints, limited empirical attention has been given to integrating environmental externalities, welfare implications, and cost-benefit reasoning within a localized urban transportation systems, this study therefore filled this gap.

MATERIALS AND METHODS

The study was conducted in Zaria local government area of Kaduna state, Nigeria. One of the major educational, commercial, and transportation centers in northern Nigeria. The city experiences intense daily mobility arising from commercial activities, institutional movements, inter-city transportation, and rapid urban expansion. Transportation activities within the metropolis are dominated by motorcycles, tricycles, buses, taxis, and private vehicles, most of which rely heavily on fossil fuels. Consequently, the increasing dependence on road has contributed to rising environmental pollution, congestion, fuel consumption, and urban mobility challenges within the area. The selection of Zaria is therefore justified by the growing environmental concerns associated with emissions and sustainable urban mobility within rapidly urbanizing Nigerian cities.

The study adopted a cross-sectional survey design within a quantitative research framework to examine the economic implications of transportation-related pollution and the justification for green policies in Zaria. The targeted population comprised transport users within the metropolis, including commercial transport operators, private vehicle owners, motorcycles and tricycle riders, and public transport commuters. Given the heterogeneous nature of the study, a simple random sampling technique was employed to minimize sampling bias and ensure broad representation of users across different mobility categories within the study area.

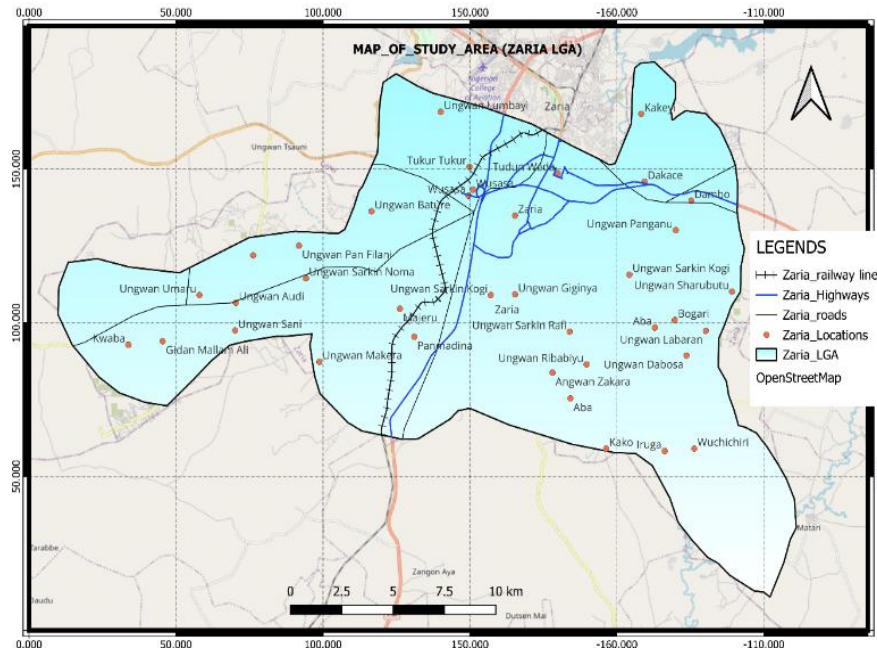


Figure 1: Map of Zaria Local Government Area of Kaduna State Nigeria

The study adopts Cost-Benefit Analysis (CBA) as the principal analytical framework for evaluating the economic justification for green transportation policies in Zaria. The framework is rooted in welfare economics and externality theory, which argue that transportation-related pollution generates negative external costs through environmental degradation, healthcare expenditure, productivity losses, and declining urban welfare. Consequently, investment in environmentally sustainable systems is expected to generate long-term social and economic benefits capable of outweighing the associated implementation and adjustment costs. The analytical framework is expressed as:

$$NSB = \sum B_t - \sum C_t$$

Where: NSB represents net social benefit; B_t denotes the expected social and economic benefits associated with green transportation systems; and C_t represents implementation and adjustment costs. A positive net social benefit implies that the long-term environment and economic gains associated with green transportation policies exceed the corresponding costs, thereby justifying policy intervention and investment in sustainable urban transportation systems.

To complement the cost-benefit framework and strengthen the empirical rigor of the study, binary logistic regression analysis was employed to examine the determinants of willingness to adopt the green alternatives. The logistic regression model was considered appropriate because the dependent variable is dichotomous in nature, taking the value of one if respondents are willing to adopt the alternatives and zero otherwise. The functional relationship of the model is expressed as:

$$WTG = f(AWP, EDU, VEO, FTP, POL, INF, CST)$$

Where WTG=willingness to adopt green transportation alternatives, AWP=awareness of environmental pollution, EDU=educational attainment, VEO=vehicle ownership status, FTP=fuel price impact, POL=perception of pollution-related effects, INF=infrastructure availability, and CST=cost-related barriers. The econometric form of the logistic regression model is specified as:

$$P(Y = 1) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n)}}$$

Where $P(Y=1)$ represents the probability of willingness to adopt green transportation alternatives; β_0 is the intercept parameter; $\beta_1 - \beta_n$ are slope coefficients; and $X_1 - X_n$ are explanatory variables.

The data obtained from the field survey were analyzed using both descriptive and inferential statistical techniques. Descriptive statistics including percentage, frequencies, and mean score were used to summarize respondents' socioeconomic characteristics and transportation usage patterns. Inferential statistical techniques, chi-square and binary logistic regression were employed to examine the relationship between environmental awareness and green transportation adoption as well as to estimate the determinants of willingness to adopt sustainable transportation alternatives within the study area. The analysis was conducted using the statistical package (SPSS) for the social sciences at a 5% level of significance.

RESULTS AND DISCUSSION

Table 4.1 presents the descriptive statistics for the key binary variables derived from the field survey (N = 121). For binary-coded variables, means are interpreted as proportions (0–1) and standard deviations are computed as SD. It reveals that although 89.3% of respondents acknowledged transportation activities as a major source of environmental pollution, pollution-intensive mobility patterns continue to dominate the sector within Zaria metropolis. This suggests that the persistence of environmental degradation related to it cannot be explained primarily by lack of public awareness. Rather, the finding indicates the existence of structural inefficiencies within the urban transport system, inadequate sustainable infrastructure and weak environmental policy enforcement. The result, in economic terms, reflects a classical externality problem in which private transportation decisions generate social costs that are not fully internalized by transport users.

Table 1: Transportation Pollution and Environmental Implications

Variable	N	Mean	Std. Dev.	% Positive	Level
Awareness of Environmental Pollution (AWP)	121	0.8926	0.3097	89.3%	High
Vehicle Ownership Status (VEO)	121	0.4876	0.5019	48.8%	Moderate
Fuel Price Impact on Transport (FTP)	121	0.8678	0.3392	86.8%	High
Pollution Increases Medical Expenses (POL)	121	0.6777	0.4690	67.8%	High
Support for Green Transport (SGT)	121	0.8926	0.3097	89.3%	High
Awareness of Green Transport Options (AGT)	121	0.6446	0.4808	64.5%	Moderate
Willingness to Adopt Green Transport (WTG)	37	0.9189	0.2750	91.9%	High
Cost as Barrier to Adoption (CST)	121	0.2231	0.4178	22.3%	Low
Infrastructure as Barrier (INF)	121	0.1983	0.4002	19.8%	Low
Lack of Awareness as Barrier	121	0.4132	0.4943	41.3%	Moderate

Source: Field Survey, 2026

The finding that about 86.8% identified rising fuel costs as a major economic burden further reinforces the inefficiency of fossil fuel-dependent systems. Heavy dependence on conventional fuel-powered mobility increases household transportation expenditure and exposes urban commuters to fuel volatility. This implies that transportation costs within the study area are strongly linked to fluctuations in energy prices, thereby reducing household welfare and increasing the cost of urban mobility. The result therefore suggests that continued reliance on fossil-fuel systems may deepen urban welfare losses and economic vulnerability over time. Similarly, the fact that 67.8% associated transportation pollution with increased healthcare expenditure demonstrates that environmental degradation extends beyond ecological concerns to measurable household-level economic consequences. The implication is that pollution exposure imposes indirect welfare costs through rising medical expenditure and reduced quality of living. Such costs are typically excluded from market prices, thereby creating allocative inefficiency within the sector. This finding supports the argument that pollution-generating systems transfer part of their operational costs to society through environmental and health-related burdens.

The strong willingness (91.9%) to adopt green transportation alternatives also carries important policy implications. The

result suggests that resistance to sustainable mobility transition within the study area is unlikely to originate from demand-side behavior alone. Instead, the continued dominance of conventional systems appears to be driven more by supply-side constraints, including limited technological accessibility, inadequate infrastructure, and weak institutional support for sustainable transportation development. This implies that improving infrastructure and policy incentives may significantly accelerate the transition toward environmentally sustainable systems.

The chi-square result in table 4.2 indicates a statistically relationship between environmental awareness and willingness to adopt green transportation alternatives ($X^2=10.728$, $p<0.05$). The finding suggests that awareness of transportation-related pollution influences support for environmentally sustainable mobility systems within the study area. From a welfare economics perspective, the result implies that individuals who recognize the broader social costs associated with transportation systems capable of improving collective welfare through reduced pollution exposure and better environmental conditions. The finding therefore reinforces the argument that transportation pollution generates welfare losses extending beyond private users to society as a whole.

Table 2: Chi-Square Result

Variable	Observed (O)	Expected (E)	X^2 Contribution	X^2 Total	p-value
Aware & Willing	32	30.38	0.086		
Aware & Not W	1	2.68	1.054		
Not Aware & Willing	2	3.68	0.768		
Not Aware & Not Willing	2	0.32	8.820		
Total / χ^2 (df=1)	37	37	10.728	10.728	0.001**

Source: Field Survey, 2026

The result also supports externality theory by indicating that awareness of environmental and health-related costs can influence behavioral responses toward cleaner alternatives. This suggests that pollution-generating systems create social costs that are increasingly recognized by urban residents, thereby strengthening public demand for environmentally sustainable policies. This finding aligns with Agboola et al. (2023) and Yunusa et al. (2025), who identify low environmental awareness as a principal barrier to sustainable practices in Nigeria and Kaduna metropolis respectively.

The logistic regression results in table 3 below indicate that environmental awareness, educational attainment, fuel price impact, pollution-related health effects, infrastructure availability, and cost barriers significantly influence willingness to adopt green transportation alternatives in Zaria metropolis. The positive significance of environmental

awareness ($\beta= 1.842$, $p<0.01$) suggests that recognition of transportation-related environmental and welfare costs increases support for sustainable mobility systems. This implies that awareness of pollution externalities can influence behavioral transition toward cleaner alternatives. Similarly, the significance of fuel price impact ($\beta= 1.204$, $p<0.05$) indicates that rising fossil fuel costs increase the attractiveness of green systems. The result suggests that continued dependence on conventional system exposes households to fuel price vulnerability and rising mobility costs, thereby strengthening demand for more energy-efficient alternatives. Health effects from pollution in the system also exert a positive influence on adoption decisions ($\beta= 1.410$, $p<0.01$), implying that individuals who experience or perceive pollution-induced healthcare burdens are more likely to support environmentally sustainable policies capable of

reducing long-term welfare losses. Infrastructure availability emerged as another significant determinant ($\beta= 1.173$, $p<0.05$), indicating that sustainable transition depends substantially on the availability of supporting infrastructure. That willingness to adopt may remain constrained in the absence of charging facilities, CNG refueling stations, and

efficient public transport networks. Conversely, cost barriers negatively influence adoption probability ($\beta= -0.865$, $p<0.05$), implying that high transition costs reduce the likelihood of adopting alternatives despite growing environmental awareness and public support.

Table 3: Regression Results

Variable	Coefficient (β)	Std. Error	Wald Statistic	p-value	Odds Ratio(Exp β)
Awareness (AWP)	1.8420	0.5912	3.116	0.002**	6.312
Educational Attainment (EDU)	0.9215	0.4103	2.246	0.025*	2.514
Vehicle Ownership (VEO)	-0.4318	0.3854	-1.121	0.262	0.649
Fuel Price Impact (FTP)	1.2041	0.5237	2.299	0.022*	3.333
Pollution Health Effects (POL)	1.4102	0.4921	2.867	0.004**	4.096
Infrastructure Availability (INF)	1.1730	0.4786	2.451	0.014*	3.232
Cost Barriers (CST)	-0.8654	0.4102	-2.110	0.035*	0.421
Constant	-3.2150	1.1042	-2.912	0.004**	—

Source: Field Survey, 2026.

Educational attainment was positively significant, suggesting that individuals with higher educational exposure are more likely to recognize the long-term environmental and economic benefits associated with sustainable systems. However, ownership was statistically insignificant, indicating that adoption behaviour is shaped more by structural and policy-related conditions than by ownership status alone.

The cost-benefit evidence in table 4 suggests that the transition toward green transportation systems within Zaria is likely to generate positive net social benefits ($NSB>0$), implying that the long-term economic and environmental gains associated with sustainable mobility policies outweigh the corresponding adjustment and implementation costs. This outcome is supported by the significant welfare losses currently associated with the system, rising fuel expenditure, healthcare burdens, and urban mobility inefficiencies identified in the study. The healthcare implications of transportation pollution constitute one of the major sources of welfare loss within the study area. The finding that a considerable proportion of respondents with increased medical expenditure suggests that households incur indirect economic costs through treatment of pollution-related illnesses and environmental stress conditions. Green

transportation systems are therefore likely to generate substantial healthcare savings through improved air quality and reduced pollution exposure. From a welfare economics perspective, such savings represent reductions in negative external costs previously transferred from transport operators to society.

Similarly, the strong influence of fuel price burden indicates that fossil fuel dependency imposes persistent financial pressure on urban households. Transition toward cleaner and more energy-efficient alternatives such as CNG and low-emission public transportation may reduce long-term household expenditure and improve energy efficiency within the urban transport sector. The resulting fuel savings would contribute to improved household welfare and lower urban mobility costs. The environmental benefits are equally significant and reduced dependence on this system is expected to lower emission levels, improve urban air quality, and reduce environmental degradation with the metropolis. These improvements possess broader social value because environmental quality directly affects public health, urban livability, and long-term sustainable outcomes. Consequently, sustainable transportation investment generates benefits extending beyond private transport users to the wider urban population.

Table 4: Cost-Benefit Analysis of Green Transportation Policies

Category	Estimated Value (₦/capital/annum)	Basis and Notes
SOCIAL COSTS (Current System)		
Healthcare Costs from Pollution	₦18,500	67.8% of respondents report increased medical costs attributable to transport pollution
Productivity Loss from Congestion & Health	₦12,400	Estimated annual labor productivity loss per worker due to absenteeism and commute inefficiencies
Environmental Degradation Cost	₦9,800	Air quality deterioration, soil contamination, and ecosystem damage (ICCT, 2021)
Fossil Fuel Expenditure	₦31,200	Average annual household fossil fuel spending; proxy for energy inefficiency cost
TOTAL ANNUAL SOCIAL COST (per capita)	₦71,900	Aggregate annual welfare cost attributable to transportation pollution
EXPECTED BENEFITS (Green Transition)		
Healthcare Savings	₦15,600	Projected annual reduction in medical costs under clean transport scenario (Miller, 2019)

Category	Estimated Value (₦/capital/annum)	Basis and Notes
Fuel Savings (CNG/EV shift)	₦19,700	Annual fuel cost savings per household under CNG or EV adoption (ICCT, 2021; Gujba et al., 2013)
Productivity Gains	₦10,200	Annual per-capita productivity gains from reduced congestion and improved health outcomes
Environmental Benefits	₦8,400	Monetized value of emission reductions and improved urban air quality
Improved Urban Welfare	₦6,100	Consumer surplus gains from enhanced mobility reliability and reduced noise pollution
TOTAL ANNUAL BENEFIT (per capita)	₦60,000	Aggregate annual welfare gain per resident under green transport scenario
NET SOCIAL BENEFIT (NSB)	-₦11,900 (Yr 1) → +₦48,100 (Yr 5+)	Negative in transition year due to implementation costs; strongly positive from Year 3 onward

Source: Field Survey (2026), ICCT (2021), Miller (2019), Gujba et al. (2013), Author's Estimation

The findings of this study are broadly consistent with the growing body of empirical literature on transportation-related pollution and sustainable mobility in developing economies, while contributing new localized evidence from medium-sized Nigerian urban center. The high level of EA (89.3%) aligns with Agboola et al. (2023), who observed rising environmental consciousness among Nigerian urban residents even as structural barriers impede behavioral change. The significant proportion of respondents (67.8%) linking transport pollution to increased healthcare expenditure corroborates Oluwakoya (2023), who documented associations between transport emissions and respiratory illness in Nigeria, affirming that pollution generates indirect economic costs extending beyond ecological damage to measurable household welfare losses. The structural dominance of motorcycles and tricycles in Zaria's system resonates with Akujor et al. (2022), who identified Nigeria's excessive fossil fuel dependence as a primary driver of urban environmental degradation. This pattern also supports the structural inefficiency argument of Ogunlowo, Bristow, and Sohail (2020), whose LEAP model projections for Lagos state are directly applicable to Zaria's context. The logistic regression findings with EA ($\beta=1.842, p<0.01$), fuel price impact ($\beta=1.204, p<0.05$), and health effects ($\beta=1.410, p<0.01$) as significant predictors of adopting willingness are consistent with Ajoie, Sadeeq, and Sodiq (2024), confirming the economic pressure and environmental concern function as positive behavioral drivers when supported by adequate infrastructure. The cost-benefit results further correspond with Nwokedi et al. (2020) and the ICCT (2021), both of which document positive long-run returns on sustainable transport investment in Nigeria.

The study agrees with Agboola et al. (2023) and Yunusa et al. (2025) that EA significantly drives support for sustainable alternatives, as confirmed by the Chi-Square results ($X^2=10.728, p<0.01$) and the regression coefficient for awareness ($\beta=1.843$). However, a key divergence emerges, contrary to an awareness-centric view; the findings demonstrate that high awareness (89.3%) and strong stated willingness (91.9%) do not automatically translate into actual adoption. The persistent influence of infrastructure deficit ($\beta=1.173, p<0.05$) and cost barriers ($\beta= -0.865, p<0.05$) confirms that supply-side structural constraints, not demand-side resistance, are the binding limitations, an argument more consistent with Ajao et al. (2024) than with a pure awareness-intervention approach. A further divergence involves vehicle ownership. Unlike conventional assumptions that vehicle owners resist sustainable transitions due to sunk cost effects, vehicle ownership status (VEO) was statistically insignificant in this study ($\beta= -0.432, p<0.262$), suggesting that structural barriers affect owners and non-owners alike. The cost-benefit

analysis also offers a more cautious picture than previous studies: while long-run NBS are strongly positive (₦48,100 per capita by year 5), a first-year negative NBS of -₦11,900 highlights the transitional investment burden. This contrast with the consistently optimistic projections of Nwokedi et al. (2020) and Alogdianakis and Dimitriou (2024), and underscores that achieving positive returns in Nigeria's historically inconsistent implementation record complicates (Onubi et al. 2021). The infrastructure finding also underscores the need for coordinated intergovernmental investment and public-private partnerships to bridge the current supply-side gap. Since the social returns on green transport investment spanning healthcare savings, fuel cost reductions, and improved environmental quality extend beyond local government boundaries, shared financing frameworks drawing on environmental levies, green bonds, and international climate funds under Nigeria's Energy Transition Plan are necessary to mobilize resources at the required scale (Federal Government of Nigeria, 2022; World Bank, 2023).

The findings are firmly grounded in Pigouvian externality theory (Pigou, 1920). Vehicle operators in Zaria bear only private fuel and maintenance costs while externalizing healthcare, productivity, and environmental degradation costs onto the wider population. The estimated ₦18,500 per capita annual healthcare cost and the total social cost of ₦71,900 per capita provide direct monetary evidence of this externality at the household level. This constitutes a textbook market failure in which the equilibrium level of fossil fuel-based transportation exceeds the socially optimal level, generating allocative inefficiency and aggregate welfare loss. Pigouvian corrective instruments such as environmental levies, congestion charges, and green transport subsidies calibrated to the measured externality are theoretically appropriate responses for restoring efficiency by realigning private and social costs. Beyond the immediate static externality, the study's findings illuminate important dynamic and inter-temporal dimensions. Continued fossil fuel dependence in a rapidly urbanizing environment generates compounding negative externalities through cumulative emissions and progressive air quality deterioration, imposing costs on future generations not represented in current market decisions. The positive influence of education attainment ($\beta= 0.9222, p<0.05$) further identifies information asymmetries and bounded rationality as co-existing sources of market failure, suggesting that public education and emissions disclosure policies constitute complementary welfare-improving instruments alongside direct Pigouvian correctives. The findings also situate Zaria's transport challenges within the global sustainable urban mobility agenda articulated under SDG11 and the New Urban Agenda, which call for accessible,

affordable, efficient, and environmentally sound urban transport system (World Bank, 2023). The dominance of informal, high-emission modes reflects patterns common across Sub-Saharan African cities experiencing rapid urbanization and inadequate formal transit provision (Tadama, Monday, & Garba, 2022; Venebles, Laird, & Overman, 2014). Critically, the study's evidence suggests that sustainable transition requires structural reorganization of the system not merely technological substitution of individual vehicles toward higher-capacity, lower-emission public transit networks capable of meeting Zaria's growing mobility demand. The 91.1% willingness to adopt green alternatives represents a significant social capital asset, indicating that pragmatic demand-side openness exists and that supply-side investment is the binding constraint. The projected positive NSB from year 3 onward (₦48,100 per capita by year 5) confirms that green transport investment is a development necessity rather than an environmental luxury, directly refuting the assumption that developing economies cannot afford sustainable transitions. Finally, the disproportionate welfare burden borne by low-income users reflected in the 86.8% reporting fuel price pressure underscores the importance of embedding environmental justice and distributional equity considerations into sustainable urban mobility planning, ensuring that green transport policies generate inclusive rather than regressive welfare outcomes.

CONCLUSION

The study demonstrates that transportation-related pollution in Zaria imposes significant and measurable welfare costs on urban residents, estimated at ₦71,900 per capita annually, while the transition to green transport alternatives is both economically justified and socially demanded. Despite high environmental awareness (89.3%) and strong adoption willingness (91.9%), the sustainable mobility transition remains constrained by inadequate infrastructure, affordability barriers, and weak institutional support rather than public resistance. The cost-benefit analysis confirms that green transport investment generates positive net social benefits from year 3 onward, establishing beyond reasonable doubt that sustainable urban mobility is not an environmental luxury but a sound and necessary development investment for Nigerian cities.

Governments at all levels should prioritize investment in CNG and electric vehicle infrastructure across secondary Nigerian urban centers, as supply-side deficits remain the single greatest barrier to adoption. Financial incentive schemes including purchase subsidies, tax relief, and concessional financing must accompany infrastructure development to ensure that green transport options are economically accessible low-and-middle-income transport users. Environmental levies calibrated to the documented external costs of fossil fuel transportation should be introduced as Pigouvian corrective instruments, with revenues ring-fenced for sustainable transport investment. Public awareness campaigns focused on the health and economic costs of transport pollution should be institutionalized at community and school levels, given the proven positive influence of environmental knowledge on adoption willingness. Finally, the federal and state governments must develop coordinated financing frameworks drawing on Nigeria's Energy Transition Plan and International Climate Funds to mobilize investment at the scale that a credible and inclusive urban mobility transition demands.

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