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Research Article

Tricycle Transport and Urban Sustainability in Zaria, Nigeria: A Multidimensional Assessment

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ABSTRACT

Rapid urbanisation and limited formal public transport in Nigerian cities have led motorised tricycles to absorb a growing share of short-distance urban travel, yet their overall contribution to sustainable mobility remains poorly understood. This study examined tricycle transportation as a sustainable urban mobility mode in Zaria metropolis, Nigeria, investigating the socioeconomic and travel characteristics of users, patterns of utilisation, and relationships between user characteristics and tricycle use. A quantitative cross-sectional survey of 290 tricycle operators and 365 patrons was conducted across eight major terminals, employing structured questionnaires and field observations. Data were analysed using descriptive statistics, Spearman's rank-order correlation, and ordinal logistic regression. The findings reveal that patrons are predominantly young (73.1% aged 18–35 years), students (33.7%), and low- to middle-income earners (60.0% earning below ₦100,000 monthly), while operators are exclusively male with secondary education or less. Sustainability perception analysis showed strong endorsement of economic sustainability (90.5% agreement on employment creation) and social sustainability (89.7% agreement on accessibility) but ambivalent environmental perceptions. An ordinal logistic regression showed that all three sustainability dimensions significantly predicted trip frequency, with economic perception the strongest predictor ($B = 0.456$, $p < 0.001$; odds ratio = 1.58), followed by social perception ($B = 0.345$, $p < 0.001$; odds ratio = 1.41) and environmental perception ($B = 0.234$, $p < 0.01$; odds ratio = 1.26), jointly explaining 28.9% of the variance in trip frequency (Nagelkerke $R^2 = 0.289$). Major challenges facing operators include poor road conditions (84.8%) and high fuel costs (77.2%). The study concludes that tricycles provide essential mobility and employment in Zaria but face significant sustainability constraints. Recommendations include infrastructure investment, regulatory reform, operator support programmes, and transition to cleaner technologies to enhance the sustainability of tricycle transport in Nigerian cities.

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1 Introduction

Urban transportation is fundamental to urban productivity, accessibility, and social inclusion, yet rapid urbanisation and rising travel demand continue to exceed the capacity of transport infrastructure and formal public transport systems, particularly in cities of the Global South (UN-Habitat, 2022; World Bank, 2022). These deficiencies manifest in congestion, unreliable travel, high transport costs, and unequal access to essential opportunities, reinforcing the need for transport systems that are affordable, accessible, efficient, safe, and environmentally sustainable (IPCC, 2022; UN-Habitat, 2022).

Across African cities, the limitations of formal public transport have encouraged the expansion of informal and semi-formal paratransit services, which provide flexible and relatively affordable mobility, especially in peripheral and underserved areas (World Bank, 2022; ITF, 2023). In Nigeria, motorised tricycles, popularly known as Keke NAPEP, have become an important component of this transport system because their operational flexibility and small size enable them to serve local streets and provide short-distance and first-/last-mile connections. However, their increasing use presents a sustainability dilemma. While tricycles can improve accessibility and mobility, concerns regarding safety, emissions, traffic conflicts, affordability, and regulatory control raise questions about their overall contribution to sustainable urban transport (World Bank, 2022; WHO, 2023).

This issue is particularly relevant to Zaria metropolis, Kaduna State, an important educational, commercial, and administrative centre with substantial intra-urban travel generated by Ahmadu Bello University, other educational institutions, markets, employment centres, and expanding residential areas. Spatial growth and limitations in conventional public transport have increased the demand for flexible transport services capable of connecting neighbourhoods with major activity centres (Vitale Brovarone & Cotella, 2020). Tricycles consequently constitute an important component of the urban mobility system, particularly for short- and medium-distance trips and areas inadequately served by conventional public

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transport (Muoghalu, 2025). Assessing their sustainability is therefore important for developing transport policies that reflect the actual mobility needs of the Zaria metropolis.

Despite the growing role of tricycles in Nigerian cities, existing studies have largely examined their operational characteristics, user perceptions, safety, and socioeconomic implications, with comparatively limited attention to their sustainability as a multidimensional transport mode (Morakinyo et al., 2024; Abdullahi et al., 2024). Furthermore, existing evidence has been predominantly descriptive, providing limited empirical understanding of how socioeconomic and travel characteristics relate to the sustainability of tricycle use. This gap is particularly evident in Zaria, where city-specific evidence on the environmental, economic, and social dimensions of tricycle transportation remains limited.

Against this background, this study examines tricycle transportation as a sustainable urban mobility mode in Zaria metropolis, Nigeria. It investigates tricycle utilisation and evaluates its sustainability across environmental, economic, and social dimensions. The novelty lies in providing a multidimensional empirical assessment of tricycle sustainability, thereby moving beyond the predominantly operational and descriptive treatment of tricycle transportation in Nigerian urban transport research. By integrating these three sustainability dimensions within a single analytical framework, the study provides evidence for understanding the broader contribution and limitations of tricycles as a component of sustainable urban mobility in a rapidly growing Nigerian city.

1.1 Literature Review

1.1.1 Theoretical Framework: Paratransit Sustainability and Mobility Justice

This study is grounded in Banister's (2008) Sustainable Mobility Paradigm, which argues that transport sustainability cannot be reduced to a single technical criterion but must be pursued simultaneously across interrelated dimensions of accessibility, equity, safety, efficiency, and environmental quality, and that achieving this requires an integrated combination of technological change, land-use planning, regulation, and demand management rather than technology alone. The paradigm is operationalised here by examining tricycle sustainability across three of its core dimensions economic, social, and environmental which are the dimensions most directly assessable through operator and patron-perception data in a paratransit context of this kind. This tri-dimensional operationalisation is consistent with how sustainability has been assessed in comparable Nigerian paratransit studies (Morakinyo et al., 2024; Abdullahi et al., 2024).

The analysis is further informed by Sheller's (2018) Mobility Justice framework, which holds that transport systems distribute the benefits and burdens of movement unevenly across social groups, so that assessing a transport mode requires asking not only whether it is efficient but who is served, who is excluded, and who bears its risks and externalities.

1.1.2 Paratransit and Sustainable Mobility in African Cities

Sustainable urban transport is increasingly conceptualised as a multidimensional system that balances mobility efficiency with accessibility, affordability, safety, social inclusion and environmental protection. Rapid urbanisation in developing countries has increased travel demand faster than the expansion of transport infrastructure and formal public transport, resulting in congestion, inadequate accessibility, rising transport costs and environmental pressures (UN-Habitat, 2022; World Bank, 2022). Consequently, sustainable mobility requires integrated transport systems that combine efficiency, equity, affordability and lower environmental impacts (IPCC, 2022; Banister, 2008).

In African cities, informal and semi-formal paratransit has become the dominant response to gaps in formal transport provision, offering flexible and relatively affordable mobility, particularly in peripheral and underserved areas (World Bank, 2022). This is not merely a residual or transitional phenomenon: a systematic review of active travel and paratransit across African cities found that informal transport is a critical mobility option for poor peripheral residents undertaking long livelihood-generation journeys, and that it functions as an effective connector into areas left unserved by formal systems, even as many city authorities continue to treat it as illegitimate or incompatible with a 'modern' urban image (Dumedah et al., 2025; Randall et al., 2023). This tension between paratransit's demonstrated social function and its persistent institutional marginalisation is central to the contemporary formalisation debate. Foundational work on paratransit governance shows that reform strategies which attempt wholesale replacement of informal operators with formal bus or BRT systems frequently underperform, whereas approaches that engage, finance and gradually upgrade existing operator associations as in the AFTU minibus-financing scheme in Dakar can improve vehicle quality, working conditions and regulatory compliance without eliminating the livelihoods the sector sustains (Behrens et al., 2016; Diaou et al., 2024). Safety, emissions, traffic conflicts and weak enforcement nonetheless remain persistent concerns across these reform experiences, reinforcing calls for the deliberate integration of paratransit rather than its displacement within urban transport systems (ITF, 2023).

Motorised tricycles have consequently become an important component of Nigeria's urban mobility system, particularly for short- and medium-distance trips (Onokala & Olajide, 2020). Their small size and operational flexibility enable them to access local and poorly maintained roads and provide direct connections between residential areas, markets, educational institutions, and major transport corridors (Morakinyo et al., 2024; Abdullahi et al., 2024). Recent city-level evidence from Ilorin and Kano corroborates this pattern, showing that tricycles are widely valued for their employment-generating capacity and for extending accessibility to areas poorly served by conventional transport, while also revealing recurring concerns over vehicle condition, driver conduct, and weak regulatory oversight (Morakinyo et al., 2024; Abdullahi et al., 2024). Their sustainability, however, is context-dependent. While tricycles can improve accessibility and first-/last-mile connectivity, their proliferation may also generate safety risks, emissions, traffic conflicts and regulatory challenges. Consistent with the formalisation literature reviewed above, their contribution should therefore be evaluated through interconnected social, economic and environmental dimensions, rather than utilisation alone (Behrens et al., 2016).

1.1.3 Social Sustainability

From a social sustainability perspective, accessibility, affordability and safety are critical. Tricycles can extend mobility to peripheral and underserved communities and provide relatively direct trips where conventional buses have limited coverage (UN-Habitat, 2022). Their affordability can facilitate access to employment, education, and essential services, particularly for households with limited private-vehicle ownership. However, affordability may be affected by fuel prices, operating costs, and fare changes and fluctuations that are well documented in Nigeria's official transport fare series (NBS, 2023), while safety depends on driver behaviour, vehicle condition, road infrastructure, and enforcement (WHO, 2023). Viewed through a mobility-justice lens (Sheller, 2018), the social sustainability of tricycles depends not only on whether they provide accessible and affordable mobility, but on whether that accessibility is achieved without imposing disproportionate safety and welfare risks on the operators who supply it (Grieco, 2015).

1.1.4 Economic Sustainability

The economic dimension concerns both patron affordability and operator viability. Tricycles can provide employment and income opportunities while serving travel markets that may be unsuitable for larger public transport vehicles. Their flexibility can also improve service responsiveness and reduce access costs for short-distance journeys. However, fuel, maintenance, regulatory, and operating costs influence fares and operator profitability, creating a need to balance patron affordability with economic viability (World Bank, 2022). Operational efficiency, reflected in travel time, reliability, occupancy, and route coverage, further determines whether tricycle services contribute efficiently to urban mobility (ITF, 2023). Evidence from paratransit financing schemes elsewhere in West Africa suggests that formalised access to vehicle finance and structured operator associations can improve economic sustainability for operators without eroding the affordability that makes paratransit attractive to low-income patrons (Diaou et al., 2024).

1.1.5 Environmental Sustainability

The environmental dimension is particularly important because transport remains a major source of greenhouse-gas emissions and urban air pollution (IPCC, 2022). Although tricycles generally consume less fuel per vehicle than larger buses, their environmental performance depends on occupancy, vehicle condition, fuel efficiency, and whether they substitute higher-emission private transport or simply add motorised trips. Consequently, their environmental sustainability cannot be inferred from vehicle size alone. Emerging evidence on the electrification of two- and three-wheelers indicates that cleaner propulsion technologies, improved vehicle efficiency and effective integration with higher-capacity public transport could substantially enhance their environmental contribution, although uptake in Sub-Saharan Africa remains at an early stage compared with South and South-East Asia (IEA, 2024).

2 Materials and Methods

2.1 Study Area

Zaria is a major urban centre in Kaduna State, north-western Nigeria, located approximately between 11°03′–11°12′N and 7°39′–7°48′E (Figure 1). Comprising the adjoining urban areas of Zaria and Sabon Gari, it serves as an important educational, commercial, and administrative centre along the Kaduna–Kano transport corridor (Kaduna State Bureau of Statistics, 2024). The concentration of Ahmadu Bello University, other educational institutions, markets, employment centres, and expanding residential areas generates substantial intra-urban travel demand, particularly between Samaru, Sabon Gari, Zaria City, and surrounding communities (Abdullahi et al., 2026).

Zaria's transport system is predominantly road-based, with major routes connecting the metropolis to Kaduna, Kano, Jos, and neighbouring settlements, while local roads provide access to residential and activity areas. Limitations in formal public transport provision and continuing urban expansion have increased reliance on

flexible paratransit services (World Bank, 2022). The urban transport system comprises minibuses, taxis, motorcycles and motorised tricycles, with tricycles playing an important role in short- and medium-distance intra-urban mobility. Their relatively small size and operational flexibility enable them to access local streets and underserved neighbourhoods and provide direct connections to markets, educational institutions and major transport corridors (ITF, 2023).

The growing reliance on tricycles also presents concerns regarding affordability, safety, traffic conflicts, emissions, vehicle condition, and regulatory enforcement (WHO, 2023; IPCC, 2022; ITF, 2023). Zaria therefore provides a relevant setting for assessing tricycle transportation within a sustainable mobility framework because of its substantial travel demand, predominantly road-based transport system, expanding urban structure, and established reliance on paratransit. The study consequently examines the socioeconomic and travel characteristics associated with tricycle utilisation and their implications for sustainable urban mobility in Zaria metropolis.

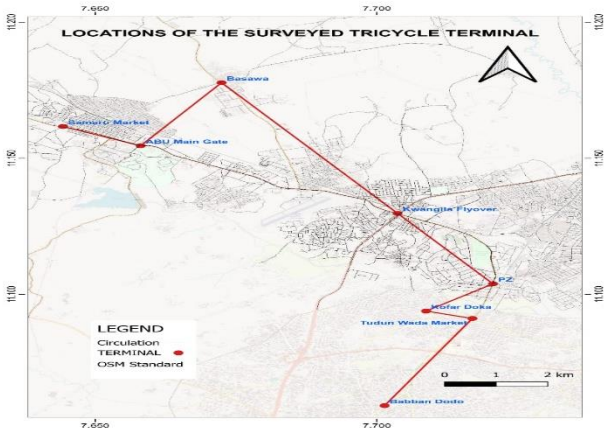

Figure 1: Location of the eight surveyed tricycle terminals within Zaria metropolis.

2.2 Data Sources

The study adopted a quantitative cross-sectional survey design to examine motorised tricycles as a sustainable urban transport mode in Zaria metropolis. Primary data were collected through structured questionnaires and field observations from two respondent groups: tricycle operators and patrons, while secondary data were obtained from relevant literature, institutional records, and government sources. This approach enabled assessment of both the supply-side characteristics of operators and the demand-side experiences of tricycle users using descriptive and inferential statistical techniques.

The study covered eight major tricycle terminals: Babban Dodo roundabout, Kofar Doka junction, Tudun Wada Market, PZ, Kwangila Flyover, Basawa Junction, ABU Main Gate, and Samaru Market (Table 1). The terminals were purposively selected based on operational importance, passenger activity, and spatial coverage. The study population comprised approximately 1,050 registered tricycle operators and an estimated 4,200 eligible patrons. Because patrons are transient and not formally registered, the patron population was defined as the estimated number of individual eligible tricycle patrons accessible during a seven-day reference period, rather than patron trips. The estimate was derived from terminal activity and passenger-flow records obtained from the Zaria Keke NAPEP Operators' Association and supplemented by field observations. During data collection, systematic intercept procedures and exclusion of repeat respondents ensured that individual patrons constituted the sampling units.

2.3 Data Collection (Sample Size and Technique)

Sample sizes for operators and passengers were determined separately using Yamane's (1967) simplified formula:

$$n = N / [1 + N(e)^2]$$

where n is the sample size, N is the population size, 1 is a constant, and e is the margin of error, set at 0.05 (95% confidence level). Substituting the operator population of 1,050 into the formula yields a sample size of approximately 290, which represents the number of questionnaires administered to tricycle operators. Substituting the estimated patron population of 4,200 yields a sample size of approximately 365, representing the number of questionnaires administered to patrons.

Table 1: Distribution of Questionnaires by Terminal

Terminal	Operators (n)	Operators (%)	Patrons (n)	Patrons (%)
Babban Dodo Roundabout	41	14.2	50	13.7
Kofar Doka Junction	39	13.5	45	12.3
Tudun Wada Market	36	12.5	45	12.3
PZ	33	11.4	40	11.0
Kwangila Flyover	30	10.4	40	11.0
Basawa Junction	30	10.4	40	11.0
ABU Main Gate	44	15.2	55	15.1
Samaru Market	36	12.4	50	13.6
Total	289	100.0	365	100.0

A multistage sampling procedure was adopted. The selected terminals were purposively identified based on operational importance, geographical coverage, and

passenger activity, after which respondents were sampled according to the relative activity of each terminal. Tricycle operators were selected systematically from available registration lists, while patrons were selected through convenience sampling at designated boarding and waiting points.

2.4 Data Processing

Completed questionnaires were screened for completeness and consistency, coded, and entered for analysis using IBM SPSS Statistics Version 26.0.

2.5 Data Analysis

Descriptive statistics, including frequencies, percentages, means and standard deviations, were used to summarise respondents' socioeconomic characteristics, travel behaviour and perceptions of tricycle sustainability. Spearman's rank-order correlation (r) was employed to examine the strength, direction, and significance of monotonic relationships between trip frequency and the three sustainability dimensions environmental, economic, and social perceptions as well as the interrelationships among the dimensions. The coefficient was calculated as:

$$r = 1 - (6\sum d_i^2) / [n(n^2 - 1)]$$

where d_i represents the difference between paired ranks and n is the number of observations. Values range from −1 to +1, with positive values indicating direct relationships and negative values indicating inverse relationships. The analysis specifically examined bivariate relationships between trip frequency (dependent variable) and each sustainability perception dimension (independent variables): environmental perception, economic perception, and social perception, in addition to the intercorrelations among the three sustainability dimensions. Statistical significance was assessed using two-tailed tests at the 0.05 and 0.01 probability levels. This non-parametric technique was particularly appropriate given the ordinal nature of the dependent variable (trip-frequency categories: rarely, monthly, weekly, daily) and the Likert-scale responses for sustainability perceptions, which cannot necessarily be assumed to satisfy the distributional requirements of Pearson's correlation.

Ordinal logistic regression (OLR) was employed to examine the influence of sustainability perceptions on trip frequency. The dependent variable was trip frequency, an ordinal variable with four categories (rarely = 1, monthly = 2, weekly = 3, daily = 4), while the independent variables were the three sustainability perception dimensions: environmental perception, economic perception, and social perception, measured on five-point Likert scales ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). OLR was selected over ordinary least squares because it does not require the dependent variable to be treated as continuous or its categories as equally spaced, making it the more statistically appropriate technique for an ordinal outcome. The model is specified as:

$$logit[P(Y \le j)] = ln\{P(Y \le j) / [1 - P(Y \le j)]\} = \theta_j - (\beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3)$$

where Y is trip frequency (1 = rarely, 2 = monthly, 3 = weekly, 4 = daily); j denotes the response category threshold; X_1, X_2 and X_3 are environmental, economic and social perception respectively; θ_j is the threshold (cut-point) for category j; and β_1–β_3 are the ordinal logit coefficients. The model was estimated using the cumulative logit link, and results were presented as unstandardised coefficients (B), Wald statistics, p-values, and odds ratios (Exp(B)). The odds ratio indicates the change in the odds of being in a higher trip-frequency category associated with a one-unit increase in each sustainability perception variable, holding other variables constant. The proportional-odds assumption was checked using the Test of Parallel Lines, and overall model fit was assessed using the Nagelkerke pseudo-R^2.

The combination of these two inferential techniques, Spearman's correlation for bivariate relationships and ordinal logistic regression for multivariate prediction, enabled the study to move beyond purely descriptive accounts towards a more comprehensive and explanatory understanding of the relationships between sustainability perceptions and trip frequency in Zaria metropolis.

3 Results

3.1 Demographic and Socio-Economic Characteristics of Tricycle Operators

Table 2 presents the demographic and socioeconomic characteristics of the 290 tricycle operators surveyed in Zaria metropolis. The operators were exclusively male (100%), confirming the strongly gendered nature of commercial tricycle operation in Nigeria, particularly in northern urban centres. The age distribution indicates a relatively young workforce, with 60.4% aged 25–39 years, while only 4.8% were aged 50 years and above. This profile suggests that tricycle operation is concentrated among economically active adults and serves as an important livelihood option within the urban informal economy.

In terms of marital status, 51.0% of operators were single, and 46.6% were married, while only 2.4% were divorced or separated. Educational attainment was predominantly at the secondary level: 49.7% had completed senior secondary education, while 68.0% had some form of formal education and only 11.0% possessed tertiary qualifications. Conversely, 30.3% had no formal

education. The relatively low level of tertiary attainment suggests that tricycle operation provides an accessible employment opportunity for individuals with limited qualifications and restricted access to formal-sector employment.

The operator profile, predominantly male, economically active, and largely educated to secondary level or below, reflects the socioeconomic characteristics commonly associated with informal paratransit employment in Nigerian cities (Morakinyo et al., 2024; Abdullahi et al., 2024). These characteristics are important for understanding the economic and social dimensions of tricycle transportation and its role in urban livelihoods.

Table 2: Demographic and Socio-Economic Characteristics of Tricycle Operators

Category	Frequency	Percent (%)
Gender		
Male	290	100.0
Female	0	0.0
Age (years)		
20–24	22	7.6
25–29	64	22.1
30–34	60	20.7
35–39	52	17.9
40–44	46	15.9
45–49	32	11.0
50–54	14	4.8
Marital Status		
Single	148	51.0
Married	135	46.6
Divorced	4	1.4
Separated	3	1.0
Education Level		
No formal education	88	30.3
Primary	12	4.1
Junior Secondary	14	4.8
Senior Secondary	144	49.7
Tertiary	32	11.0

Note: Education-level percentages are rounded to one decimal place and sum to 99.9% rather than 100.0% due to rounding.

3.2 Socio-Economic Characteristics of Tricycle Patrons

Table 3 presents the socioeconomic characteristics of the 365 tricycle patrons surveyed in Zaria metropolis. Males constituted 56.7% and females 43.3%, indicating that tricycles serve both genders, despite the male-dominated operator workforce. The patrons were predominantly young, with 73.1% aged 18–35 years, including 50.1% aged 18–25 years. This pattern reflects Zaria's strong educational function and the substantial travel demand generated by students and young adults.

Students constituted the largest occupational group (33.7%), followed by business owners (23.3%), self-employed persons (14.8%), civil servants (13.2%), unemployed persons (9.0%), and retirees (6.0%). This occupational diversity demonstrates the broad role of tricycles in serving educational, commercial, and employment-related trips. Income distribution further indicates that 60.0% of patrons earned below ₦100,000 monthly, comprising 31.8% below ₦50,000 and 28.2% between ₦50,000 and ₦99,999, while only 18.9% earned ₦150,000 or more.

The patron profile indicates that tricycles predominantly serve young, economically diverse, and low- to middle-income users, particularly students and informal-sector workers. This reinforces their importance for affordable and accessible urban mobility in Zaria, especially among populations that may have limited access to private vehicles or formal public transport (Morakinyo et al., 2024; World Bank, 2022).

Table 3: Socio-Economic Characteristics of Tricycle Patrons

Category	Frequency	Percent (%)
Gender		
Male	207	56.7
Female	158	43.3
Age Range (years)		
< 18	19	5.2
18–25	183	50.1
26–35	84	23.0
36–45	48	13.2
46–60	26	7.1
> 60	5	1.4
Occupation		
Student	123	33.7
Business Owner	85	23.3
Self-Employed	54	14.8
Civil Servant	48	13.2
Unemployed	33	9.0
Retired	22	6.0
Monthly Income (₦)		
Below 50,000	116	31.8
50,000–99,999	103	28.2
100,000–149,999	77	21.1
150,000–199,999	40	11.0
200,000 and above	29	7.9

3.3 Environmental Sustainability of Tricycle Operations in Zaria

Table 4 indicates a mixed perception of the environmental sustainability of tricycle operations in Zaria. The highest mean score (4.55) was recorded for petrol use, with patrons agreeing that tricycles predominantly rely on petrol, highlighting their continued dependence on fossil fuels and associated emissions (IPCC, 2022). Nevertheless, respondents perceived tricycles as relatively fuel-efficient (mean = 3.93) and lower-emission (mean = 3.95) than other modes, while 60.0% agreed that they help reduce congestion (mean = 3.56). These perceived advantages may reflect their smaller size and operational flexibility, although actual environmental benefits depend on occupancy levels, vehicle condition, and the modes they replace (ITF, 2023).

Conversely, environmental governance was perceived as weak. Only 37.7% agreed that effective emission regulations exist (mean = 3.07), while just 26.6% considered operational waste adequately managed (mean = 2.88). The lowest mean (2.85) concerned the absence of noise and air pollution, with 47.6% disagreeing, indicating recognition of tricycle-related environmental externalities. These findings suggest that although patrons perceive relative efficiency and congestion benefits, petrol dependence, emissions, noise, inadequate waste management, and weak regulatory enforcement constrain environmental sustainability. Improving performance therefore requires cleaner propulsion technologies, stronger emission controls, and improved waste-management practices, in line with the accelerating global shift toward electrified two- and three-wheelers (WHO, 2023; IEA, 2024).

Table 4: Environmental Sustainability of Tricycle Operations in Zaria

Environmental Factor	SA (%)	A (%)	U (%)	D (%)	SD (%)	Mean
Lower emissions than other modes	25.1	56.4	9.5	6.7	2.3	3.95
More fuel-efficient than other modes	28.4	46.9	15.2	7.0	2.5	3.93
Use of tricycles reduces traffic congestion	18.7	41.3	20.4	16.2	3.4	3.56
Most tricycles use petrol as fuel	64.2	29.1	4.8	1.9	0.0	4.55
Effective emission regulations exist	9.1	28.6	31.4	22.5	8.4	3.07
Waste from operations is properly managed	7.4	19.2	36.6	27.8	9.0	2.88
Tricycles do not generate noise/air pollution	10.3	24.2	17.9	35.6	12.0	2.85

SA = Strongly Agree, A = Agree, U = Undecided, D = Disagree, SD = Strongly Disagree.

3.4 Economic Sustainability of Tricycle Operations in Zaria

Table 5 shows generally positive perceptions of the economic sustainability of tricycle operations. Employment creation recorded the highest mean (4.23), with 90.5% of patrons agreeing that the sector generates employment directly for operators and indirectly through mechanics, spare-parts dealers, and related businesses. Similarly, 88.4% agreed that tricycles positively contribute to local businesses and the wider urban economy (mean = 4.08), highlighting their role in facilitating access to markets, employment, and commercial activities (Morakinyo et al., 2024).

Affordability also received strong support, with 74.1% agreeing that tricycles are more affordable than alternative modes (mean = 3.84), reinforcing their importance to low- and middle-income users, particularly students. However, perceptions of maintenance costs were comparatively moderate, with 60.8% agreement (mean = 3.66), suggesting that operating and maintenance expenses remain relevant economic constraints.

The lowest mean (3.51) concerned satisfaction with working conditions and income, with only 56.4% agreeing. The relatively high neutral (23.3%) and disagreement (20.3%) responses suggest concerns regarding income stability, long working hours, operating costs, safety, and regulatory conditions.Tricycles make a strong economic contribution through employment generation, local business support, and affordable mobility, but their long-term economic sustainability is constrained by operating costs and relatively uncertain operator welfare. These findings support policies that improve working conditions, access to finance, maintenance support, and regulatory protection while maintaining passenger affordability (ITF, 2023).

Table 5: Economic Sustainability of Tricycle Operations in Zaria

Economic Factor	SA (%)	A (%)	U (%)	D (%)	SD (%)	Mean
The tricycle industry creates employment for the people	42.8	47.7	5.8	2.7	1.0	4.23
Positive impact on local businesses and economy	36.7	51.7	6.9	3.3	1.4	4.08
Tricycles are more affordable than other modes	30.4	43.7	14.8	8.2	2.9	3.84
The cost of maintenance is cheaper than other modes	22.5	38.3	20.6	13.4	5.2	3.66
Working conditions and income from operation are satisfactory	18.6	37.8	23.3	14.5	5.8	3.51

SA = Strongly Agree, A = Agree, U = Undecided, D = Disagree, SD = Strongly Disagree.

3.5 Social Sustainability of Tricycle Operations in Zaria

Table 6 indicates generally positive perceptions of the social sustainability of tricycle operations, particularly regarding accessibility and connectivity. Accessibility to different demographic groups, including older persons and people with disabilities, recorded the highest mean (4.22), with 89.7% agreeing. Similarly, 81.9% agreed that tricycles improve connectivity to underserved areas (mean = 4.00), while 78.6% considered them reliable for different social groups (mean = 3.94). Their positive contribution to community life also received substantial support (78.1%; mean = 3.90), highlighting their role in promoting inclusive and spatially connected urban mobility (World Bank, 2022).

However, important weaknesses were identified in safety and regulatory compliance. Only 54.3% agreed that operators possess the required permits (mean = 3.48), while just 48.1% considered tricycles to have a good safety record (mean = 3.27) and 43.8% perceived safety regulations and enforcement as adequate (mean = 3.20). The lowest mean (2.68) concerned compliance with traffic rules, with 48.9% disagreeing that operators generally obey traffic regulations. These findings indicate concerns about risky driving, weak enforcement, and regulatory deficiencies, consistent with broader road-safety concerns surrounding three-wheeled transport (WHO, 2023).

Tricycles demonstrate strong social sustainability through accessibility, connectivity, reliability, and community integration, but these benefits are constrained by safety and regulatory shortcomings. Strengthening driver training, enforcement, vehicle standards, and regulatory monitoring is therefore essential for improving their social sustainability.

Table 6: Social Sustainability of Tricycle Operations in Zaria

Social Factor	SA (%)	A (%)	U (%)	D (%)	SD (%)	Mean
Accessible for different demographics, including the elderly and disabled	41.2	48.5	5.8	3.3	1.2	4.22
Provides better connectivity to underserved/remote areas	34.5	47.4	11.0	5.2	1.9	4.00
Reliable transport service for all classes of people	30.7	47.9	14.0	5.2	2.2	3.94
Presence positively affects community life and social interaction	29.6	48.5	14.8	5.5	1.6	3.90
Operators often possess the required permits to operate	18.6	35.7	24.1	15.6	6.0	3.48
Good safety record compared to other transport modes	14.8	33.3	26.8	18.1	7.0	3.27
Adequate safety regulations and enforcement measures exist	12.9	30.9	28.2	20.3	7.7	3.20
Operators do not disobey traffic rules/regulations	6.0	20.2	24.9	34.8	14.1	2.68

SA = Strongly Agree, A = Agree, U = Undecided, D = Disagree, SD = Strongly Disagree.

3.6 Operational Characteristics of Tricycle Operators in Zaria

Table 7 shows that tricycle operations in Zaria are characterised by moderate earnings, relatively long working hours, varying levels of experience, and substantial daily trip frequencies. Most operators (37.9%) earn ₦10,001–₦15,000 daily, followed by 26.6% earning ₦5,001–₦10,000 and 21.0% earning ₦15,001–₦20,000. However, these figures represent gross income and do not account for fuel, maintenance, remittances, and regulatory costs, which can substantially reduce net earnings (World Bank, 2022; Morakinyo et al., 2024).

Half of the operators (50.0%) work 8–10 hours daily, while 30.0% work more than 10 hours, indicating relatively demanding working conditions. Regarding experience, 32.1% had operated for more than six years, while 30.0% had 1–3 years of experience, suggesting that tricycle operation serves as both an established livelihood and an accessible entry point into informal employment.

Daily trip frequency was concentrated between 10 and 20 trips, with 39.0% completing 10–15 trips and 30.0% completing 16–20 trips. About 16.9% reported more than 20 trips daily. Higher trip frequencies may increase

earnings but also intensify fuel consumption, vehicle wear, and operator fatigue (ITF, 2023). The findings indicate that tricycle operations provide important livelihoods and mobility services but are associated with long working hours, variable earnings, and operational pressures, highlighting the need for policies that improve operator welfare, efficiency, and economic sustainability.

Table 7: Operational Characteristics of Tricycle Operators in Zaria

Category	Frequency	Percent (%)
Daily Income (₦)		
5,001–10,000	77	26.6
10,001–15,000	110	37.9
15,001–20,000	61	21.0
Above 20,000	42	14.5
Daily Operating Hours		
Less than 8 hours	58	20.0
8–10 hours	145	50.0
11–12 hours	61	21.0
Above 12 hours	26	9.0
Years of Operation		
Less than 1 year	32	11.0
1–3 years	87	30.0
4–6 years	78	26.9
Above 6 years	93	32.1
Daily Trip Frequency		
Less than 10 trips	41	14.1
10–15 trips	113	39.0
16–20 trips	87	30.0
Above 20 trips	49	16.9

3.7 Challenges Faced by Tricycle Operators in Zaria

Table 8 indicates that poor road conditions and high fuel costs are the most critical challenges confronting tricycle operators. Poor roads recorded the highest mean (4.34), with 84.8% of operators agreeing, while high fuel costs ranked second (mean = 4.13; 77.2% agreement). These challenges increase vehicle maintenance requirements, fuel expenditure, travel time, and overall operating costs, thereby constraining the economic sustainability of tricycle services (World Bank, 2022; NBS, 2023).

Governance and infrastructure challenges were also evident. Extortion by law enforcement agents recorded a mean of 3.66, with 60.0% agreement, while lack of designated parking spaces recorded a mean of 3.48 (54.1% agreement). Multiple levies were moderately reported (mean = 3.29). These findings indicate that weak enforcement practices, inadequate terminal/parking infrastructure, and multiple charges impose additional burdens on operators and contribute to operational inefficiency (ITF, 2023).

Conversely, traffic congestion (mean = 3.06), low passenger numbers (2.86), competition from other modes (2.71), and unfavourable government policies (2.48) were perceived as less severe challenges. The relatively low concern about passenger numbers and competition suggests that tricycles have established a stable market niche in Zaria, supported by demand from students, traders, and other urban residents.

The findings show that infrastructure deterioration and rising operating costs constitute the dominant constraints, followed by governance and parking deficiencies. Addressing these challenges through road rehabilitation, improved parking/terminal facilities, transparent enforcement, rationalised levies, and measures to improve fuel efficiency would strengthen the operational and economic sustainability of tricycle transport in Zaria.

Table 8: Challenges Faced by Tricycle Operators in Zaria

Challenge	SA (%)	A (%)	U (%)	D (%)	SD (%)	Mean
Poor road conditions	58.3	26.5	8.6	4.5	2.1	4.34
High fuel costs	51.0	26.2	11.7	7.6	3.5	4.13
Extortion from law enforcement agents	34.8	25.2	18.6	14.5	6.9	3.66
Lack of designated parking spaces	28.3	25.8	21.0	15.9	9.0	3.48
Multiple levies	22.8	23.1	25.2	17.9	11.0	3.29
Traffic congestion	17.9	21.1	24.1	22.1	14.8	3.06
Low passenger numbers	13.8	17.6	26.2	25.2	17.2	2.86
Competition from other transport modes	10.3	15.6	28.3	26.9	18.9	2.71
Unfavourable government policies	6.9	11.0	30.0	29.0	23.1	2.48

SA = Strongly Agree, A = Agree, U = Undecided, D = Disagree, SD = Strongly Disagree.

3.8 Spearman's Correlation Between Trip Frequency and Sustainability Perceptions

Table 9 shows significant positive relationships between trip frequency and all three sustainability dimensions among tricycle patrons. Economic perception recorded the strongest association ($r = 0.234$, $p < 0.01$), indicating that frequent users tend to perceive tricycles more positively in terms of affordability, employment generation, and contribution to local economic activities. Social perception also showed a significant positive relationship ($r = 0.198$, $p < 0.01$), suggesting that frequent users are more likely to recognise tricycles' contributions to accessibility, connectivity, and reliable mobility (ITF, 2023).

The weakest but still significant relationship occurred between trip frequency and environmental perception ($r = 0.167$, $p < 0.05$). This indicates that frequent users have somewhat more favourable environmental perceptions, although the relationship is weaker than those observed for economic and social dimensions. The result may reflect mixed environmental assessments of tricycles, which combine perceived fuel efficiency and lower emissions with concerns about petrol dependence, noise, and air pollution (IPCC, 2022; IEA, 2024).

The findings indicate that economic and social considerations are more strongly associated with frequent tricycle use than environmental perceptions, highlighting the importance of affordability, accessibility, and livelihood-related benefits in sustaining patronage in Zaria.

Table 9: Spearman's Correlation Between Trip Frequency and Sustainability Perceptions

Variables	Trip Frequency	Environmental Perception	Economic Perception	Social Perception
Trip Frequency	1.000			
Environmental Perception	0.167*	1.000		
Economic Perception	0.234**	0.345**	1.000	
Social Perception	0.198**	0.289**	0.412**	1.000
Overall Sustainability Perception	0.245**	0.789**	0.756**	0.723**

**p < 0.05, **p < 0.01 (two-tailed test).*

3.9 Ordinal Logistic Regression Predicting Trip Frequency from Sustainability Perceptions

An ordinal logistic regression (OLR) was estimated to examine the effect of sustainability perceptions on trip frequency, in place of the ordinary least-squares model reported in an earlier version of this analysis, given the ordinal nature of the dependent variable (rarely = 1, monthly = 2, weekly = 3, daily = 4). The proportional-odds assumption was satisfied, as confirmed by the Test of Parallel Lines ($\chi^2 = 6.234$, df = 6, $p = 0.398$), indicating that the relationship between each predictor and trip frequency was consistent across all response thresholds. The model explained a substantial share of the variance in trip frequency (Nagelkerke pseudo-$R^2 = 0.289$).

All three sustainability dimensions were significant, positive predictors of trip frequency (Table 10). Economic perception was the strongest predictor ($B = 0.456$, Wald = 24.567, $p < 0.001$; OR = 1.578), followed by social perception ($B = 0.345$, Wald = 15.724, $p < 0.001$; OR = 1.412) and environmental perception ($B = 0.234$, Wald = 6.912, $p < 0.01$; OR = 1.264). Each one-unit increase in economic, social, and environmental perception raised the odds of falling into a higher trip-frequency category by 57.8%, 41.2%, and 26.4%, respectively. The practical significance of this hierarchy is illustrated by predicted probabilities of

daily use, which rose from 21.0% to 54.8% across low to high economic perception, from 22.8% to 51.1% across low to high social perception, and from 24.5% to 45.4% across low to high environmental perception.

These results confirm that affordability remains the dominant consideration shaping tricycle-use frequency among Zaria's predominantly low- and middle-income patrons, consistent with broader evidence that cost is a fundamental determinant of paratransit patronage in African cities (World Bank, 2022; UN-Habitat, 2023). Social sustainability attributes accessibility, safety, and inclusiveness exert a secondary but still meaningful influence, while environmental perception, although the weakest predictor, remains statistically significant. This suggests that policies that safeguard affordability and strengthen safety and accessibility are likely to have the greatest effect on tricycle patronage, while awareness campaigns highlighting fuel-efficiency and congestion-reduction benefits can complement these interventions.

Table 10: Ordinal Logistic Regression Predicting Trip Frequency from Sustainability Perceptions

Predictor	B	Wald	df	p-value	Odds Ratio (Exp B)
Economic Perception	0.456	24.567	1	< 0.001	1.578
Social Perception	0.345	15.724	1	< 0.001	1.412
Environmental Perception	0.234	6.912	1	< 0.01	1.264

Dependent variable: Trip frequency (ordinal: 1 = rarely, 2 = monthly, 3 = weekly, 4 = daily). Link function: Cumulative logit. Nagelkerke pseudo $R^2 = 0.289$. Test of Parallel Lines: $\chi^2(6) = 6.234$, $p = 0.398$.

4 Conclusion

The study examined motorised tricycles as a sustainable urban transport mode in Zaria metropolis using data from 290 operators and 365 patrons. Findings show that tricycles are an important component of urban mobility, particularly for young, education-related, and low- to middle-income users. Users strongly perceived economic sustainability, especially employment creation (90.5%) and local economic contribution (88.4%), while social sustainability was reflected in accessibility (89.7%) and connectivity to underserved areas (81.9%). Environmental perceptions were comparatively mixed, with users recognising fuel efficiency and lower emissions but also identifying noise, air pollution and weak environmental regulation as concerns. Economic perception was the strongest sustainability predictor of trip frequency, while affordability, accessibility and other socioeconomic and travel characteristics also influenced utilisation. Operators identified poor road conditions (84.8%), high fuel costs (77.2%), extortion (60.0%), and inadequate parking (54.1%) as major challenges. In essence, tricycles provide essential mobility and employment in Zaria but require improved infrastructure, regulation, safety, and environmental management to enhance their long-term sustainability.

The findings translate into five prioritised, actionable recommendations, ordered from most to least urgent based on the severity of the challenge identified in Section 4.7 and the strength of the corresponding sustainability finding. Each recommendation names a responsible agency and an indicative timeframe; because this study collected perception data rather than engineering or financial data, the specific cost estimates and quantitative performance targets required for a full implementation plan are indicative only and should be confirmed through a dedicated costing and baseline-monitoring exercise, as noted for each item below.

i. Road Infrastructure Rehabilitation

The Kaduna State Ministry of Works, Housing and Transport, in coordination with Zaria Local Government, should prioritise rehabilitation of the road sections serving the Zaria City cluster of terminals (Babban Dodo, Kofar Doka, Tudun Wada Market, PZ) and their link to the Samaru/ABU cluster (Figure 1), within a short-term horizon (12–18 months). Indicative performance indicators: a measurable reduction in operator-reported road-related maintenance costs and in the proportion of operators rating road conditions as a severe challenge (both to be measured via a follow-up operator survey against the Table 8 baseline). Cost estimate: to be determined through a detailed engineering survey of the affected road lengths.

ii. Terminal and Parking Facilities

Zaria Local Government, in partnership with the Zaria Keke NAPEP Operators' Association, should develop designated terminal and parking infrastructure at the eight surveyed terminals, prioritising ABU Main Gate and Samaru Market given their highest questionnaire allocations (Table 1). Medium-term horizon (18–24 months). Indicative indicator: reduction in the share of operators citing lack of designated parking as a challenge, measured against the 54.1% baseline.

iii. Regulatory Reform, Licensing and Anti-Extortion Enforcement

The Kaduna State Transport Regulatory Authority (KASTRA), together with Zaria Local Government,

should strengthen transparent registration and licensing procedures, introduce a monitored grievance-reporting mechanism for extortion by law-enforcement personnel, and mandate periodic vehicle inspection and driver training in defensive driving and traffic regulations. Short- to medium-term horizon (12–24 months). Indicative indicators: increase in the share of operators reporting possession of required permits (baseline 54.3%, Table 6) and a measurable reduction in reported extortion incidents.

iv. Operator Finance and Working-Conditions Support

Kaduna State's relevant enterprise-support and microfinance agencies, working with financial institutions, should design accessible vehicle-ownership credit schemes modelled on operator-association financing arrangements shown to improve formalisation elsewhere in West Africa without eroding affordability (Diaou et al., 2024). Medium-term horizon (18–24 months). Indicative indicator: increase in operator agreement that working conditions and income are satisfactory, measured against the 56.4% baseline (Table 5).

v. Transition to Cleaner Propulsion Technologies

The Kaduna State Ministry of Environment and Natural Resources, with KASTRA, should pilot incentives for gradual transition from petrol-powered to electric or CNG tricycles and enforce proper management of used oil and tyres, drawing on the global acceleration in electric two-/three-wheeler uptake (IEA, 2024). Long-term horizon (24–36 months), given the capital cost of fleet transition. Indicative indicator: increase in operator/patron agreement that operational waste is properly managed and that regulations on emissions are effective, measured against the Table 4 baseline.

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