Gender, Mobility, and Energy Poverty at the Informal Transport Frontier: Female Patronage of Okada and Keke NAPEP in Ibadan and Enugu

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Abstract:

Transport and energy poverty are structurally intertwined in peri-urban sub-Saharan Africa, yet the gendered dimensions of this intersection are almost entirely absent from the peer-reviewed literature. Women in Nigerian peri-urban settlements face a compound mobility burden: they disproportionately undertake care-related trips across fragmented transport networks, allocate higher shares of household budgets to transport (relative to income) than men, and experience informal transport, specifically okada (commercial motorcycles) and keke NAPEP (auto rickshaws), through distinctive safety, affordability, and social norm constraints that are invisible in gender disaggregated modal share data alone. This study develops and applies an intersectional gender energy mobility framework to analyze the determinants and consequences of female patronage of okada and keke NAPEP in peri urban Ibadan (Oyo State) and Enugu (Enugu State), Nigeria. Data were derived from a mixed-methods household survey of 960 female- and male-headed households (480 per city), supplemented by 48 in-depth interviews with female commuters and 12 focus group discussions with female transport users and motorcycle operators. A probit model of mode choice (okada vs. keke NAPEP vs. walking/other) is estimated on the survey data, and TEES indicator, a novel metric that captures the share of household energy budget absorbed by motorized transport, is used to measure energy poverty exposure. The key findings are as follows: Women are significantly less likely than men to use okada (probit AME = −0.218; $p < 0.001$), primarily due to safety concerns (cited by 79.4% of female non-users) and social norm constraints (cited by 63.2% in Enugu vs. 41.8% in Ibadan). Women who rely exclusively on walking absorb the highest non-monetary mobility burden: they spend a mean of 94.3 min per day on on-foot trips, representing significant time and energy poverty. Female keke NAPEP users face a TEES of 28.4% of household income, nearly double the 15.2% faced by male okada users, constituting transport energy poverty by the 20% threshold widely used in fuel poverty research. Intersectional analysis reveals that widowed, low-income, uneducated women in Enugu face the most severe energy poverty due to compound mobility. These findings call for a gender-responsive informal transport policy that integrates safety certification, female-friendly aeke design, and fare subsidy mechanisms within a broader energy poverty analytical framework.

Keywords— Keywords: gender; mobility; energy poverty; okada; aeke NAPEP; Nigeria; probit; intersectionality; transport energy expenditure; informal transport; peri-urban

I. Introduction

The literature on global energy poverty has overwhelmingly focused on the household energy dimension of deprivation, specifically access to clean cooking fuels, reliable electricity, and heating, largely overlooking the energy embedded in mobility. Yet transport is intrinsically an energy service: the ability to move across space to access livelihoods, healthcare, education, and markets depends on the availability of mechanical energy, and where mechanical energy is unavailable, inaccessible, or unaffordable, it is substituted by human embodied energy, alking, carrying, pulling, at significant time and physical cost. In sub-Saharan African peri-urban settlements, where formal transit networks are sparse and informal motorized transport constitutes the primary mobility option, transport energy poverty is a daily reality for millions of women. Nigeria's informal transport sector, dominated by okada (commercial motorcycles) and aeke NAPEP (auto rickshaws, also known as tricycles), provides the connective tissue of peri-urban mobility. These modes serve communities that formal buses and rail cannot reach, offering door-to-door service at relatively low per-trip fares. Their energy inputs are entirely based on fossil fuels (petrol for Okada, CNG or petrol for Keke), and their fares reflect real-time fuel price volatility, creating a direct transmission mechanism from energy market shocks to household transport budgets. Nigeria's May 2023 fuel subsidy removal, which increased petrol prices by over 200%, provides a sharp real-world illustration of this transmission: Okada and Keke fares in Ibadan and Enugu increased by

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60%–90% within weeks of the subsidy removal, disproportionately affecting low-income households for whom transport constitutes a larger budget share.

Gender shapes the experience of this energy mobility system in multiple intersecting ways. First, women in Nigerian peri-urban settings disproportionately undertake care-related trips, school runs, healthcare visits, and market provisioning, which are less amenable to batching and optimization than commuting trips, resulting in higher trip frequencies per day (Peters, 2001; Uteng & Cresswell, 2008). Second, women face distinctive safety and social norm constraints on informal transport use: riding Okada as a female passenger is associated with social stigma in many Nigerian communities, particularly in contexts where physical proximity to male operators is seen as immodest (Hanson, 2010; Olawole, 2019). Third, women's lower average incomes mean that equal fares translate into unequal budget burdens, a point recognized in the literature on fare poverty (Lucas, 2011) but rarely applied to informal transport in Nigerian contexts. Despite the evident importance of these intersections, almost no peer-reviewed work has been published that addresses gendered okada and aeke NAPEP use through an energy poverty lens. The literature on transport geography has examined gender and mobility in African cities (Mutua et al., 2020; Olawole, 2019; Peters, 2001) but does not deploy energy poverty frameworks. The literature on energy poverty has increasingly acknowledged gender (Matinga & Annecke, 2013; Sovacool et al., 2012) but has rarely engaged with the transport sector or with informal mobility. This study bridges these literature through an intersectional gender energy mobility framework, making three primary contributions.

First, we introduce the TEES indicator as a novel metric for measuring transport energy poverty among informal mode users, analogous to the energy expenditure share used in fuel poverty measurement but applied to motorized transport costs as a share of household energy budgets and income. Second, a probit model of mode choice that isolates gender effects on okada and aeke NAPEP use, controlling for trip purpose, income, distance, and social norm proxies. Third, we deploy intersectional analysis, jointly examining gender, marital status, income, and location, to identify the subgroups most deprived of energy mobility and the policy levers most likely to address their compound disadvantage.

The paper is structured as follows: Section 2 presents a review of the theoretical and empirical literature. Section 3 describes the study context, data, and mixed-methods design. Section 4 presents the analytical framework, TEES indicator, and probit specification. Section 5 reports the results. Section 6 discusses the policy implications. Section 7 concludes.

II. Theoretical Framework and Literature Review

A. Energy Poverty: Expanding the Transport Framework

Energy poverty is conventionally defined with reference to the household energy domain: the inability to access sufficient, affordable, and clean energy services for basic household needs (Bouzarovski & Petrova, 2015; Sovacool, 2012). The multidimensional energy poverty index (MEPI; Nussbaumer et al., 2012) and the SDG7 framework (IEA/IRENA, 2023) measure access to electricity, clean cooking, and minimum energy consumption thresholds. Notably, the energy embedded in mobility is absent from all dominant frameworks. The petrol, CNG or electricity required to power the motorized transport on which billions of people depend for access to productive and reproductive activities.

Fuel poverty literature offers a partial bridge: the 10% rule (Boardman, 1991) and its successor metrics define fuel poverty as the condition in which a household must spend more than a threshold share of income (typically 10% in the UK; 20% in some low- and middle-income countries (LMIC) applications) to maintain adequate warmth or energy services. Scholars of transport energy expenditure (Lucas et al., 2016; Berry et al., 2016) have argued for extending this logic to motorized transport, defining transport energy poverty as the condition in which households must spend an unaffordable share of income on transport energy services or, alternatively, must forgo transport entirely, incurring access poverty. Our TEES indicator operationalizes the first definition: the share of household income (and total household energy expenditure) absorbed by MTCs.

The literature on mobility as capability (Nussbaum, 2000; Sen, 1999; Hanson, 2010) provides a normative foundation for treating transport access as a dimension of human development deprivation. When women are denied affordable, safe transport options, whether by cost, social norm, physical design, or safety failure, their ability to access livelihood, healthcare, and education is directly constrained. In a peri-urban Nigerian context where the nearest secondary school, antenatal clinic, or market may be 3–8 km away over poor road surfaces, transport capability is not a luxury: it is a precondition for many other dimensions of human development.

B. Intersectionality and Gendered Mobility in African Cities

Intersectionality, the theoretical framework that recognizes that gender does not operate in isolation but is constituted through and structured by its intersection with race, class, marital status, location and other social categories (Crenshaw, 1989), has been applied to urban mobility analysis, primarily in the context of the Global North (Pereira et al., 2017). Its application to informal transport in Africa is limited. Uteng and Cresswell (2008) provide the foundational conceptual treatment of gendered mobilities, arguing that mobility is not simply a function of income or physical access but is constituted through social norms, embodied practices, and power relations that position women as more constrained in both their movement and transport options.

In the Nigerian context, Olawole (2019) examined gendered travel behavior in Osun State, documenting that women make more frequent but shorter trips, primarily for care purposes, and face greater safety concerns on commercial motorcycle transport. Peters (2001) provided an early evidence that rural

African women carry disproportionate transport burdens in terms of time and physical load. Hanson (2010) theorizes the spatial embeddedness of gender inequality in transport, arguing that women's mobility constraints reflect and reproduce their subordinate position in social and economic life. None of these studies, however, integrates an energy poverty measurement framework or deploys formal econometric mode choice analysis alongside qualitative intersectional analysis.

In Nigeria, social norm constraints on female okada use are particularly salient in the Igbo-speaking south-easternern (encompassing Enugu), where norms of female modesty and the physical intimacy of motorcycle riding intersect with patriarchal household governance structures to constrain women's independent use of okada. The Yoruba-speaking south-western region (encompassing Ibadan) exhibits somewhat more flexible norms on female motorcycle patronage, although safety concerns are universal. This contrast between cities provides a natural comparative framework for examining how social norms modulate gender transport energy relationships independently of income and infrastructure differences.

C. Mode choice modeling and gender

The standard econometric approach in transport demand analysis is discrete choice modeling of transport mode, most commonly logit or probit estimation on stated or revealed preference data (Ben-Akiva & Lerman, 1985; Train, 2009). Gender is consistently included as a control variable in mode choice models, and a robust finding across global contexts is that women are less likely to use two-wheeled motorized modes (motorcycles, mopeds, cycle rickshaws) and more likely to use public transit or walking (Ng & Acker, 2018; Pew Research Center, 2018). The mechanisms underlying this difference, such as safety fears, social norms, trip purpose composition, and income, are rarely disentangled. Our study contributes to disentangling these mechanisms through a probit specification that controls each potential pathway separately and through qualitative interviews that illuminate the subjective experience behind the statistical patterns.

In the Nigerian informal transport context, mode choice is constrained in ways that standard mode choice theory does not capture well: riders do not have a full menu of alternatives, schedules do not exist, and safety is a latent and multidimensional attribute that affects mode utility differently across gender, age, and trip purpose. We address these limitations through the mixed methods design, which uses qualitative data to interpret probit residuals and illuminate the social mechanisms that cannot be recovered by pure econometric models.

III. STUDY CONTEXT, DATA, AND METHODS

A. Study Sites: Peri Urban Ibadan and Enugu

Two peri-urban study areas were selected to provide geographic, cultural, and economic contrasts. In Ibadan (Oyo State, south-western Nigeria), the peri-urban study zone comprises the rapidly expanding residential districts of Akinyele, Ona-Ara, and Egbeda LGAs. These areas are characterized by dense informal housing, limited BRT coverage, heavy okada and keke reliance, a predominantly Yoruba-speaking population, and a rapidly growing female-headed household prevalence (estimated at 22.4% in the 2023 household listing). In Enugu (Enugu State, south-eastern Nigeria), the peri-urban zone covers Enugu North, Igbo-Eze North, and Udi LGAs, with similar physical characteristics but predominantly an Igbo-speaking population with distinct social norms around female mobility and a somewhat higher prevalence of keke NAPEP than okada (reflecting in part historical attitudes toward female motorcycle patronage).

The two cities were selected because they represent the two largest urban agglomerations in southwestern and southeastern Nigeria, respectively. They differ meaningfully on the social norm dimension most theoretically relevant to gendered okada use, and they both fall outside the Lagos State okada ban zone, ensuring that the modal alternatives under study remain legally available in the study area. Based on the 2023 inter-census estimates, the study zones encompass a peri-urban population of approximately 2.1 million (Ibadan peri-urban) and 840,000 (Enugu peri-urban).

B. Sampling and Survey Design

A stratified multistage sampling design was employed. In each city, enumeration areas (EAs) from the 2023 National Population Commission listing were stratified by female-headed household prevalence (high/medium/low), and five EAs per stratum (15 total per city) were selected by probability proportional to size sampling. Within each EA, 32 households were randomly selected using the random walk method. Within each selected household, the primary survey respondent was an adult woman (aged 18+) responsible for most household travel decisions, identified in a brief household listing conducted before the main interview. In the absence of an adult woman, the next sampled household was selected as a replacement. This design yielded 480 female primary respondents per city (960 total) and, for the mode choice probit, an additional male respondent module was administered to a 50% random subsample of households (n = 240 per city, 480 total males) for gender comparison.

Fieldwork was conducted from February to April 2024 by teams of trained female enumerators (to minimize social desirability bias in reporting of transport experiences, safety incidents, and social norm constraints). Interviews were conducted in Yoruba (Ibadan) and Igbo (Enugu) using back-translated instruments. A 10-day pilot (n = 40) was used to refine the wording and response categories of the questions. Overall response rate: 94.8% (Ibadan) and 93.2% (Enugu). Ethical approval: Ethics Committee of the University of Ibadan, Ref: UI/EC/24/0062

C. Qualitative component

The quantitative survey was complemented by 48 semi-structured in-depth interviews (24 per city) with female commuters purposively selected to represent the full range of transport mode use, income levels, marital statuses, and trip

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purposes documented in the survey. Interviews explored the following: (i) the subjective experience of okada and keke NAPEP use, including safety incidents, social commentary received, and personal comfort levels; (ii) the energy budget decision-making process, including how women negotiate transport costs against household food, cooking, and electricity budgets; and (iii) the impact of the 2023 fuel subsidy removal on transport decisions and alternative coping strategies. Twelve FGDs, six per city, each with 8–10 participants, supplemented the interviews with peer norm elicitation on social acceptability of female okada use.

Qualitative data were analyzed using reflexive thematic analysis (Braun & Clarke, 2006). NVivo 14 was used to code transcripts against a theory-driven initial codebook derived from the intersectionality and energy poverty frameworks, supplemented by inductive codes emerging from the data. Key themes were integrated with quantitative findings through a convergent mixed methods synthesis, in which qualitative narratives were used to interpret and contextualize probit results and TEES distributions.

D. Key variables and measurement

Table 1 summarizes the key survey variables. Mode choice is operationalized as the primary mode used for the respondent's most recent non-home trip (okada / keke NAPEP / walking only or other non-motorized), reflecting revealed behavior rather than stated preference. The binary probit models estimate (i) okada use vs. aeke or other and (ii) motorized mode use vs. walking only. The collected trip characteristics include distance, purpose (work/care/market/health/social), time of day, and whether the respondent made the trip alone. Transport energy expenditure is the monthly sum of okada and keke fares paid by the household, expressed as a share of total household monthly income (TEES_income) and the sum of transport fares, cooking fuel costs, and electricity expenditure (TEES_energy) as a share of total monthly household energy expenditure. The social norm constraint was measured using a three-item Likert scale (alpha = 0.82) assessing the perceived community disapproval of female okada use, normalized to [0,1].

Table 1. Key Variables: Definitions and Statistics

Variable	Definition and measurement	Female Mean (SD)	Male Mean (SD)	p-value (diff.)
Okada use (binary)	1 if the primary mode on the last trip = Okada	0.21 (0.41)	0.58 (0.49)	< 0.001***
Keke NAPEP use (binary)	1 if the primary mode = aeke NAPEP	0.44 (0.50)	0.28 (0.45)	< 0.001***
Walking-only (binary)	1 if primary mode = walking or NMT	0.35 (0.48)	0.14 (0.35)	< 0.001***
Monthly income (₦, log)	Log of self-reported monthly net income	10.41 (0.82)	10.88 (0.74)	< 0.001***
TEES_income (%)	Transport fares / monthly income × 100	24.8 (11.4)	15.2 (8.6)	< 0.001***
TEES_energy (%)	Transport fares / total energy expenditure × 100	41.3 (14.8)	28.6 (11.2)	< 0.001***
Social norm constraint (0–1)	3-item Likert, perceived community disapproval of female okada users	0.58 (0.24)	0.32 (0.21)	< 0.001***
Trip time burden (min/day)	Total number of daily minutes on all travel (recall)	94.3 (38.6)	62.8 (29.4)	< 0.001***
Care trip share (%)	% of weekly trips for care	48.3 (19.2)	12.7 (10.8)	< 0.001***
Secondary education (binary)	1 If the respondent completed secondary school	0.54 (0.50)	0.63 (0.48)	0.004**
Enugu City (binary)	1 if the respondent is in the Enugu study zone	0.50	0.50	, (balanced)

*Note: Female n = 960; male n = 480. *** p < 0.001; ** p < 0.01. TEES = transport energy expenditure share. NMT = non-motorized transport. Monthly income in Nigerian Naira (₦). All differences were tested using the two-sample t-test (continuous) or chi-square test (binary).*

IV. Analytical Framework

A. Transport energy expenditure share (TEES)

The TEES indicator is defined at the household level as follows:

$$\textbf{TEES\_income\_h} = (\Sigma_t F_{ht}) / Y_h \times 100$$

$$\textbf{TEES\_energy\_h} = (\Sigma_t F_{ht}) / (\Sigma_t F_{ht} + C_h + E_h) \times 100$$

where F_ht is the monthly expenditure on informal motorized transport fares (okada + keke NAPEP) for household h across all trips t, Y_h is monthly household net income, C_h is monthly cooking fuel expenditure (firewood, kerosene, LPG) and E_h is monthly electricity expenditure (grid tariff + generator fuel, where applicable). TEES_income captures the income burden of transport; TEES_energy captures the share of transport in the total household energy budget, contextualizing transport within the full energy portfolio of the household. A household is classified as experiencing transport energy poverty (TEP) if TEES_income ≥ 20%, analogous to the 20% fuel poverty threshold applied in LMIC energy studies (Berry et al., 2016) , or if TEES_income ≥ 10% and total household income falls below the national poverty line.

The TEES framework is novel in the Nigerian transport energy literature and provides a unified metric that links the literature on transport demand, which typically treats fares as a cost of access, with the literature on energy poverty, which aggregates household energy expenditures across domains. By expressing transport fares as a share of the total energy budget, TEES_energy reveals the structural competition between transport access and other energy services (e.g., cooking and lighting): households that spend more on transport fares necessarily spend less on cleaner cooking fuels or more reliable electricity, creating cross-domain energy poverty feedbacks.

B. Probit Model of the Mode of Choice

The binary probit model, conditional on a vector of individual, household, trip, and contextual covariates, estimates the probability that respondent i chooses okada as their primary mode:

$$\textbf{P(OKADA\_i = 1)} = \Phi(\alpha + \beta_1 \cdot \textbf{FEMALE\_i} + \beta_2 \cdot \textbf{INC\_i} + \beta_3 \cdot \textbf{NORM\_i} + \beta_4 \cdot \textbf{DIST\_i} + \beta_5 \cdot \textbf{CARE\_i} + \beta_6 \cdot \textbf{ENUGU\_i} + \beta_7 \cdot \textbf{FEMALE\_i} \times \textbf{NORM\_i} + \beta_8 \cdot \textbf{FEMALE\_i} \times \textbf{ENUGU\_i} + \varepsilon_i)$$

where Φ(·) is the standard normal CDF, FEMALE is a binary gender indicator, INC is the log monthly income, NORM is the social norm constraint scale [0 to 1], DIST is the self-reported one-way trip distance (km), CARE is the share of weekly trips with a care purpose, and ENUGU is a city indicator. The interaction FEMALE × NORM tests whether social norm constraints differentially affect women's okada use beyond the main effects; the interaction FEMALE × ENUGU tests whether the gender gap in okada use is larger in Enugu than in Ibadan, consistent with the social norm hypothesis. Average marginal effects (AME) are reported throughout and are computed using the delta method. A parallel probit model estimates walking only vs. motorized mode use. All probit models cluster standard errors at the EA level (30 EAs per city, total 60).

C. Intersectional subgroup analysis

Intersectional analysis follows McCall (2005) and Bauer (2014), constructing a typology of respondent subgroups defined by the cross tabulation of gender, marital status (partnered or widowed or separated / single), income tercile (low / medium / high), and city (Ibadan / Enugu). The mean TEES_income, Okada use probability, and trip time burden are computed within each cell of the typology. Multivariate decomposition (Blinder-Oaxaca, as extended by Fairlie (2005) for nonlinear models) is used to apportion the gender gap in okada use between the explained (differences in income, trip distance, and education) and unexplained (differences in the returns to these characteristics, attributed to social norms and unmeasured discrimination) components.

V. Results

A. Descriptive patterns of modal use and energy expenditure

Table 1 reveals sharp gender differences in modal use. Only 21.0% of the female respondents used okada as their primary mode on their most recent trip, compared with 58.0% of the male respondents, a gap of 37 percentage points. Women are substantially more likely than men to use aeke NAPEP (44.0% vs. 28.0%) and walk (35.0% vs. 14.0%). The gender gap in okada use is wider in Enugu (female okada use: 14.2%; male: 61.3%) than in Ibadan (female: 28.1%; male: 54.6%), consistent with the stronger social norm constraints anticipated in the Igbo SE region. The mean daily trip time burden is 94.3 min for women vs. 62.8 min for men, a gap of 31.5 min, concentrated among walking only users (who record a mean of 128.4 min/day travel time) and reflecting the care trip intensity of women's travel patterns.

The TEES patterns are striking. Among female motorized mode users, the mean TEES_income is 24.8%, already above the 20% transport energy poverty threshold, compared with 15.2% for male users ($p < 0.001$). Within the female sample, walking-only users might appear to have zero TEES, but this misses the time-energy poverty dimension: walking-only female users spend a mean of 128.4 min per day on foot travel, equivalent to approximately 2.8 h of embodied energy expenditure per day. Expressed as opportunity cost at the minimum wage, this represents a daily implicit income loss of approximately ₦1,820, a non-monetary component of

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transport energy poverty that is disproportionately borne by women and TEES_income does not capture.

B. Probit Results: Determinants of the Use of Okada

Table 2 presents the probit average marginal effects for the probability of okada use (vs. keke or other) and walking-only use (vs. any motorized mode). The gender effect is large and highly significant: being female reduces the probability of okada use by 21.8% (AME = −0.218; p < 0.001), controlling for income, trip distance, care trip share, social norm constraint, and city. This is the largest single predictor of okada nonuse in the model, exceeding the income effect in magnitude.

Table 2. Average Probit Marginal Effects: Determinants of Okada Use and Walking

Variable	AME: Okada	SE	p-value	AME: Walking	SE	p-value
Female (1=Yes)	**−0.218*** **	0.034	< 0.001	**+0.146*** **	0.028	< 0.001
Log monthly income	+0.084***	0.022	< 0.001	−0.112***	0.019	< 0.001
Social norm constraint (0–1)	−0.141***	0.048	0.003	+0.063*	0.038	0.097
Trip distance (km)	+0.038***	0.009	< 0.001	−0.044***	0.010	< 0.001
Care trip share (%)	−0.092***	0.028	0.001	+0.081***	0.024	0.001
Enugu (vs. Ibadan)	−0.074**	0.031	0.018	+0.048*	0.026	0.064
Female × Norm constraint (interaction)	−0.098**	0.041	0.017	+0.071*	0.036	0.048
Female × Enugu (interaction)	−0.084**	0.038	0.028	+0.068*	0.034	0.046
Secondary education (1=Yes)	+0.032	0.026	0.218 (ns)	−0.041*	0.022	0.062

*Note: *** p < 0.001; ** p < 0.01; * p < 0.10; ns = not significant. Average marginal effects of binary probit. Standard errors were clustered at the EA level (60 EAs). N = 1,440. Pseudo-R^2 (McFadden): Okada model = 0.31; walking model = 0.28. Outcome for Okada model: 1 = Okada primary mode; 0 = Keke or other. Outcome for the walking model: 1 = walking only; 0 = any motorized mode.*

The social norm constraint has a significant independent negative effect on okada use (AME = −0.141; p = 0.003), and the Female × Norm interaction (AME = −0.098; p = 0.017) confirms that even after controlling for income and distance, social norm constraints are significantly more binding for women than for men. The Female × Enugu interaction (AME = −0.084; p = 0.028) demonstrates that the female penalty in okada use is significantly larger in Enugu than in Ibadan, consistent with the hypothesized role of stronger Igbo social norm constraints on female motorcycle patronage. Together, the main female effect and the Female × Norm and Female × Enugu interactions imply that in Enugu, women with high norm constraints face a total gender norm penalty on okada use of approximately −0.218 − 0.084 − 0.098(×0.72) = −0.373 percentage points, making them more than 37 percentage points less likely to use okada than otherwise comparable men in Ibadan.

Income exerts a significant positive effect on okada use (AME = +0.084; p < 0.001) and an equally significant negative effect on walking (AME = −0.112; p < 0.001), confirming that access to motorized modes is enabled by economic resources. Higher care trip shares reduce okada use (AME = −0.092; p = 0.001) and increase walking (AME = +0.081; p = 0.001), consistent with the hypothesis that care trips, which often involve accompanying children or the elderly, are perceived as incompatible with motorcycle transport. Blinder-Oaxaca decomposition (Supplementary Table S1) found that 58.2% of the gender gap in okada use was unexplained by observable income, distance, and education differences, attributable to social norms and other unmeasured gender constraints, confirming that the gender gap is not simply a proxy for income disadvantage.

C. Poverty in Transport Energy by Gender and Intersectional Subgroup

Table 3 presents TEES_income by intersectional subgroup. Overall, 54.8% of female respondents and 22.3% of male respondents were classified as transport energy poor (TEES_income ≥ 20%). Among women, transport energy poverty is most severe for widowed low-income women in Enugu (mean TEES_income = 38.6%), who face the compound burden of sole earner status, restricted okada access, higher keke dependence, and fare increase after subsidy removal. Female aeke users in Enugu's lowest income tercile report TEES_income of 34.2%, nearly 2.3 times the 15.2% recorded for male okada users in the same income tercile.

Table 3. Transport energy expenditure share (TEES_income) by intersectional subgroup (%)

Subgroup	Ibadan (F)	Ibadan (M)	Enugu (F)	Enugu (M)	TEP prevalence (F, %)
Low income, partnered	26.8	14.2	31.4	15.6	**68.4%**
Low income, widowed,	29.2	16.8	38.6	18.4	**81.3%**

or separated					
Low income, single	24.6	13.8	29.8	14.2	**61.2%**
Medium income, partnered	18.4	12.6	22.8	13.2	42.8%
Medium income, widowed, or separated	21.4	13.4	26.2	14.1	54.6%
High income, partnered	12.8	10.4	15.4	11.2	18.2%
High income, widowed, or separated	14.2	11.8	18.6	12.4	26.4%
Full sample mean	**21.4**	**13.2**	**28.4**	**16.8**	**54.8%**

Note: TEES_income = transport fares as a percentage of monthly household income. TEP = transport energy poverty (TEES_income ≥ 20%). F = female respondents; M = male respondents. Ibadan and Enugu n = 480 females and 240 males

The city effect is pervasive: Enugu women record consistently higher TEES than Ibadan women within every marital status income cell, primarily because Enugu's more restrictive social norms constrain women to keke NAPEP, which has higher per kilometer fares than okada, rather than the cheaper motorcycle mode. This represents a social norm-induced fare premium that compounds with income disadvantage: being both low income and Igbo in the context of this study effectively mandates the use of the more expensive transport mode, creating negative feedback between norm-enforced mode restriction and transport energy poverty.

TEES energy presents an even more concerning picture. Women allocate a mean of 41.3% of their total household energy budget to transport fares, compared with 28.6% for men (Table 1). For low-income female respondents, this share reaches 51.4%, implying that transport fares crowd out more than half of the household energy budget, leaving very limited allocable income for cooking fuel or electricity. Qualitative interviews illuminate the coping strategies employed by women:

When the transport cost increases, I stop using gas and go back to firewood. I cannot cut school runs for the children, so I cut cooking fuel and electricity. We use candles some nights now. , Female respondent, Enugu, low income, widowed, Wave 2 interview.

This narrative, replicated across 31 of 48 interviews in various forms, illustrates the energy budget competition that TEES_energy statistically captures: transport energy expenditure displaces cooking and electricity expenditure, creating a compound multi-domain energy poverty outcome that is invisible to frameworks measuring energy domains separately.

Qualitative Insights into Safety, Norms, and Agency

Thematic analysis of the 48 in-depth interviews and 12 FGDs identified four recurrent themes that contextualize and extend the quantitative findings.

First, safety as embodied vulnerability: Women consistently articulated safety concerns about okada not only in terms of accident risk but also as embodied vulnerability, including physical proximity to male operators, the impossibility of maintaining modest dress while mounted, and exposure to harassment during stops and negotiations. As one Ibadan respondent noted: 'The accident I fear, yes, but also the touching, the looking. With aeke, I sit inside.' It feels more like I am a person, not cargo.' This articulation connects physical safety with social dignity in a way that the probit model's social norm scale only imperfectly captures.

Second, temporal poverty and the care penalty: women with young children articulated the time cost of walking in concrete terms, often connecting it to lost market trading time, late school arrivals, and foregone income. The temporal poverty dimension, in which women spend 94.3 minutes daily on travel, is a direct embodied energy cost that connects transport inaccessibility to the literature on women in developing economies (Blackden & Wodon, 2006).

Third, fare shock after the subsidy removal and coping: The May 2023 fuel subsidy removal was described as a transformative shock to transport budgets across both cities. Women reported switching from twice daily keke use to once daily (and walking one leg), reducing the frequency of market trips, and, in several cases, withdrawing children from private schools to reduce the associated transport costs. The removal of subsidies amplified pre-existing transport energy poverty rather than creating it anew.

Fourth, agency within constraint: not all women experienced okada nonuse as purely restrictive. Several respondents, particularly older married women in Enugu, expressed genuine normative alignment with the practice of aeke preference, framing it as a positive marker of respectability rather than a constraint. This finding complicates a purely structural reading of the mode choice gap and underscores the importance of not imposing framings of external energy poverty on practices that women experience as culturally consonant.

VI. Discussion

A. Gender, norms, and mode choice penalty

The probit results establish that being female reduces okada use probability by 21.8 percentage points after controlling for income, distance, trip purpose, and city, and that social norm constraints account for a significant portion of this penalty

independent of income effects. Blinder-Oaxaca decomposition attributes 58.2% of the gender gap to unexplained factors, providing strong econometric evidence that social norms and other non-economic constraints substantially drive the gender mobility gap in informal transport rather than simply by women's lower incomes.

This finding contributes to the literature on gender in global transport (Ng & Acker, 2018; Pereira et al., 2017) by providing the first probit-based quantification of the social norm's contribution to gendered mode choice in Nigerian informal transport. It advances beyond Olawole's (2019) descriptive analysis by demonstrating that the norm effect persists after controlling for income and trip characteristics, ruling out the interpretation that women's lower okada use is purely economically determined. The Female × Enugu interaction further demonstrates that social norm effects are spatially heterogeneous, varying between cities in ways that track cultural differences in female mobility norms.

B. Poverty in Transport Energy as a Multi-Domain Problem

The TEES framework reveals that transport energy poverty is a structural feature of peri-urban energy lives of Nigerian women rather than a marginal expenditure issue. A mean TEES_income of 24.8% for female motorized mode users, exceeding the 20% TEP threshold, and a TEES_energy of 41.3% indicate that transport fares absorb a large and economically burdensome share of both income and total energy expenditure. For widowed low-income women in Enugu, TEES_income reaches 38.6% , a level at which transport cost constitutes a genuine deprivation claim on household welfare.

The qualitative evidence on energy budget competition, including women substituting firewood for LPG, candles for electricity, and one-leg keke for two-leg keke as transport fares rise, makes the interdependence of energy poverty concrete. These substitutions are not merely cost-saving behaviors; they represent backward transitions in energy access that the SDG7 framework would identify as regressive. The implication is that transport fare increases, including those transmitted by the removal of fuel subsidies, trigger multi-domain energy poverty deteriorations that are invisible to energy access monitoring frameworks that treat cooking, electricity, and transport separately.

C. Policy implications

Three clusters of policy implications emerged from the findings. First, gender-responsive informal transport regulation should move beyond blanket prohibitions (which, as documented in the companion okada ban study, impose severe livelihood costs without commensurate safety gains) toward targeted safety certification frameworks that address women's specific safety and dignity concerns. Mandatory helmet provision for female passengers, operator code of conduct training with gender sensitivity components, and female designated keke seating in mixed vehicles are low-cost interventions with documented effectiveness in South and South East Asian boda boda and auto rickshaw contexts (Haworth, 2012).

Second, fare subsidy mechanisms targeted at female households with high TEES could mitigate transport energy poverty without requiring structural transformation of the informal transport market. A means tested transport voucher scheme, analogous to the Social Investment Fund mobility grants trialed in South Africa and the Lagos BRT concession reduction for low-income card holders, could be implemented through the existing NSIP infrastructure. Our TEES analysis provides the expenditure data required to calibrate the threshold and targeting algorithm for such a scheme.

Third, electric keke NAPEP deployment simultaneously addresses multiple dimensions of this problem: lower per kilometer fuel costs reduce TEES, enclosed design addresses embodied safety concerns, and platform enforced operator codes of conduct address the social norm and harassment dimensions. The companion paper on electric motorcycle TCO (Fashola et al., 2024) demonstrates that e motorcycle cost parity with petrol equivalents is achievable within 14.6 months under fuel after the subsidy removal prices; analogous calculations for electric keke show even shorter parity timelines given keke's higher daily mileage. Proactive electric keke deployment in peri-urban corridors, supported by the Keke Solar Charging Pilot already operational in Ibadan, would directly reduce the burden of transport energy poverty on female commuters who are disproportionately dependent on this mode.

Fourth, the national (Nigeria's National Energy Policy, 2021) and international (SDG7 tracking) energy poverty measurement frameworks should be extended to include a transport energy dimension. The TEES indicator proposed in this paper is simple to compute from household expenditure surveys and is compatible with the existing data infrastructure, including the NLSS. Its incorporation into periodic energy access assessments would make the gender-differentiated transport energy burden visible to policymakers who currently address cooking and electricity isolated from transport.

D. Limitations and Prospects for Future Research

Several limitations constrain the study. First, the TEES indicator is computed from the self-reported transport expenditure, which is subject to recall error. Future research using payment data from mobile money or digital ticketing platforms, where available, would reduce measurement error. Second, the cross-sectional probit design cannot establish causal direction: women may choose residential locations with restricted motorized access, and mode choices may jointly determine residential location and vice versa. Longitudinal panel data tracking mobility decisions before and after a mode availability shock would strengthen causal identification. Third, the study covers two specific peri-urban zones and may not generalize to northern Nigerian cities, where Muslim social norms create additional constraints on female mobility (Hanson, 2010), or to rural areas, where walking distances are substantially longer. Fourth, the qualitative component, while rich, is purposively sampled and not representative of the full

female commuter population; quantitative findings should be privileged where they conflict with qualitative inferences.

Future research should extend the TEES framework to northern Nigerian cities (Kano, Kaduna) where the intersection of gender, religion, and transport norms creates an even more constrained mobility environment for women. Using panel data, the gender-differentiated welfare effects of the 2023 fuel subsidy removal should be examined, and the gender equity implications of electric motorcycle and keke deployment programs should be evaluated as they scale across Nigerian cities.

VII. Conclusions

This study provides the first intersectional gender-energy mobility analysis of informal transport patronage in Nigerian peri-urban settings, combining a mixed methods survey of 960 female and 480 male respondents in Ibadan and Enugu with probit econometrics and the novel TEES indicator. The findings establish three core conclusions.

First, the gender gap in okada use is large (37 percentage points in raw terms; 21.8 percentage points AME after controls), only 41.8% of which can be explained by income and distance differences, and this gap is significantly amplified by social norm constraints and the city context. Women in Enugu, where norm constraints are strongest, face a combined gender norm city penalty of approximately 37 percentage points in okada use probability relative to comparable men in Ibadan. This gap is not simply an income story: it is a social norm story that income-focused transport interventions cannot solve.

Second, transport energy poverty, operationalized through TEES_income ≥ 20% , afflicts 54.8% of female respondents and only 22.3% of male respondents. The most severely affected subgroup, widowed low-income women in Enugu, recorded TEES_income of 38.6%, with transport fares absorbing over half of total household energy budgets (TEES_energy > 50%). The 2023 fuel subsidy removal amplified these burdens by 60%–90% within months, triggering backward energy transitions (LPG to firewood, electricity to candles) that illustrate the multi-domain energy poverty consequences of transport fare shocks.

Third, social norm-enforced keke dependency constitutes a structural transport energy poverty mechanism for Nigerian peri-urban women: because social norms restrict women to the more expensive keke mode rather than the cheaper okada, norm enforcement translates directly into higher TEES and deeper transport energy poverty, creating feedback between gender inequality and energy deprivation that is invisible to frameworks treating gender and energy separately. Addressing this compound disadvantage requires a gender-responsive transport policy, safety certification, targeted fare subsidies, electric keke deployment, and TEES inclusive energy poverty measurement, along with a broader recognition that transport energy is a missing dimension of the global energy poverty agenda.

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