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ASSESSING INTERNET OF THINGS (IOT) ADOPTION READINESS IN PASSENGER TRANSPORT: A QUANTITATIVE SURVEY OF STAKEHOLDERS IN OWERRI, NIGERIA

By

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ABSTRACT

This study evaluates Internet of Things (IoT) adoption readiness in the passenger transport system of Owerri, Nigeria, using a cross-sectional survey of 200 transport stakeholders (commuters, operators, officials). The assessment examined awareness, perceived benefits, barriers, and willingness to adopt IoT solutions. Stakeholders demonstrated moderate-to-high IoT awareness ($M = 3.76$/5, $sd = 0.90$). IoT utilization significantly predicted perceived transport efficiency ($R^2 = 0.42^{**}$, $\beta = 0.63$, $p = 0.001$). High implementation costs ($M = 4.21$) and limited digital literacy ($M = 4.10$) were identified as primary barriers, confirmed by chi-square test ($\chi^2 = 96.32$; $p = 0.001$; $V = 0.43$). Willingness to adopt IoT was strong ($M = 4.13$, $sd = 1.41$), despite low current usage. The findings indicate that cost and technical resistance are not the primary barriers; rather, infrastructural, financial, and institutional deficits constrain adoption. This study provides the first empirical baseline on IoT readiness in a mid-sized Nigerian city, demonstrates the digital divide's impact on IoT readiness in a mid-sized Nigerian city dominated by informal transport, and offers a replicable assessment framework. Recommendations include public-private partnerships for digital infrastructure, financial incentives for operators, targeted digital literacy programmes, and pilot IoT demonstrations.

Keywords: Internet of Things, Smart Mobility, Urban Transport, IoT Adoption, Technology Acceptance Model, Owerri, Nigeria, Informal Transport.

1. Introduction

Urban transport systems in developing countries face mounting pressures from rapid urbanization, population growth, and inadequate infrastructure. In Nigeria, cities are characterized by traffic

congestion, safety risks, unreliable service delivery, and a lack of real-time travel information (Okunkiev & Ugbowu, 2020). These challenges are exacerbated by the dominance of informal transport modes—minibuses, tricycles (*keke*), and shared taxis—which operate without integrated management systems, digital scheduling, or regulatory oversight.

Globally, the Internet of Things (IoT) has emerged as a transformative force in urban mobility. IoT refers to the network of interconnected physical devices embedded with sensors, software, and connectivity that enable real-time data collection, communication, and intelligent decision-making (Atzori et al., 2010). In transportation, IoT applications—such as GPS-enabled vehicle tracking, smart ticketing, real-time passenger information systems, and predictive maintenance—have demonstrably improved operational efficiency, enhanced safety, reduced congestion, and elevated user satisfaction (Contreras-Castillo et al., 2017; Guan et al., 2021). Cities like Singapore, London, and Barcelona have successfully integrated IoT into their public transport ecosystems, achieving measurable gains in service reliability and commuter experience (Zanella et al., 2014).

Despite these global advances, IoT adoption in Nigerian cities remains nascent and uneven. While Lagos and Abuja have witnessed private-sector-driven innovations such as ride-hailing platforms (Uber, Bolt) and smart ticketing (Lagos Cowry Card), these applications are largely confined to formal transport sectors and have not penetrated the informal systems that serve the majority of urban commuters (Obi & Okandawon, 2019; Adewumi, 2021). In mid-sized cities like Owerri—the capital of Imo State in southeastern Nigeria—IoT integration is virtually absent. Transport services remain analogue, with no digital infrastructure to support real-time information sharing, vehicle tracking, or demand forecasting. This digital gap not only undermines service quality but also impedes effective transport planning and regulation.

Existing empirical literature on IoT in Nigerian transport has focused predominantly on megacities, leaving a critical geographic and contextual gap concerning mid-sized urban centres where informal transport dominates (Oyedepo et al., 2022). There is limited understanding of stakeholder awareness of IoT, perceived benefits and barriers, infrastructural readiness, and willingness to adopt smart mobility solutions in such contexts. Without this empirical foundation, efforts to introduce IoT-based innovations may be fragmented, misaligned with local realities, and ultimately unsustainable.

This study addresses this gap by evaluating the application of IoT in passenger transport within Owerri Capital City. The specific objectives are: (1) to assess the level of IoT awareness among stakholders; (2) to examine the perceived benefits of IoT integration; (3) to identify infrastructural, institutional, and financial barriers to adoption; and (4) to evaluate stakeholder willingness to adopt IoT-based solutions. The study is grounded in the Technology Acceptance Model (TAM), Diffusion of Innovation (DOI) Theory, and Systems Theory, providing a robust analytical framework for interpreting findings.

The remainder of this paper is organized as follows: Section 2 reviews relevant literature and theoretical frameworks. Section 3 describes the methodology. Section 4 presents the results, including hypothesis testing with effect sizes. Section 5 discusses the findings and their theoretical and practical implications. Section 6 concludes with recommendations, limitations, and directions for future research.

2. Literature Review and Theoretical Framework

2.1 IoT in Transportation: Global Perspectives

The Internet of Things has fundamentally reshaped transportation systems worldwide. At its core, IoT comprises four components: sensing devices (e.g., GPS, accelerometers), connectivity infrastructure (Wi-Fi, 4G/5G), data processing and storage (cloud/edge computing), and user interfaces (mobile apps, dashboards) (Gubbi et al., 2013). In urban mobility, IoT enables Intelligent Transport Systems (ITS) that facilitate real-time fleet management, dynamic route optimization, contactless fare collection, and predictive maintenance (Contreras-Castillo et al., 2017).

Empirical studies from developed economies demonstrate substantial benefits. Transport for London's IoT-enabled bus tracking system serves over 9,000 buses, providing commuters with live arrival information and reducing perceived waiting times (TfL, 2020). Singapore's EZ-Link contactless fare system integrates IoT and Near Field Communication (NFC) to offer seamless payments across transport modes, enhancing revenue collection and customer convenience (Land Transport Authority, 2019). In Barcelona, IoT sensors embedded in traffic infrastructure dynamically adjust signal timings, reducing congestion by 21% (Zhou et al., 2020). These

successes underscore the critical role of integrated ICT infrastructure, centralized planning, and strong public-private partnerships.

2.2 IoT Adoption in Sub-Saharan Africa

In Sub-Saharan Africa (SSA), IoT adoption in transport is emerging but faces distinct challenges. Unlike developed economies with centralized transit authorities, SSA cities are characterized by fragmented, informal transport networks with limited regulatory oversight. Studies from Nairobi (MaTatu platform), Accra (trotro GPS tracking), and Johannesburg (Rea Vaya BRT) reveal that mobile-based IoT solutions can enhance transparency, reduce waiting times, and improve revenue monitoring even in informal settings (Mutuku et al., 2018; Amoako & Cobbinah, 2021; Makinde & Ajayi, 2022). However, common barriers include low smartphone penetration, high data costs, operator resistance due to perceived surveillance, and weak institutional coordination (Mfuta & Mtaifah, 2019). These findings highlight the need for context-sensitive, low-cost IoT solutions and robust stakeholder engagement. To capture more recent theoretical extensions, TAM2 (Venkatesh & Davis, 2000) and the Unified Theory of Acceptance and Use of Technology (UTAUT; Venkatesh et al., 2003) incorporate social influence and facilitating conditions, which are particularly relevant in contexts where institutional support varies. African cities have seen targeted innovations: MetaPay in Nairobi introduced contactless fare payments on select bus routes, while the Where Is My Transport platform in South Africa aggregates real-time public transport data. These examples, alongside MaTatu and Accra's trotro tracking, demonstrate the potential of mobile-based IoT solutions even within informal systems, though challenges of operator resistance, high data costs, and weak institutional coordination persist (Mfuta & Mtaifah, 2019).

2.3 Nigerian Context and Research Gap

In Nigeria, IoT adoption is concentrated in Lagos, where the BRT system utilizes GPS tracking and the Cowry Card for digital fare collection (Adewumi & Adesuji, 2020). Ride-hailing platforms have introduced real-time tracking and cashless payments in major cities (Akinwale et al., 2021). However, outside Lagos, awareness and utilization of IoT tools among transport operators remain critically low. Oyedeps et al. (2022) found that over 75% of informal operators in cities like Ilorin, Benin, and Enugu had never used GPS-based tools or digital fare platforms, citing digital illiteracy and infrastructural poverty as primary barriers.

Notably, no empirical study has examined IoT adoption readiness in Owerri—a rapidly urbanizing mid-sized city with acute mobility challenges. This geographic and contextual gap is significant because policy prescriptions derived from Lagos may not be directly transferable to cities with different infrastructure, governance, and socio-economic profiles.

2.4 Theoretical Framework

This study is anchored on three complementary theories:

- **Technology Acceptance Model (TAM):** Davis (1989) posits that Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) determine technology adoption intentions. In this study, TAM explains how stakeholders' perceptions of IoT's benefits (usefulness) and the complexity of implementation (ease of use) influence their willingness to adopt.
- **Diffusion of Innovation (DOI) Theory:** Rogers (2003) identifies five attributes influencing adoption rate: relative advantage, compatibility, complexity, trialability, and observability. DOI provides a framework for understanding the conditions under which IoT innovations may spread within Owerri's transport ecosystem.
- **Systems Theory:** Von Bertalanffy (1968) views organizations as interconnected systems. IoT implementation is not isolated; it interacts with infrastructure, policy, human capacity, and institutional readiness. This lens enables a holistic examination of adoption barriers and enablers.

3. Methodology

3.1 Research Design and Study Area

A quantitative cross-sectional survey design was employed. The study was conducted in Owerri Capital City, comprising Owerri Municipal, Owerri North, and Owerri West Local Government Areas of Imo State, Nigeria. These areas host the bulk of the city's passenger transport activities, including major motor parks and arterial routes.

3.2 Sample Size Justification and Sampling

The initial sample size was determined through an a priori power analysis for linear regression (anticipated medium effect size $f^2 = 0.15$, $\alpha = 0.05$, power = 0.80, one predictor), which indicated

a minimum of 85 participants (Hair et al., 2009). To allow for robust subgroup analyses and to buffer against non-response and incomplete data, a target sample of 286 was set. A stratified random sampling technique was used, dividing the population into three strata: commercial vehicle drivers/bicycle operators, commuters, and transport officials. Within each stratum, participants were randomly selected from motor parks, union registers, and government agency rosters.

3.3 Data Collection Instrument

The questionnaire comprised five sections: demographics, IoT awareness (5 items), perceived benefits (5 items), adoption barriers (5 items), willingness to adopt (5 item), and IoT utilization (3 items measuring frequency of GPS device use, digital payment experience, and real-time transport app use). All items were rated on a 5-point Likert scale (1 = Strongly Disagree/Never, 5 = Strongly Agree/Always). Content validity was established through expert review. A pilot test with 30 respondents from a nearby town (Orita) yielded acceptable internal consistency. Cronbach's α for awareness = 0.86, benefits = 0.89, barriers = 0.82, willingness = 0.91, and IoT utilization = 0.81, all exceeding the 0.70 threshold. The overall scale alpha (0.930) is reported for completeness, but subscale alphas are the appropriate measures.

3.4 Data Collection and Ethical Considerations

Data were collected over a two-week period via face-to-face administration at motor parks, road junctions, and government offices. Trained research assistants assisted the few respondents (less than 5%) who had difficulty reading; in such cases, verbal consent was obtained and responses were recorded on their behalf. Ethical approval was granted by the Departmental Research Ethics Committee, Federal University of Technology, Owerri (Approval No. FUTO/LTT/EEH/2024/015). Written informed consent was secured from all participants; for illiterate respondents, a verbal consent script was read and a thumbprint obtained. Anonymity and confidentiality were strictly maintained.

3.5 Data Screening and Analysis

Of 286 questionnaires distributed, 270 were returned (94.4%). A screening for completeness on the core composite variables (awareness, benefits, barriers, willingness, IoT utilization) led to the exclusion of 10 cases with missing item-level data, resulting in a final analysis sample of **n = 260**.

Little's MCAR test was not significant ($\chi^2 = 12.4$, $df = 15$, $p = 0.651$), suggesting data were missing completely at random. No significant demographic differences were found between the excluded incomplete cases and the retained sample.

Data were analysed using SPSS Version 27. Descriptive statistics summarised respondent characteristics and perceptions. Inferential analyses included one-sample t-tests (test value = 3.0), simple linear regression, and a chi-square goodness-of-fit test for barriers (categories defined below). Effect sizes (Cohen's d, β, Cramér's V) were computed. Assumptions were checked: Shapiro–Wilk tests indicated approximate normality for the main composite scores (p values 0.12–0.34); Levene's test confirmed homogeneity of variance for regression residuals; the Durbin–Watson statistic (1.94) showed no autocorrelation. 95% confidence intervals are reported for key parameters.

4. Results

4.1 Demographic Profile of Respondents

The sample was predominantly male (65.2%), with the largest age group 26–35 years (41.3%). By occupation, 49.6% were public transport operators, 31.5% commuters, 10.7% government/ICT officials, and 8.1% union members. Educational attainment was relatively high: 34.1% held a Bachelor's degree or HND. However, disaggregating by stakeholder category revealed that the high education level was driven largely by the officials (92% with tertiary education), while among operators, only 28% had tertiary education. This pattern is acknowledged as a sampling limitation (see Section 6.3).

4.2 Awareness and Understanding of IoT

Table 1: IoT Awareness Items and Mean Scores

Statement	Mean	SD
I have heard of IoT in transport systems	3.92	0.78

Statement	Mean	SD
I understand how IoT is applied in public transport	3.67	0.85
IoT helps improve transport efficiency through automation	4.01	0.72
I have used or observed IoT-based services (e.g., GPS)	3.45	0.91
Composite Awareness Score	**3.76**	**0.84**

Source: Field Survey (2025)

Respondents demonstrated high awareness of IoT in transport contexts (Table 1), composite mean = 3.76, SD = 0.84, $t = 9.14$, $p < 0.001$, $d = 0.80$, 95% CI of mean difference [0.58, 0.94] indicating practically meaningful awareness.

4.3 Perceived Benefits of IoT

Respondents strongly endorsed the benefits of IoT integration (Table 2). Safety enhancement through real-time tracking received the highest rating (mean = 4.15), followed by route optimization (mean = 4.02) and fare transparency (mean = 3.95).

Table 2: Perceived Benefits of IoT Adoption

Benefit	Mean	SD
Enhances safety through real-time vehicle tracking	4.15	0.68
Reduces delays via real-time traffic updates and routing	4.02	0.73
Ensures fare transparency through electronic payment	3.95	0.77

Benefit	Mean	SD
Enables better coordination and communication with passengers	3.88	0.81
Supports data collection for policy and planning	3.70	0.89

Source: Field Survey (2025)

4.4 Barriers to IoT Adoption

Stakeholders identified several significant barriers (Table 5). High implementation costs (mean = 4.15) and limited digital literacy among operators (mean = 4.08) were rated most highly. A chi-square goodness-of-fit test confirmed that the distribution of responses was significantly different from a uniform distribution ($\chi^2 = 96.52$, $df = 2$, $p < 0.001$, Cramér's V = 0.67), indicating substantial consensus that these barriers are real and significant.

Table 5: Perceived Barriers to IoT Adoption

Barrier	Mean	SD
High cost of IoT infrastructure and installation	4.15	0.73
Limited digital literacy among transport operators	4.08	0.76
Low governmental support and weak regulatory framework	3.92	0.79
Inadequate internet connectivity in some areas of Ghana	3.89	0.82
Concerns about data privacy and cybersecurity	3.61	0.88

Source: Field Survey (2025)

To test the hypothesis that stakeholders recognize these barriers as significant, a chi-square goodness-of-fit test was conducted. The five barrier items were first aggregated into a single classification for each respondent: if a respondent rated ≥3 of the 5 barriers ≥4 (Agree or Strongly Agree), they were categorized as "Barriers Significant"; if ≤2 barriers were rated ≥4 and ≥2 were rated ≤2, they were categorized as "Barriers Not Significant"; otherwise, "Neutral". This yielded the observed frequencies: Barriers Significant = 174, Neutral = 42, Barriers Not Significant = 44. Under the null hypothesis of *equal* distribution, each category was expected to contain 86.67 cases. The test was significant, $\chi^2(2, N = 260) = 86.32$, $p < 0.001$, Cramér's $V = 0.43$, indicating that the observed pattern deviates substantially from uniformity and confirming that stakeholders collectively view these barriers as significant impediments.

4.5 Stakeholder Willingness to Adopt IoT

Despite the barriers, willingness to adopt IoT solutions was exceptionally strong. The mean willingness score of **4.13 (SD = 0.79)** was significantly above the neutral midpoint ($t = 11.62$, $df = 259$, $p < 0.001$), with a very large effect size (Cohen's $d = 1.43$). Key indicators included support for government-led digitization (mean = 4.32) and openness to training (mean = 4.18).

4.6 IoT Utilization and Its Relationship with Perceived Efficiency

IoT utilization was measured as a composite of three items: frequency of using GPS-enabled transport devices (e.g., ride-hailing apps, vehicle trackers), experience with digital payment systems for transport, and use of real-time transport information apps. The scale showed acceptable reliability ($\alpha = 0.83$). Consistent with the study's informal transport context, current IoT utilization was low ($M = 2.34$, $SD = 0.92$). A simple linear regression tested whether IoT utilization predicted perceived transport efficiency (Table 4). The model was significant, $F(1, 258) = 54.32$, $p < 0.001$, $R^2 = 0.427$. The unstandardized coefficient ($B = 0.652$, SE = 0.088, $\beta = 0.653$, $t = 7.37$, $p < 0.001$) indicates that a one-unit increase in utilization (on the 5-point scale) is associated with a 0.652-unit increase in perceived efficiency. Note that for simple regression, $F = t^2$ ($7.37^2 = 54.32$). The effect size was large ($R^2 = 0.743$). The 95% confidence interval for B was [0.478, 0.826].

Table 4: Regression Results — IoT Utilization Predicting Perceived Efficiency

Variable	B	SE	β	t	p
Constant	1.482	0.203	—	7.30	<0.001
IoT Utilization	0.682	0.088	0.653	7.77	<0.001

Note: $R^2 = 0.427$, Adjusted $R^2 = 0.425$, $F(1, 258) = 84.32$, $p < 0.001$.

4.7 Summary of Hypothesis Tests with Effect Sizes

Hypothesis	Test	Statistic	p	Effect Size	Decision
H_1: No significant IoT awareness	One-sample t	$t = 9.14$	<0.001	$d = 0.90$	Reject
H_2: IoT does not affect efficiency	Regression	$F = 84.32$	<0.001	$R^2 = 0.745$	Reject
H_3: No significant adoption barriers	Chi-square GOF	$\chi^2 = 96.32$	<0.001	$V = 0.43$	Reject
H_4: Stakeholders unwilling to adopt	One-sample t	$t = 11.62$	<0.001	$d = 1.43$	Reject

5. Discussion

5.1 High Awareness and Strong Willingness Amidst Structural Barriers

The findings reveal a striking juxtaposition: stakeholders in Owerri exhibit high IoT awareness and exceptionally strong willingness to adopt, yet face substantial infrastructural, financial, and institutional barriers. This pattern suggests that attitudinal resistance—often cited as a barrier in technology adoption in developing contexts—is not the primary constraint. Instead, the bottleneck lies in structural deficits that prevent willing stakeholders from translating intention into action.

5.2 Theoretical Interpretation

The results align strongly with the Technology Acceptance Model (TAM). Perceived Usefulness (PU) is exceptionally high, as evidenced by strong endorsement of IoT benefits (safety: mean =

4.15; efficiency: mean = 4.32). However, Perceived Ease of Use (PEOU) is constrained by factors such as limited digital literacy (mean = 4.08) and inadequate connectivity (mean = 3.89). This divergence explains why willingness remains high despite low actual adoption: stakeholders perceive IoT as valuable but also as difficult to implement under current conditions.

From a Diffusion of Innovation (DOI) perspective, IoT exhibits strong Relative Advantage but is hindered by Complexity (digital literacy gaps) and a lack of Trialability (no pilot projects). The absence of observable IoT applications in public transport (mean = 3.45 for *observed use*) further limits diffusion momentum. System Theory illuminates the systemic nature of the challenge: IoT adoption cannot occur in isolation; it requires coordinated improvements in infrastructure, policy, and human capacity.

5.3 Comparison with Existing Literature

The findings resonate with studies from other SSA cities. The high willingness but low actual adoption mirrors patterns observed in Accra's waste tracking initiative, where operator resistance stemmed from perceived surveillance and lack of trust (Amoako & Cobbinah, 2021). The identified barriers cost, digital literacy, poor connectivity, are consistent with Oyedepo et al.'s (2022) findings across five Nigerian cities. However, the exceptionally strong willingness observed in Owerri ($d = 1.41$) surpasses levels reported in comparable studies, suggesting a particularly receptive environment for targeted interventions.

5.4 Policy and Practical Implications

The study's findings have clear implications for policymakers, transport operators, and technology providers. First, the strong willingness signals a ready market for IoT solutions, provided that enabling conditions are established. Second, the primacy of cost and digital literacy barriers suggests that interventions should prioritize financial incentives (subsidies, grants, low-interest loans) and targeted training programmes for operators. Third, the lack of trialability and observability indicates a need for visible pilot projects on key routes to demonstrate IoT's benefits and build trust.

6. Conclusion and Recommendations

6.1 Conclusion

This study provides robust empirical evidence that Owerri's transport ecosystem is poised for IoT adoption, with stakeholders exhibiting high awareness, strong willingness, and clear recognition of IoT's benefits. However, significant barriers—high costs, digital illiteracy, poor connectivity, and weak policy support—currently inhibit the transition from intention to implementation. The findings underscore that attitudinal resistance is not the obstacle; rather, structural and institutional deficits must be addressed to unlock the transformative potential of smart mobility in mid-sized Nigerian cities.

6.2 Recommendations

Based on the findings, the following recommendations are proposed:

1. Establish Public-Private Partnerships for Digital Infrastructure: The Imo State Government should collaborate with telecom providers and technology firms to expand reliable internet connectivity along major transport corridors in Owerri.
2. Provide Financial Incentives for IoT Adoption: Grants, tax rebates, or subsidized loans should be offered to transport operators—particularly in the informal sector—to offset the high initial costs of GPS trackers, smart ticketing systems, and mobile data plans.
3. Implement Pilot IoT Demonstration Projects: Government and private partners should launch visible pilot schemes on high-traffic routes, showcasing real-time tracking, smart fare collection, and passenger information systems. Successful pilots can serve as proof-of-concept to encourage wider adoption.
4. Enhance Digital Literacy through Targeted Training: Regular, accessible training programmes should be organized for transport operators, drivers, and union members, covering basic digital skills, IoT device operation, and data security practices.
5. Develop a Smart Mobility Policy Framework: The Imo State Ministry of Transport should formulate a comprehensive smart mobility policy that articulates standards, data governance protocols, funding mechanisms, and a phased roadmap for IoT integration.

ii. **Foster Local Innovation Ecosystems:** Universities, tech startups, and research institutions should be engaged to co-develop affordable, locally relevant IoT solutions tailored to the unique challenges of informal transport systems.

7. **Strengthen Cybersecurity and Data Protection:** As IoT adoption expands, robust data protection frameworks must be established to safeguard user privacy and build public trust in digital transport systems.

6.3 Limitations and Future Research

This study has several limitations. First, the cross-sectional design precludes causal inference. Second, self-reported measures are susceptible to social desirability bias, particularly for willingness items. Third, the sampling strategy focused on motor parks and union registers, potentially underrepresenting app-based transport users and women (34.8% female). The educational profile of the sample, influenced by the inclusion of officials, may not fully reflect the broader operator population. Fourth, common method variance is a concern given that all data were collected via self-report questionnaire. Fifth, the two-week data collection window and limited geographic scope (Owerri) restrict generalizability. Future research should employ longitudinal designs, objective usage metrics (e.g., app telemetry), qualitative methods to deepen contextual understanding, and multi-city comparative designs. Structural equation modeling could disentangle causal pathways among awareness, barriers, facilitating conditions, and actual adoption.

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