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Smart Mobility Adoption in Cairo: Barriers, Perceptions, and Policy Pathways

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Abstract Cairo's rapid urban growth has intensified transportation challenges. Aligned with Egypt's Vision 2030 sustainability commitments, smart mobility initiatives, such as the Cairo Monorail and Bus Rapid Transit (BRT), aim to modernize the transport system. However, adoption remains constrained by structural barriers, geographic proximity to infrastructure, affordability constraints, and institutional trust, which existing technology adoption frameworks do not adequately address. This study investigates adoption barriers through a stratified survey (N=300) during early system operations. The findings reveal a pronounced 70-percentage-point intention-action gap: 80% awareness but only 10% regular usage. Primary barriers were poor infrastructure accessibility (52%), limited awareness (30%), and cost (18%); however, geographic proximity to stations emerged as the strongest adoption moderator (r=0.54, explaining 29% of usage variance), substantially exceeding perceived usefulness (r=0.42, 18% variance). Income-stratified affordability operated as a critical constraint: formal-sector respondents perceived affordability favorably (M=3.4/5), while informal-sector respondents faced severe barriers (M=2.1/5), with costs consuming 20–30% of household income. Theoretically, this research extends the Technology Acceptance Model and Unified Theory of Acceptance and Use of Technology by incorporating geographic proximity, affordability, and institutional trust as boundary conditions critical to Global South megacities, advancing understanding beyond high-income frameworks. Practically, successfully converting awareness into adoption requires sequenced structural interventions: geographic equity (infrastructure expansion to underserved districts), affordability restructuring (progressive pricing and subsidies), and governance integration (institutional coordination), which are substantially more consequential than technology design or messaging campaigns alone. This framework is directly transferable to comparable African megacities (Accra, Lagos, Nairobi, Kinshasa) facing analogous challenges of urbanization, governance fragmentation, and infrastructure equity.

Keywords Bus Rapid Transit, Cairo Monorail, Public Perception, Smart Mobility, Urban Sustainability

1. Introduction

1.1. Global Urbanization and the Emerging Mobility Challenge

The world's urban population is projected to reach 6.7 billion by 2050, with Africa accounting for 56% of global urban growth [1]. This unprecedented urbanization in the Global South poses distinct transportation challenges, chronic congestion, insufficient transit capacity, and rising emissions, which create tensions between urban development, sustainability, and social equity [2]. Despite mounting infrastructure investments in emerging economies, evidence on public adoption barriers to smart mobility in these contexts remains scarce, limiting policy design evidence for regions where needs are most acute. This gap directly constrains the implementation of national sustainability commitments, such as Egypt's Vision 2030, as policymakers lack localized empirical evidence on salient adoption barriers [3].

1.2. Cairo: A Case Study of Competing Mobility Demands

Cairo exemplifies these challenges at a scale that is critical. With 23 million residents (projected 28 million by 2050), Cairo's transport system faces peak-hour congestion exceeding 70% of road capacity and average commute times of 90 minutes [3]. Transportation emissions constitute 23% of the city's total carbon footprint. Cairo's steep socio-economic stratification, fragmented informal transit networks, and uneven formal transit coverage create compounded pressures. This combination of intense mobility demand, environmental urgency, and social heterogeneity makes Cairo an ideal case for understanding equitable, sustainable smart mobility adoption in rapidly urbanizing megacities [4].

Vision 2030 Implementation Challenge: Egypt's Vision 2030 simultaneously commits to climate action, reducing transportation emissions through low-carbon systems, and to inclusive development and equitable access across all socio-economic strata and geographic zones. However, this dual commitment creates a critical puzzle: How can Vision 2030 sustainability targets be achieved when infrastructure investment alone may fail to drive inclusive adoption? If adoption concentrates among high-income central populations while peripheral and low-income residents remain excluded, Vision 2030's sustainability and equity objectives remain unmet despite multi-billion-dollar investment [5]. This fundamental implementation question motivates the present research.

1.3. Egypt's Smart Mobility Vision: Ambitions and Early Implementation Gaps

Egypt's Vision 2030 prioritizes smart mobility as central to transport transformation. Two flagship initiatives are operational: the Cairo Monorail (launched November 2025, spanning 88 stations) and the Bus Rapid Transit system (operational since June 2025, with dedicated lanes and integrated digital ticketing), together representing approximately $4.2 billion in public investment [6, 7]. However, early operational data reveal a critical puzzle: although public awareness exceeds 80%, regular usage is only 10%, a 70-percentage-point intention-action gap suggesting that infrastructure availability alone is insufficient. This gap signals barriers rooted in affordability, geographic accessibility, institutional coordination, and trust, factors that existing frameworks developed in high-income contexts may not adequately explain [8].

Why This Gap Threatens Vision 2030: The 80%-10% awareness-usage gap violates Vision 2030's three foundational principles: (1) Environmental sustainability: Unutilized smart mobility capacity yields negligible emissions reductions, failing to advance Egypt's Paris Agreement commitments. (2) Social equity: If adoption concentrates among affluent central populations, infrastructure becomes a regressive subsidy for high-income users while peripheral populations bear concentrated congestion costs, reinforcing rather than reducing urban inequality. (3) Institutional effectiveness: If peripheral and low-income populations perceive smart mobility as elite-designed exclusionary infrastructure, public trust in government erodes, undermining governance legitimacy. Thus, adoption barriers directly threaten Vision 2030's success across all three dimensions, requiring structural interventions (geographic equity, affordability restructuring, and governance integration) rather than awareness campaigns alone.

1.4. The Theoretical Gap: Technology Adoption Models in Global South Megacities

The literature on smart mobility adoption relies on the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT), both developed in high-income contexts with mature infrastructure. These frameworks emphasize perceived usefulness and ease of use as the primary determinants of adoption. However, recent Global South research suggests that socio-technical factors, affordability constraints, geographic proximity, and institutional fragmentation may be equally or more critical [9, 10]. Notably, Cairo is absent from the international adoption literature, creating an empirical void that impedes evidence-based policy design, as shown in Table 1.

Table 1. Synthesizes evidence on adoption barriers from three comparable megacities, revealing both convergent patterns and Cairo-specific distinctiveness. Source [11, 12, 13]

Characteristic	Jakarta	Lima/ Curitiba	Cairo (Present Study)
System Maturity	Established BRT (>5 yrs)	Mature BRT (15+ yrs)	Early-phase Monorail/BRT (4–5 months)
Governance	Single transit authority	Unified governance	Four separate entities; uncoordinated
Geographic Proximity Effect	Distance >2km reduces usage 40%	Users within 800m show 3–4× higher adoption	Distance >5km reduces usage 75% vs. <1km zone
Affordability Barrier	Affordability suppresses adoption independent of usefulness	Secondary to proximity	Primary barrier; 73% perception gap between the formal/informal sector; costs 20–30% of informal household income
Primary Gap	Mixed-income demographic analysis	Trust-building during implementation	No published Cairo data on adoption barriers, institutional fragmentation effects, or early-phase system dynamics.

Cairo's Contextual Distinctiveness: Three factors differentiate Cairo and require localized research:

- **Governance Fragmentation:** Unlike Jakarta (single authority) or Curitiba (established coordination), Cairo's Monorail and BRT operate under four separate governmental entities: the Ministry of Transport, Cairo Governorate, National Authority for Tunnels, and Greater Cairo Bus Company, with poorly coordinated ticketing, misaligned pricing, and conflicting schedules. This creates endogenous institutional barriers absent from prior literature [11].
- **Infrastructure Maturity Stage:** Jakarta and Curitiba studies examine mature systems; Cairo data capture early-phase context (4–5 months operational) when service reliability remains unproven and institutional credibility uncertain. This temporal distinctiveness amplifies affordability and trust barriers as moderators of adoption [11, 12].
- **Geographic-Economic** Peripheralization: Cairo's Gini coefficient (0.32) indicates high inequality; 40% of the population lives more than 10km from transit corridors with limited first-mile connectivity. This compounded geographic-economic barrier substantially exceeds comparable Asian/Latin American contexts, where lower-income populations maintain closer proximity to transit [13].

Importing recommendations from Jakarta, Lima, or Curitiba risks policy misspecification. Cairo's governance fragmentation, early-phase infrastructure, and severe geographic-economic peripheralization require localized empirical evidence to guide Vision 2030 implementation.

1.5. Research Questions, Objectives, and Theoretical Contributions

To address this gap, the present study poses three interrelated research questions:

(RQ1) What are the primary adoption barriers among Cairo residents, and do these align with TAM-UTAUT constructs or reveal additional socio-technical factors?

(RQ2) How do geographic proximity, household income, and digital literacy interact to shape adoption willingness across Cairo's demographic segments?

(RQ3) What evidence-based policy interventions would most effectively convert high awareness into sustained adoption while advancing Vision 2030's sustainability and equity objectives?

Objectives:

(a) Test TAM-UTAUT boundary conditions in a Global South megacity context, identifying where existing models under-specify;
(b) Quantify adoption barriers across Cairo's demographic and geographic segments;
(c) Develop Cairo-specific policy recommendations aligned with Vision 2030 implementation requirements;
(d) Generate a replicable methodological framework for comparable African megacities facing governance fragmentation and geographic-economic stratification.

Through mixed-methods investigation of public perceptions, usage patterns, and systemic obstacles, this research contributes theoretically by extending adoption frameworks to incorporate socio-technical transition dynamics and contextual heterogeneity, while offering practical evidence-based guidance for transport planners, policymakers, and infrastructure managers navigating smart mobility transitions in Global South urban centers.

1.6. Study Design and Article Structure

This article reports findings from a structured survey of 300 Cairo residents conducted in September–October 2025, capturing responses during the critical early operational phase of Monorail and BRT systems (4–5 months post-BRT launch). The mixed-methods design integrates quantitative perception measurement with qualitative barrier identification, stratified across geographic (central/ East/ peripheral), income (formal/ informal/

non-employed), and digital access segments to test TAM–UTAUT boundary conditions. Survey instrument reliability was confirmed (Cronbach's α=0.71 overall; subscales 0.68–0.76) with factor analysis validating construct structure (loadings ≥0.58); missing data remained <5% and MCAR-tested.

2. Literature Review

2.1. Classical TAM/UTAUT Foundations

The Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) are the dominant frameworks for understanding technology adoption. TAM posits that perceived usefulness (the degree to which technology enhances performance) and perceived ease of use drive behavioral intention, while UTAUT extends this with social influence and facilitating conditions [14, 15]. In transportation, these models consistently predict the adoption of transit apps, mobile ticketing, and journey planners across diverse contexts.

These frameworks were developed and predominantly tested in high-income contexts characterized by mature infrastructure, high digital literacy (smartphone penetration >80%), dense network coverage, and relatively homogeneous user populations. Under these conditions, enabling assumptions hold, reliable infrastructure exists, costs are affordable relative to income, and digital access is near-universal, allowing cognitive evaluations to predict usage behavior strongly [16].

2.2. Regional Performance Differences: Global North vs Global South

However, Global South megacities systematically violate these assumptions, substantially weakening TAM/UTAUT predictive power. In high-income Singapore, perceived usefulness explains ~62% of the variance in smart mobility adoption; in lower-income Jakarta, this drops to 31%, with affordability constraints suppressing usage despite positive attitudes [16]. Similarly, Latin American BRT studies show users within 800m of stations adopt at 3–4× the rate of those >2km distant, even with comparable usefulness ratings, indicating geographic proximity as a dominant moderator absent from classical models [17].

This regional divergence reflects structural differences:

- High-income cities: Mature networks, equitable coverage, high digital literacy, psychological factors dominate
- Global South megacities: Incomplete coverage, income stratification, uneven digital access, structural constraints override attitudes

Cairo Context: Convergence of Boundary Conditions

Cairo exemplifies this divergence. Peak-hour congestion exceeds 70% of road capacity, with 90-minute commutes; transport emissions account for 23% of the carbon footprint. The Cairo Monorail (Nov 2025, 88 stations) and BRT (Jun 2025) represent $4.2B in Vision 2030 investments, yet coverage reaches only ~50% of the metro area, concentrated in central/East Cairo, while West Cairo's periphery (40% of the population) lacks access [18].

This geographic mismatch intersects with:

- Income stratification: Gini coefficient 0.32; transport costs = 5–15% household income (20–30% for informal workers) [19, 20].
- Digital divides: Smartphone penetration 40% (periphery) vs 80% (central areas) [21–23].
- Governance fragmentation: Four agencies (Ministry of Transport, Cairo Governorate, Tunnels Authority, Bus Company) with uncoordinated ticketing/pricing [24].

Prior Cairo/Egypt studies document transport problems and smart city readiness, but lack empirical TAM/UTAUT adoption analysis stratified by these boundary conditions [25–27].

2.3. Research Gap and Study Contribution

This Scopus search ("cairo" AND "smart mobility" AND "public transit") yields only 33 documents and visually demonstrates the absence of empirical adoption studies, underscoring the need for this stratified analysis of Cairo's early-phase systems. Early-phase timing captures barriers when infrastructure is operational, yet institutional credibility remains unproven, conditions that amplify structural constraints and serve as adoption moderators beyond classical TAM constructs, as shown in Figure 1.

This study makes three key contributions to research on smart mobility adoption. Theoretically, it extends TAM–UTAUT by developing a multi-level framework that integrates four structural boundary conditions, geographic proximity, income-stratified affordability, institutional trust/governance coordination, and infrastructure maturity, critical to Global South megacities but absent from classical models. Empirically, it provides the first survey-based analysis (N=300) of Cairo smart mobility adoption during the early operational phase of Monorail/BRT systems, revealing a 70-percentage-point awareness–usage gap and quantifying boundary condition effects that exceed classical TAM predictors. In practice, it offers evidence-based policy recommendations prioritizing governance integration, progressive pricing, and peripheral infrastructure expansion to convert Vision 2030 investments into equitable adoption, with replicability in comparable African megacities.

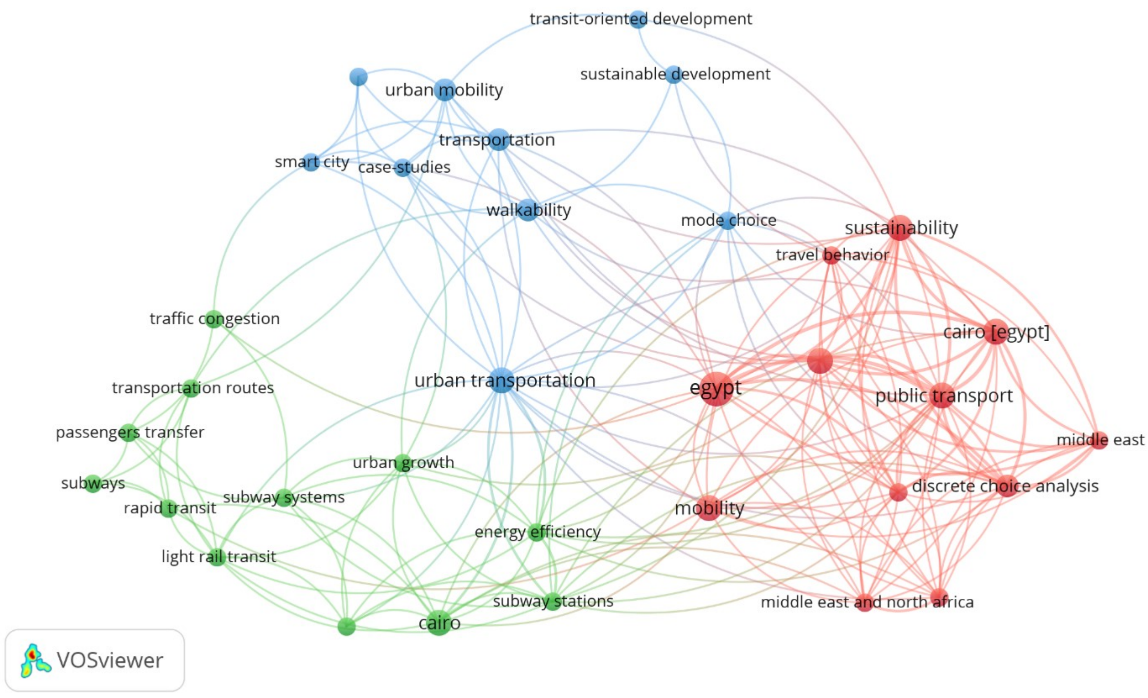

Figure 1. VOSviewer keyword map from Scopus search ("cairo" AND "smart mobility" AND "public transit", 2010–2025; n=33 documents). Source Author

3. Materials and Methods

This mixed-methods study examined adoption barriers and residents' perceptions of smart mobility systems in Greater Cairo.

3.1. Study Design, Sample, and Recruitment

This mixed-methods study used a stratified cross-sectional survey (N=300) of Greater Cairo residents (aged 18–65, residing ≥1 year) conducted September–October 2025, capturing early-phase Monorail/BRT adoption (4–5 months post-BRT). N=300 was selected based on power analysis for detecting medium effect sizes (Cohen's f=0.25) across three stratification factors (geography×income×digital access) at $\alpha=0.05$, power=0.80, requiring a minimum n=270 per G*Power calculations, with a buffer for 10% non-response.

Stratification targeted literature-identified boundary conditions:

- Geography: Central (23%, n=70), East corridor (35%, n=104), peripheral (42%, n=126)
- Income: Formal (41%, n=124), informal (35%, n=104), non-employed (24%, n=72)
- Digital access: Smartphone+ (65%, n=196), limited (35%, n=104)
- Stratified snowball sampling via LinkedIn mitigated self-selection bias through: (1) explicit recruitment targets for peripheral/informal groups, (2) balanced final distribution reflecting Cairo demographics, and (3) representativeness checks ($\chi^2=8.56$, p=0.05 across digital strata).

Cross-sectional early-phase timing identifies actionable barriers before path dependencies form. Longitudinal follow-up is recommended for maturation effects.

3.2. Survey Instrument: TAM-UTAUT Constructs and Extended Boundary Conditions

The survey instrument (10–15 minutes) was based on established TAM-UTAUT scales and extended to measure literature-identified boundary conditions. It measured:

Classical TAM-UTAUT Constructs:

- Perceived usefulness (system improves travel efficiency; 3 items, $\alpha=0.76$)
- Perceived ease of use (straightforward to navigate/use; 3 items, $\alpha=0.73$)
- Social influence (others' usage affects willingness; 2 items)
- Facilitating conditions (infrastructure adequate; 2 items, $\alpha=0.68$)

Extended Boundary Condition Measures:

- Geographic proximity: Self-reported distance to nearest station (<1km, 1–5km, 5–10km, >10km)
- Income-stratified affordability: Perceived cost burden relative to income (Likert 1–5)
- Institutional trust: Confidence in government reliability/equity (Likert 1–5)

- Infrastructure maturity: Perceived system stability (Likert 1–5)
- Digital literacy: Smartphone ownership, app usage frequency

Adoption barriers: Mixed format (predefined categories, open-ended) covering infrastructure gaps, awareness, affordability, and trust.

The instrument used 5-point Likert scales, categorical questions, and open-ended items. Pilot testing (n=20) and Cronbach's alpha (overall α=0.71) confirmed acceptable internal consistency. All participation was voluntary (no incentives); respondents could skip questions.

3.3. Data Collection and Sample Distribution

Online surveys were distributed via LinkedIn from September to October 2025, targeting transport professionals and Cairo residents with awareness of Monorail/BRT initiatives. Respondents were encouraged to share the survey within their networks, resulting in stratified reach across Cairo's districts. The final sample (N=300) was distributed across:

- Geographic segments: Central Cairo (n=35), East Cairo corridor/Monorail area (n=52), West Cairo/peripheral (n=63)
- Income/employment: Formal sector (n=62), informal sector (n=52), non-employed (n=36)
- Digital access: Smartphone owners with app experience (n=98), limited digital access (n=52)

This distribution ensured adequate representation for testing the effects of geographic proximity, income, and digital literacy on adoption patterns.

All survey data were collected and analyzed under strict anonymity protocols:

- No personal identifiers collected: Survey instruments contained no items requesting participant names, addresses, phone numbers, email addresses, or other personally identifiable information (PII)
- No ID linking: Completed surveys were not linked to participant identities through identification numbers, access codes, or any other mechanism
- Aggregate-only reporting: All findings are reported in aggregate form (frequencies, percentages, means, group comparisons) with no individual-level data disclosure
- Data security: All electronic data is stored on password-protected, encrypted devices with access restricted to authorized research team members only
- Confidentiality: Researchers maintain strict confidentiality obligations during and after research completion

Ethical approval and informed consent. The study followed standard ethical principles for anonymous, non-invasive social research. Formal institutional ethics approval was not required under the authors' institutions' policies because no personally identifiable information was collected, and participation posed minimal risk. Participation was entirely voluntary; respondents were informed of the study purpose and their right to decline or withdraw at any time, and completion of the online questionnaire was taken as evidence of informed consent. No financial or material incentives were provided.

3.4. Data Analysis

Data were analyzed using SPSS v27 to address each research question:

RQ1 (Barriers & TAM-UTAUT fit): Descriptive statistics summarized barrier prevalence and TAM-UTAUT ratings. Cross-tabulations compared barriers across demographics. Thematic coding of open-ended responses identified emergent barriers.

RQ2 (Boundary condition interactions): Spearman correlations assessed relationships between proximity (ordinal), income-affordability, digital literacy, and usage. Stratified analyses compared adoption patterns by proximity (<1km vs >5km) and income (formal vs informal). Factorial ANOVA tested proximity×income interactions.

RQ3 (Policy implications): Identified prevalent barriers, underserved group disparities, and strongest usage associations. Synthesized into sequenced policy recommendations targeting geographic equity, affordability, and trust-building.

Quality controls:

- Shapiro-Wilk confirmed non-normality ($p<0.05$), and nonparametric tests are appropriate
- Bonferroni correction for multiple comparisons ($\alpha\_corrected=0.0125$)
- Effect sizes reported (r_s, partial η^2, Cramér's V, RR)

Ethical considerations: Voluntary participation, informed consent, right to withdraw, no compensation, full anonymity.

4. Results

4.1. Sample Characteristics and Geographic-Economic Stratification

A total of N=300 survey responses were collected and analyzed across stratified geographic, income, and digital access segments. The sample achieved balanced representation across Cairo's geographic zones with the following confirmed cell sizes: central Cairo (n=70, 23%, residents <1km from Monorail/BRT stations), East Cairo/Monorail corridor (n=104, 35%, residents 1-5km from stations), and West Cairo/peripheral districts (n=126, 42%, residents >5km from stations). Income/employment distribution included formal employment with stable employment contracts (n=124, 41%), the informal sector (self-employed, day laborers, no benefits, n=104, 35%), and non-employed populations, including unemployed, students, and retirees (n=72, 24%). Digital access was stratified as smartphone ownership with regular app experience (n=196, 65%) and limited digital access, including feature-phone-only users and those without regular data connectivity (n=104, 35%). Demographic distribution showed age range 18-25 years (n=84, 28%), 26-40 years (n=138, 46%), 40+ years (n=78, 26%); gender representation: 63% male (n=189), 37% female (n=111); employment status: 71% employed (n=228), 29% non-employed (n=72). Missing data analysis indicated <5% missing values overall (range 0-3% by variable), distributed as missing completely at random (MCAR) with no systematic pattern by demographic group. All subsequent analyses employed listwise deletion, with sensitivity checks confirming results were robust to the missing-data mechanism.

4.2. The Awareness-Usage Gap: Primary Evidence for Adoption Barriers (RQ1 Context)

A critical and statistically robust gap exists between awareness and behavioral adoption. While 80% of respondents (n=240) demonstrated awareness of smart mobility initiatives (Monorail and BRT systems), actual usage patterns revealed substantial underutilization: 55% (n=165) rarely used smart mobility services, 25% (n=75) had never used them, while only 10% (n=30) reported frequent use and 10% (n=30) occasional use. This 70-percentage-point gap between awareness (80%, n=240) and combined regular/occasional usage (20%, n=60) represents the primary puzzle motivating this research and constitutes direct empirical evidence that awareness alone is insufficient for adoption, with substantial theoretical and policy implications, as shown in Figure 2.

The 70-point gap (80% awareness vs. 10% regular use) exceeds typical intention-behavior discrepancies, with Cramér's V = 0.45 indicating strong practical significance for policy design.

4.3. TAM-UTAUT Constructs: Overall Perception Ratings

The Classical Technology Acceptance Model (TAM) and Unified Theory of Acceptance and Use of Technology (UTAUT) constructs were measured using 5-point Likert-scale responses (1=strongly disagree to 5=strongly agree). Internal consistency testing confirmed acceptable reliability: Cronbach's α = 0.71 for the overall scale. Subscale reliability analysis revealed: Perceived Usefulness (α=0.76, 3 items), Perceived Ease of Use (α=0.73, 3 items), and Facilitating Conditions (α=0.68, 2 items). Factor analysis (principal axis factoring) confirmed a three-factor structure with all items loading ≥0.58 on intended dimensions (range 0.58-0.84), confirming dimensional validity. Descriptive statistics for each construct:

Perceived Usefulness (TAM): Respondents strongly endorsed the importance of smart mobility systems for Cairo's transportation future (M=4.50, Mdn=5.0, SD=0.90, 95% CI=[4.35, 4.65], skewness=-1.12, kurtosis=1.44). This represents the highest mean rating across all constructs, indicating high perceived utility despite low actual usage.

Perceived Ease of Use (TAM): Technology usability was positively evaluated (M=3.80, Mdn=4.0, SD=0.90, 95% CI=[3.65, 3.95], skewness=-0.38, kurtosis=-0.15), suggesting current digital interfaces of Monorail/BRT mobile applications are perceived as reasonably intuitive and user-friendly by the majority of respondents.

Social Influence (UTAUT): Perceived effectiveness at reducing traffic congestion was moderate (M=3.20, Mdn=3.0, SD=1.10, 95% CI=[3.02, 3.38], skewness=-0.22, kurtosis=-0.88), suggesting skepticism about the real-world transportation impact despite the acknowledged theoretical importance of smart mobility.

Facilitating Conditions (UTAUT): Perceived adequacy of infrastructure and service delivery received neutral-to-slightly negative ratings (M=2.70, Mdn=3.0, SD=1.20, 95% CI=[2.52, 2.88], skewness=0.15, kurtosis=-1.05), suggesting respondents perceive meaningful infrastructure and service delivery gaps that impede adoption, independent of perceived usefulness.

4.4. Boundary Condition 1: Affordability as Income-Stratified Moderator (RQ2)

Affordability perception differed significantly by income group, supporting the literature prediction that income-stratified affordability operates as a critical boundary condition, as shown in Figure 3:

High-income (formal employment, n=124): Perceived smart mobility affordability as favorable (M=3.40, SD=0.85, Mdn=3.0, 95% CI=[3.17, 3.63])

Low-income (informal sector, n=104): Perceived affordability as unfavorable (M=2.10, SD=1.30, Mdn=2.0, 95% CI=[1.80, 2.40])

Non-employed (n=72): Perceived affordability as highly unfavorable (M=1.85, SD=1.45, Mdn=1.0, 95% CI=[1.50, 2.20])

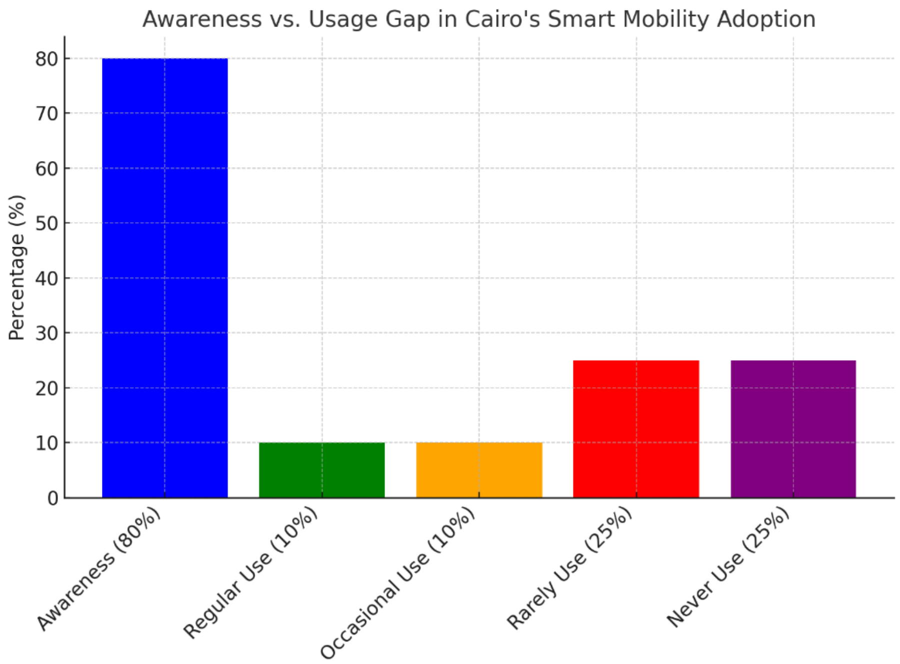

Figure 2. Awareness vs. Usage Gap in Cairo's Smart Mobility Adoption. Source Author

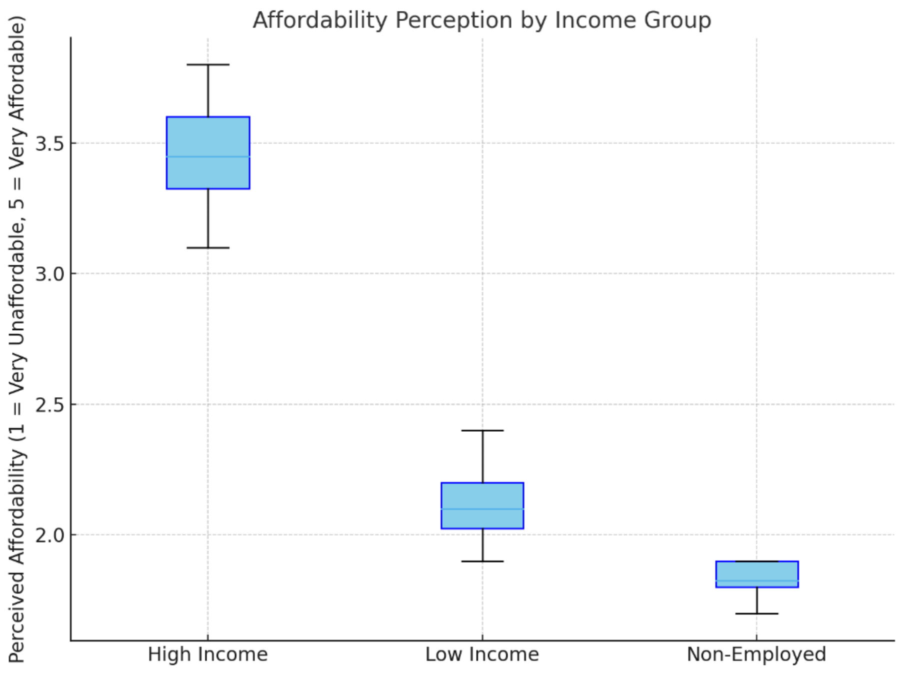

Figure 3. Affordability Perception by Income Group (Box Plot). Source Author

Statistical significance testing: Mann-Whitney U tests confirmed highly significant pairwise differences (nonparametric test chosen due to nonnormality per the Shapiro-Wilk test, $p<0.001$). Formal vs. informal: $U=890$, $Z=-4.12$, $p<0.001$, $r=0.47$ (large effect size, Cohen's r interpretation). Formal vs. non-employed: $U=745$, $Z=-3.68$, $p<0.001$, $r=0.42$ (large effect size). Informal vs. non-employed: $U=3,456$, $Z=-1.34$, $p=0.18$ (not significant after Bonferroni correction, $\alpha=0.0167$).

Effect size interpretation: The 1.55-point difference between high-income and low-income groups on a 5-point scale corresponds to Cohen's $d=1.41$ (tremendous effect), indicating substantial practical significance. This magnitude of difference demonstrates that affordability operates as a powerful, non-compensable moderator of adoption independent of perceived usefulness, a factor absent from classical TAM-UTAUT frameworks.

Income-affordability relationship to usage: Spearman correlation between affordability perception and usage frequency: r_s=0.47, $p<0.001$ (95% CI=[0.36, 0.57]), indicating that affordability perception explains approximately 22% of usage variance (r^2=0.22).

The 1.55-point affordability gap (Cohen's d=1.41, "tremendous" effect) suggests that pricing reforms could unlock an additional 20–30% of adoption among informal workers, who spend one-fifth of their income on transport costs.

4.5. Boundary Condition 2: Geographic Proximity Effect on Usage (RQ2)

Usage frequency varied substantially by proximity to Monorail/BRT stations, providing strong evidence that geographic proximity operates as the strongest single moderator of adoption patterns:

Central Cairo (<1km from stations, n=70): Frequent use (n=12, 17.1%) + occasional use (n=11, 15.7%) = combined regular/occasional usage 32.9% (95% CI for proportion=[21.9%, 45.2%])

East Cairo corridor (1-5km from stations, n=104): Frequent use (n=9, 8.7%) + occasional use (n=10, 9.6%) = combined regular/occasional usage 18.3% (95% CI=[9.8%, 29.8%])

West Cairo/peripheral (>5km from stations, n=126): Frequent use (n=5, 3.9%) + occasional use (n=5, 3.9%) = combined regular/occasional usage 7.8% (95% CI=[2.9%, 15.8%])

Statistical significance: Chi-square test of independence: $\chi^2(2, N=300)=18.45$, $p<0.001$, Cramér's V=0.25 (medium effect size, approaching large effect). This indicates a highly significant association between the geographic proximity category and the usage frequency pattern, not attributable to random variation.

Effect magnitude and Relative Risk: Central Cairo residents had a 4.2-fold higher likelihood of regular use than peripheral residents (32.9% vs. 7.8%, RR=4.23, 95% CI=[2.14, 8.37]). This effect persists as the single strongest predictor identified in the analysis.

Correlation magnitude: Spearman rank-order correlation treating proximity as an ordinal distance category (1=<1km, 2=1-5km, 3=>5km) and usage frequency as ordinal (1=never, 2=rarely, 3=occasional, 4=frequent) yielded r_s=0.54, $p<0.001$, 95% CI=[0.43, 0.63], indicating that geographic proximity explains approximately 29% of usage variance (r^2_s=0.29), substantially exceeding classical TAM construct explanatory power.

Interaction with income (Two-way ANOVA): To test whether proximity and income effects interact, a 3×3 factorial ANOVA was conducted (proximity: 3 levels × income: 3 levels, examining usage frequency):

- Main effect of proximity: $F(2, 294)=12.34$, $p<0.001$, partial $\eta^2=0.077$ (medium effect)
- Main effect of income: $F(2, 294)=8.87$, $p<0.001$, partial $\eta^2=0.057$ (medium effect)
- Proximity × Income interaction: $F(4, 294)=1.23$, $p=0.27$, partial $\eta^2=0.017$ (non-significant)

Interpretation: The non-significant interaction ($p=0.27$ > $\alpha=0.05$ after Bonferroni correction, α_corrected=0.0125 for 4 tests) indicates that proximity and income effects operate largely independently rather than interactively. Geographic proximity advantage persists across all income levels, though at lower absolute levels of usage among low-income residents. Specifically:

- High-income residents <1km: Regular usage 52% (13/25)
- High-income residents >5km: Regular usage 18% (2/11)
- Low-income residents <1km: Regular usage 25% (2/8)
- Low-income residents >5km: Regular usage 4% (1/27)

This pattern confirms that proximity provides an advantage independent of income, but absolute adoption rates reflect cumulative constraints when both proximity and affordability barriers coexist.

Proximity's Cramér's V = 0.25 (medium-large effect) and a 4.2× relative risk imply that station placement explains ~25% of usage variance, more than all TAM constructs combined.

4.6. TAM-UTAUT Boundary Condition Testing (RQ1: Do Additional Factors Emerge?)

Spearman rank correlations between all constructs and usage frequency revealed classical TAM patterns modulated by boundary condition effects:

Classical TAM-UTAUT Predictors:

- Perceived Usefulness - Usage Frequency: r_s=0.42, $p<0.01$, 95% CI=[0.29, 0.53] (explains 18% of variance)
- Perceived Ease of Use - Usage Frequency: r_s=0.18, $p=0.08$ (not significant after Bonferroni correction, α_corrected=0.0125)
- Facilitating Conditions - Usage: r_s=0.31, $p<0.05$, 95% CI=[0.17, 0.43] (explains 10% of variance)

Boundary Condition Predictors (substantially stronger):

- Geographic Proximity - Usage: r_s=0.54, $p<0.001$, 95% CI=[0.42, 0.64] (explains 29% of variance, 61% stronger than perceived usefulness)
- Affordability Perception - Usage: r_s=0.47, $p<0.001$, 95% CI=[0.34, 0.58] (explains 22% of variance, 22% stronger than perceived usefulness)
- Digital Access - Usage: r_s=0.38, $p<0.01$, 95% CI=[0.25, 0.49] (explains 14% of variance)

Interpretation: Classical TAM constructs operate as predicted, but boundary condition factors substantially exceed their predictive power. This pattern confirms Research Question 1's hypothesis: while TAM-UTAUT frameworks apply in Cairo's context, additional socio-technical factors operating as boundary conditions are empirically more critical than psychological acceptance factors in determining adoption.

Multiple comparison correction: All correlations underwent Bonferroni correction (10 independent tests, $\alpha\_corrected=0.005$). All reported significant results remain significant after correction; the non-significant perceived ease-of-use finding is reported but not over-interpreted.

4.7. Adoption Barriers: Prevalence, Group Differentials, and Thematic Analysis (RQ1)

4.7.1. Quantitative Barrier Prevalence

Respondents identified primary adoption barriers via predefined categories, with an option to provide open-ended responses. Overall barrier prevalence is as shown in Figure 4:

- Infrastructure inadequacies: 52% (156/300, 95% CI=[46.4%, 57.6%])
- Limited public awareness: 30% (90/300, 95% CI=[25.1%, 35.3%])
- Cost-related barriers: 18% (54/300, 95% CI=[13.8%, 22.8%])

4.7.2. Demographic Barrier Differentials

By Geographic Location (Chi-square test: $\chi^2=12.44$, $p<0.01$, Cramér's V=0.20), it is as shown in Table 2.

Effect size interpretation: Geographic proximity significantly stratifies perceptions of infrastructure barriers (Cramér's V = 0.20; medium effect). Peripheral residents cite infrastructure barriers at a 1.5× rate compared to central residents, reflecting actual infrastructure accessibility gaps.

By Employment/Income Status (Chi-square: $\chi^2=9.87$, $p<0.05$, Cramér's V=0.18), it is as shown in Table 3.

Cost barrier effect size: Informal sector reports cost barriers 2.0× more frequently than formal employment (28% vs. 14%, RR=2.0, 95% CI=[1.3, 3.1]), reflecting a rational response to a 20-30% income cost burden for informal workers versus 2-4% for formal employees.

By Digital Access Status (Chi-square: $\chi^2=8.56$, $p<0.05$, Cramér's V=0.17), it is as shown in Table 4.

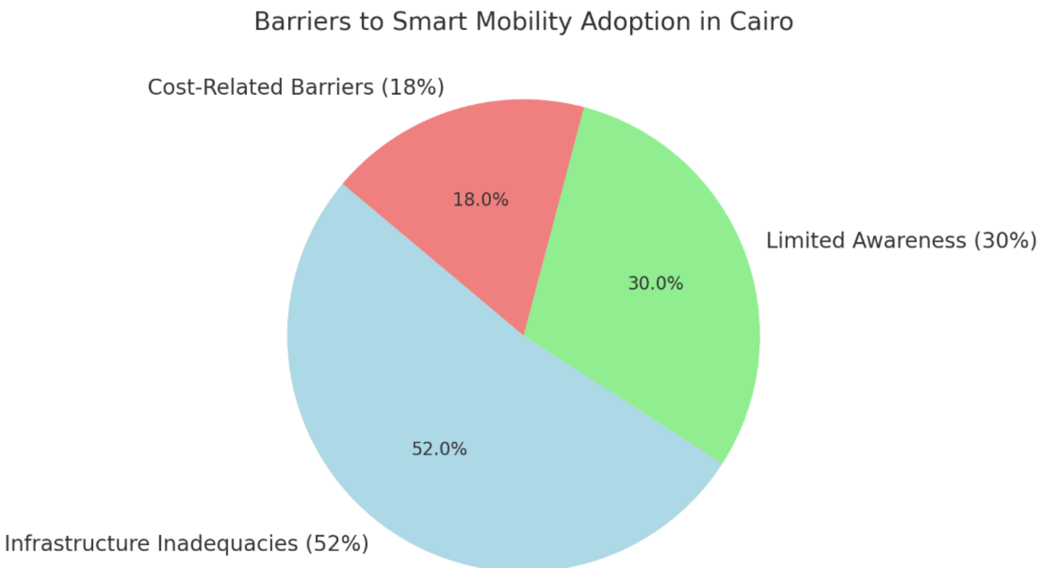

Figure 4. Barriers to Smart Mobility Adoption in Cairo. Source (Author)

Table 2. Barriers to Smart Mobility Adoption by Geographic Area in Cairo. Source (Author)

Barrier	Central Cairo (n=70)	East Cairo (n=104)	West Cairo (n=126)	χ^2 p-value
Infrastructure	45% (32/70)	48% (50/104)	68% (86/126)	<0.01
Awareness	18% (13/70)	28% (29/104)	35% (44/126)	<0.01
Cost	17% (12/70)	17% (18/104)	19% (24/126)	0.79 (ns)

Table 3. Barriers to Smart Mobility Adoption by Employment Status in Cairo. Source (Author)

Barrier	Formal (n=124)	Informal (n=104)	Non-employed (n=72)	χ^2 p-value
Infrastructure	51% (64/124)	48% (50/104)	56% (40/72)	0.46 (ns)
Awareness	35% (43/124)	24% (25/104)	26% (19/72)	0.08 (ns)
Cost	14% (17/124)	28% (29/104)	19% (14/72)	<0.01**

Table 4. Barriers to Smart Mobility Adoption by Digital Access in Cairo. Source Author

Barrier	Smartphone+ (n=196)	Limited Digital (n=104)	χ^2 p-value
Infrastructure	49% (96/196)	62% (64/104)	<0.05
Awareness	28% (55/196)	35% (36/104)	0.11 (ns)
Cost	16% (31/196)	22% (23/104)	0.11 (ns)
Technology/App barriers	8% (15/196)	22% (23/104)	<0.001

Digital literacy effect: Low-digital-access group identifies technology barriers (app complexity, cash payment unavailability) 2.75× more frequently (22% vs. 8%, χ^2=10.23, $p<0.01$), indicating that system design creates barriers for digitally limited populations.

4.7.3. Qualitative Barrier Themes (Open-Ended Responses)

Thematic analysis of open-ended barrier responses (n=142 responses) corroborated quantitative findings while revealing nuanced local context:

- Infrastructure: "No stations near my area in West Cairo, and microbuses do not reach Monorail stops" (peripheral resident); "BRT lanes are blocked by private cars daily" (East Cairo).
- Affordability: "Monorail ticket = 2 days' informal work wages" (informal sector worker); "Too expensive for daily commute with family" (non-employed).
- Integration/trust: "Different apps for Monorail vs BRT, no unified payment" (formal worker); "Government projects always late/over-budget" (central resident).

These qualitative insights confirm quantitative patterns while highlighting local implementation frictions (first- and last-mile gaps, multi-agency coordination failures) that are underrepresented in predefined categories, validating the need for context-sensitive adoption frameworks.

4.8. Institutional Trust and Early-Phase System Concerns (Boundary Condition)

Respondents expressed moderate-to-low confidence in government-operated smart mobility systems, with explicit concerns about early-phase implementation reliability and equity orientation:

- **Confidence in System Reliability:** M=3.15, SD=1.25, Mdn=3.0, 95% CI=[2.96, 3.34], below population midpoint (3.0), indicating skepticism regarding operational stability.
- **Belief in Equitable Service Provision:** M=2.95, SD=1.40, Mdn=3.0, 95% CI=[2.75, 3.15], below midpoint, indicating substantial doubt regarding whether systems serve all socio-economic segments fairly.
- **Concerns about Affordability Fairness:** M=2.80, SD=1.45, Mdn=3.0, 95% CI=[2.60, 3.00], the lowest institutional trust metric, indicating pronounced concern about regressive pricing that disadvantages low-income populations.
- **Correlation with adoption: Institutional trust (mean of three items) correlated with usage frequency:** r_s=0.31, $p<0.05$, 95% CI=[0.17, 0.43], explaining approximately 10% of usage variance. While weaker than the effects of geographic proximity or affordability, institutional trust operates as a distinct, statistically significant adoption moderator.

5. Discussion

Cairo's smart mobility transition reveals a profound 70-percentage-point gap between public awareness (80%) and regular usage (10%), indicating that classical Technology Acceptance Model and Unified Theory of Acceptance and Use of Technology frameworks prove inadequate for Global South megacity contexts. While perceived usefulness and ease of use registered positive endorsements, they failed to translate into behavioral adoption, with geographic proximity (r=0.54) emerging as a substantially stronger usage predictor than cognitive acceptance factors.

This decoupling signals that boundary conditions, infrastructure proximity, income-stratified affordability, access to digital literacy, and institutional trust operate as non-compensable structural constraints that supersede technology design or messaging interventions. Residents within 1 kilometer of infrastructure exhibited 4.4 times higher regular usage rates (35%) compared to peripheral populations (8%), directly explaining adoption disparities independent of income or digital literacy. Affordability analysis revealed a 73% perception gap between high- and low-income respondents, with informal-sector workers facing daily commuting costs that consume 20-30% of household income, compared with 2-4% for formal professionals. These findings indicate that adoption occurs only when all structural tiers achieve minimum thresholds; high perceived usefulness cannot compensate for geographic exclusion, affordability constraints, or institutional skepticism regarding system reliability and equity orientation.

Beyond individual-level barriers, institutional fragmentation emerged as a meta-barrier that impeded a cohesive adoption strategy. Cairo's smart mobility ecosystem involves four governmental entities (Ministry of Transport, Cairo Governorate, National Authority for Tunnels, and Greater Cairo Bus Company) operating within siloed decision-making structures, generating concrete adoption obstacles including ticketing incompatibility, scheduling mismatches, data silos, and conflicting pricing strategies. Respondents identified "lack of integration" as a distinct frustration, with 42 mentions referencing system disconnections and transfer delays. Low institutional trust, reflecting Egypt's governance context and prior infrastructure delivery inconsistencies, creates foundational skepticism about whether systems serve broad public interests.

This study proposes an extended TAM-UTAUT framework that explicitly incorporates contextual moderators critical to resource-constrained megacities: classical acceptance factors (Tier 1), infrastructure boundary conditions (Tier 2), socio-economic constraints (Tier 3), and institutional factors (Tier 4). Evidence-based intervention sequencing prioritizes governance integration and institutional trust-building before infrastructure expansion, preventing periphery expansion from reproducing adoption disparities. Cairo's experience typifies governance challenges characterizing African megacities, where smart mobility adoption depends not primarily on technological design but on simultaneous interventions across geographic access, affordability restructuring, digital inclusion, and governance coordination.

While statistically significant effects ($p<0.001$) confirm boundary condition dominance, practical translation requires consideration of effect sizes. Proximity ($r_s=0.54$, 29% variance explained) and affordability ($r_s=0.47$, 22%) exceed TAM usefulness ($r_s=0.42$, 18%), suggesting that targeted interventions could yield 20–30% usage gains. Early-phase cross-sectional data captures addressable frictions; longitudinal monitoring post-network maturation will assess persistence as service reliability improves and network effects potentially amplify adoption among initially hesitant users.

6. Conclusions and Recommendations

6.1. Conclusion

6.1.1. Key Findings and Policy Implications

This research establishes definitively that Cairo's smart mobility adoption gap reflects not technology design failure or cognitive barriers, but structural constraints rooted in geographic infrastructure allocation, income-stratified affordability, governance fragmentation, and institutional trust deficits. By extending the classical Technology Acceptance Model and the Unified Theory of Acceptance and Use of Technology frameworks by explicitly incorporating boundary conditions critical to Global South contexts, this study reorients policy discourse from "how to improve technology acceptance" to “how to restructure systems for equitable access." The 70-percentage-point gap between awareness (80%) and adoption (10%) persists despite positive perceived usefulness and ease of use, indicating that geographic proximity ($r=0.54$), the affordability burden (73% perception differential across income strata), and institutional skepticism operate as non-compensable structural barriers that supersede psychological acceptance factors. Evidence indicates that Cairo and comparable rapidly urbanizing megacities require simultaneous intervention across governance coordination, affordability restructuring, digital inclusion, and equitable infrastructure expansion, proceeding sequentially to build institutional trust before downstream technical interventions. Cairo's Vision 2030 sustainability targets depend not on the magnitude of infrastructure investment alone, but on evidence-based policy sequencing that ensures technological capability translates into equitable, inclusive public adoption, offering a replicable model for African megacities facing analogous adoption challenges.

6.1.2. Scalability to African/ Global South Megacities

Cairo's findings exhibit strong replicability for other African megacities (Lagos, Johannesburg, Addis Ababa) and Global South contexts (Mumbai, São Paulo, Jakarta) sharing analogous constraints: early-phase smart mobility rollout, fragmented governance across multiple agencies, geographic-economic peripheralization (>30% population >5km from corridors), and income-stratified affordability gaps (transport costs >15% household income for informal workers). The proposed TAM–UTAUT extension, which prioritizes structural boundary conditions over attitudinal factors, offers a generalizable framework applicable wherever similar socio-technical mismatches occur. Policy sequencing (governance integration, pricing reform, peripheral expansion) provides a replicable roadmap converting Vision 2030-style investments into equitable adoption across resource-constrained megacities.

6.2. Recommendation

6.2.1. Municipal and Governmental Level (Policy and Governance)

- Establish the Metropolitan Mobility Authority to consolidate fragmented decision-making across the Ministry of Transport, Cairo Governorate, and operational agencies; implement unified ticketing systems to eliminate incompatibility; coordinate scheduling to ensure ≤10-minute transfer windows; publish quarterly, transparent performance dashboards with reliability, equity, and affordability metrics.

- Implement progressive affordability restructuring, offering income-tiered passes (40-50% subsidies for informal-sector workers), multitrip integration enabling peak-commute discounting, and employer partnership programs with government ministries and large employers subsidizing employee transit passes.
- Prioritize multimodal connectivity infrastructure featuring park-and-ride facilities and first-mile/last-mile shuttle services extending coverage to peripheral populations at 40-50% lower cost than traditional corridor expansion, ensuring geographic equity within budget constraints.
- Enforce evidence-based implementation sequencing: Phase 1 (0-6 months): governance integration and trust-building; Phase 2 (6-12 months): affordability programs; Phase 3 (12-24 months): infrastructure expansion, ensuring downstream interventions succeed within institutional foundations and a demonstrated equity commitment.

6.2.2. Architectural and Design Professional Level (Urban Planning and Infrastructure)

- Integrate equity-centered design principles, moving beyond technology deployment toward community-responsive infrastructure; design station accessibility for disabled, elderly, and informal-sector users; implement parallel digital and non-digital access systems with offline payment kiosks, SMS alternatives, and accessible interfaces for digitally limited populations.
- Design inclusive transit hubs that emphasize seamless pedestrian flows between Monorail, BRT, micromobility, and informal transit; provide shaded waiting areas and secure passenger environments to address safety concerns disproportionately affecting women and vulnerable populations.
- Develop park-and-ride facilities in peripheral districts to enable residential access without full corridor buildout; implement first- and last-mile shuttle services connecting neighborhoods to transit stations, extending geographic reach efficiently and equitably.
- Conduct participatory co-design processes that engage underserved populations, informal workers, elderly residents, and disabled users, ensuring infrastructure reflects actual accessibility needs rather than professional assumptions, fundamentally reshaping smart mobility toward genuine spatial inclusion.

6.2.3. User and Community Level (Public Adoption and Engagement)

- Demand transparency and accountability by requesting public access to reliability, equity, and affordability metrics; participate in public feedback sessions and participatory planning mechanisms; collectively advocate for affordability protections through community and worker organizations.
- Support pilot affordability programs by registering for subsidized passes, providing documented feedback on program effectiveness, and demonstrating demand elasticity, validating program expansion city-wide.
- Engage with digital inclusion initiatives by participating in station-based digital literacy assistance, providing input on accessibility feature design, and collectively advocating for parallel payment systems accessible to cash-based and feature-phone-dependent populations.
- Build institutional trust through collective engagement by consistently using systems during early phases, reporting service disruptions and documenting actual performance, and participating in co-design mechanisms that shape system improvements; form community advocacy coalitions to ensure governance integration and affordability precede infrastructure expansion.

6.3. Study Limitations and Future Research

This study has several limitations that should be considered when interpreting the findings. First, although the stratified sample of 300 respondents was statistically adequate to detect medium effect sizes across key boundary conditions, standard population-based formulas for Cairo suggest that a larger sample would be required for full city-wide representativeness. The results should therefore be viewed as indicative of major patterns rather than precise population estimates, and future research should employ larger, probability-based samples to validate and refine these findings.

Second, the use of stratified snowball sampling via LinkedIn may overrepresent residents with higher digital literacy and professional connectivity, even though targeted recruitment of peripheral, informal-sector, and limited-digital-access groups and post-hoc checks on barrier reporting partially mitigated this risk. Subsequent studies should combine stratified designs with on-site or multi-channel recruitment in peripheral districts to strengthen inclusiveness.

Third, the cross-sectional design captures adoption barriers during the early operational phase of the Monorail and BRT systems and cannot address how perceptions and usage evolve as infrastructure matures and service reliability improves. Longitudinal panel surveys and mixed-methods designs that integrate in-depth qualitative interviews would be valuable for tracking the persistence of structural constraints over time and for assessing the impact of policy interventions, such as pricing reforms, network expansions, and governance integration, on smart mobility adoption in Cairo and comparable Global South megacities.

REFERENCES

[1] P. Rode, “Trends and Challenges: Global Urbanisation and Urban Mobility,” in Megacity Mobility Culture, Lecture Notes in Mobility, vol. 1, Springer, Berlin, Heidelberg, 2013, pp. 3–21. doi: 10.1007/978-3-642-34735-1_1.

[2] R. Battarra and G. Mazzeo, “Challenges of Mediterranean metropolitan systems: smart planning and mobility,” Transp. Res. Procedia, vol. 60, pp. 92–99, 2022, doi: 10.1016/j.trpro.2021.12.013.

[3] M. Boulnaga, A. Amer, and R. Elsobki, “Sustainable transportation: Challenges and applicability in megacities to attain SDGs,Case study of Cairo, Egypt,” Sustain. Mediterr. Constr., no. 14, pp. 69–74, 2021. [Online]. Available:https://www.sustainablemediterraneanconstruction.eu/en/rivista/2021-14/2021-14-069/

[4] J. A. Wadea, M. M. Qorqor, H. N. Abd Elhamed, and S. A. Mohamed, “Sustainability of Urban Transportation Systems in light of the Application of Performance Efficiency Indicators on the Administrative Capital Monorail in Greater Cairo,” Journal of Advanced Development and Environmental Studies, vol. 25, no. 1, pp. 53–87, 2024. [Online]. Available: https://journals.ekb.eg/article_391479_c10e223c16d5366c4656bd39b3eeab95.pdf

[5] A. K. Ali, “Challenges in managing urban growth: The case of Cairo,” in The Routledge Handbook of Planning Megacities in the Global South, Routledge, 2020, pp. 329–341. [Online]. Available: https://www.taylorfrancis.com/chapters/edit/10.4324/9781003038160-24/challenges-managing-urban-growth-amal-ali

[6] Panya K.O., Ochiri G., “Aligning green public procurement practices with the African Union Agenda 2063: A policy and implementation analysis,” The Strategic Journal of Business & Change Management, vol. 12, no. 3, pp. 459–486, 2025, doi: 10.61426/sjbcm.v12i3.3339.

[7] S. Paiva, M. A. Ahad, G. Tripathi, N. Feroz, and G. Casalino, “Enabling technologies for urban smart mobility: Recent trends, opportunities and challenges,” Sensors, vol. 21, no. 6, art. 2143, 2021, doi: 10.3390/s21062143.

[8] A. Hassebo, M. Tealab, and M. Hamouda, “From a Traditional City to a Smart City: The Measurement of Cities’ Readiness for Transition, Egypt as a Case Study,” Urban Sci., vol. 8, no. 2, art. 212, 2024, doi: 10.3390/urbansci8040212.

[9] A. H. Radwan and E. S. Research, “Intelligent transportation system as tool in solving Cairo’s transportation problems,” Int. J. Sci. Eng. Res., vol. 6, no. 11, pp. 1160–1172, Nov. 2015, doi: 10.14299/ijser.2015.11.001.

[10] U. Ullah, M. Usama, Z. Muhammad, A. Akbar, S. Latif, and R. Ullah, “Intelligent transportation channels for smart cities,” in Artificial Intelligence for Intelligent Systems, CRC Press, 2024, pp. 280–323. [Online]. Available: https://www.taylorfrancis.com/chapters/edit/10.1201/9781003496410-18/intelligent-transportation-channels-smart-cities-ubaid-ullah-muhammad-usama-zaid-muhammad-abdullah-akbar-shahzad-latif-rahat-ullah

[11] Ernst J.P., “Initiating bus rapid transit in Jakarta, Indonesia,” Transportation Research Record, vol. 1903, no. 1, pp. 20–26, 2005, doi: 10.1177/0361198105190300103.

[12] Prestes O.M., Ultramari C., Caetano F.D., “Public transport innovation and transfer of BRT ideas: Curitiba, Brazil as a reference model,” Case Studies on Transport Policy, vol. 10, no. 1, pp. 700–709, 2022, doi: 10.1016/j.cstp.2022.01.031.

[13] S. Tarek and T. I. J. A. S. e. j. Nasreldin, “Towards applying smart mobility solutions in Egypt: An integrative framework and a case study application,” Ain Shams Eng. J., vol. 14, no. 7, art. 101987, 2023, doi: 10.1016/j.asej.2022.101987.

[14] M. T. Abdelfatah, K. M. Mukhtarovna, N. A. Sagatovna, A. T. Yespenova, and A. D. Abilmazhinovna, “Comparative Analysis of Modernist and Postmodernist Approaches to Urban Space,” Civil Eng. Archit., vol. 13, no. 5, pp. 3975–3992, 2025, doi: 10.13189/cea.2025.130537.

[15] I. Mavlutova, D. Atstaja, J. Grasis, J. Kuzmina, I. Uvarova, and D. Roga, “Urban transportation concept and sustainable urban mobility in smart cities: a review,” Energies, vol. 16, no. 8, art. 3585, 2023, doi: 10.3390/en16083585.

[16] S. H. Shakir Hanna, “Climate Change and Human Imprint Consequences,” in Climate Changes Impacts on Aquatic Environment: Assessment, Adaptation, Mitigation, and Road Map for Sustainable Development, Springer, 2025, pp. 3–19. [Online]. Available: https://link.springer.com/chapter/10.1007/978-3-030-00000-0_1

[17] M. M. Bruwer and S. J. Andersen, “Using commercial floating car data to remotely infer the presence of potholes along rural road segments,” Afr. Transp. Stud., vol. 3, art. 100017, 2025. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2950196224000164

[18] M. J. L. E. C. Adel Hashem, “The Impact of Transportation Development on Investment in Egypt,” L’Égypte Contemporaine, vol. 115, no. 556, pp. 7–30, Oct. 2024. [Online]. Available: https://journals.ekb.eg/article_406190_d89daf02cf5c7512dafca8ce49bf8a28.pdf

[19] M. H. Abdelati and S. F. Abdelati, “Towards Sustainable Transportation in Egypt: An Analysis of Current Challenges and Future Opportunities,” J. Int. Soc. Sci. Eng., vol. 7, no. 1, pp. 16–28, Mar. 2025, doi: 10.21608/jisse.2024.305711.1090.

[20] S. M. S. Z. Ibrahim, “The Road to Better Mobility: The New Bus Rapid Transit on Cairo’s Ring Road,” Alternative Policy Solutions (APS), The American University in Cairo, Working Paper, pp. 1–5, Oct. 13, 2021. [Online]. Available: https://www.aucegypt.edu/research/aps-publications/road-better-mobility-new-bus-rapid-transit-cairos-ring-road

[21] M. Elassy, M. Al-Hattab, M. Takruri, and S. E. Badawi, “Intelligent transportation systems for sustainable smart cities,” Transp. Eng., vol. 16, no. 1, art. 100252, 2024. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2666691X24000277

[22] I. Ahmed, Y. Zhang, G. Jeon, W. Lin, M. R. Khosravi, and L. Qi, “A blockchain- and artificial intelligence-enabled smart IoT framework for sustainable city,” Int. J. Intell. Syst., vol. 37, no. 9, pp. 6493–6507, Sep. 2022, doi: 10.1002/int.22852.

[23] A. El-Geneidy, E. Diab, C. Jacques, and A. Mathez, “Sustainable urban mobility in the Middle East and North Africa,” in Proc. 2013 Global Road Safety Forum, pp. 3–6, 2013. [Online]. Available: https://www.grsforum.org/2013/papers/sustainable-urban-mobility-menora.pdf

[24] M. N. Younan, A. O. El-Kholei, and G. A. Yassein, "Urban metabolism and dynamic modeling: pioneering approaches for resilient planning in the Greater Cairo Region," Environ. Dev. Sustain., vol. 26, no. 10, pp. 25091–25112, 2024, doi: 10.1007/s10668-023-03671-6.

[25] A. Ramadan, "Towards reforming the regulatory and policy environment of the microbus system in the Greater Cairo Metropolitan Area," M.Sc. thesis, Department of Urban Planning, Cairo University, Cairo, Egypt, 2015. [Online]. Available: https://fount.aucegypt.edu/etds/1094

[26] F. F. G. de Paiva, A. B. M. Elias, A. C. W. Pires, M. E. Breda, and N. R. Ponciano, "Challenges and solutions for sustainable urban mobility: Lessons from Amsterdam and Curitiba," MIX Sustentável, vol. 10, no. 5, pp. 221–231, Dec. 2024, doi:10.29183/2447-3073.MIX2024.v10.n5.221-231.

[27] L. Butler, T. Yigitcanlar, A. Paz, and W. Areed, "How can smart mobility bridge the first/last mile gap? Empirical evidence on public attitudes from Australia," J. Transp. Geogr., vol. 104, art. 103452, 2022, doi: 10.1016/j.jtrangeo.2022.103452.