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Electric Mobility Integration in Indian Urban Planning: Challenges, Opportunities, and Policy Implications

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Abstract

India's urban transport system is facing unprecedented challenges due to rapid population growth, vehicular congestion, and escalating pollution levels. Against this backdrop, the transition toward electric mobility (e-mobility) offers a promising pathway for sustainable urban development. This study investigates the extent to which electric mobility is being integrated into urban planning in Indian cities. It explores critical challenges such as inadequate charging infrastructure, limited policy coordination, and citizen hesitancy. Drawing upon both primary data collected through surveys in five urban centres—and secondary sources from government and institutional reports, the research applies statistical methods, including factor analysis and regression modelling, to examine the drivers of electric vehicle (EV) adoption. The findings reveal that infrastructure readiness and public policy awareness are strong predictors of urban EV acceptance. The study concludes by offering practical policy recommendations, such as zoning reforms and enhanced fiscal incentives, aimed at creating EV-supportive urban environments aligned with national climate goals.
Key Words: *Electric Vehicle, Electric Mobility Integration, Indian Urban Planning, Policy Implications.*

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1. Introduction

India's urban landscape is undergoing a transformative shift, driven by economic growth, demographic changes, and a corresponding surge in private vehicle ownership. According to the Ministry of Housing and Urban Affairs (MoHUA, 2018), India's urban population is expected to exceed 600 million by 2031, placing tremendous pressure on city infrastructure, air quality, and public health. Vehicular emissions contribute significantly to urban air pollution, and traditional internal combustion engine (ICE) vehicles continue to dominate Indian roads, exacerbating environmental challenges.

In response, electric mobility (e-mobility) has emerged as a key solution to address these challenges. As a clean, energy-efficient alternative, electric vehicles (EVs) align with India's commitment to the Paris Agreement and its targets for reducing greenhouse gas emissions. National initiatives such as the National Electric Mobility Mission Plan (NEMMP, 2013), Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME-I and FAME-II), and state-specific EV policies have sought to accelerate the transition. However, the extent to which electric mobility has been systematically integrated into urban planning frameworks remains under-explored.

This study addresses the critical intersection of urban planning and electric mobility adoption in Indian cities. It aims to investigate the current status of EV integration within urban systems, identify the systemic barriers inhibiting growth, and propose forward-looking strategies for urban planners and policymakers. The research takes a multidisciplinary approach, examining technical, economic, infrastructural, and behavioural factors influencing EV adoption in India.

To ensure evidence-based insights, the study incorporates both primary data—gathered from urban dwellers and planning authorities—and secondary sources from national policy documents and institutional studies. The use of quantitative tools such as factor analysis and regression modelling adds analytical depth to the evaluation. Ultimately, this research seeks to contribute to the development of inclusive and sustainable urban mobility systems in India.

2. Research Objectives

To structure the scope of the research, the following objectives are established:

- [i] To assess the current state of electric mobility integration in Indian urban planning initiatives.
- [ii] To identify and analyze key infrastructural, policy-related, and behavioural challenges to EV adoption.
- [iii] To evaluate public perception, readiness, and awareness of electric vehicles through empirical methods.
- [iv] To propose actionable policy and planning recommendations that aligns with India’s sustainability and urban development goals.

3. Literature Review

The integration of electric mobility within urban planning has been widely studied across developed economies, yet its exploration within the Indian context remains comparatively limited and fragmented. This review synthesizes research findings across five critical domains: policy frameworks, infrastructure readiness, consumer behaviour, technological enablers, and urban planning practices.

3.1. Policy Framework and Government Initiatives

India’s electric mobility journey began with the National Electric Mobility Mission Plan (NEMMP, 2013), which aimed to achieve national fuel security through electric vehicle adoption. Subsequent schemes like FAME-I (2015) and FAME-II (2019) offered financial incentives for EV purchase and infrastructure development. However, the actual implementation has faced bottlenecks at state and municipal levels due to lack of clarity in interdepartmental coordination (NITI Aayog & Rocky Mountain Institute, 2020).

Recent studies by Sahoo et al. (2021) emphasize the need for local urban planning authorities to align city-level transport master plans with EV transition strategies. Without this vertical policy alignment, the national push often fails to materialize into city-level execution.

3.2. Infrastructure and Charging Ecosystem

Infrastructure is one of the most cited bottlenecks in EV adoption. According to BNEF (2022), India's ratio of EVs to public chargers is far lower than the global average. Chaudhary and Dhir (2020) argue that urban land-use planning has yet to accommodate charging stations in zoning regulations and building codes. The lack of standardized grid infrastructure, especially in Tier-II and Tier-III cities, further complicates EV deployment.

3.3. Public Perception and Consumer Behaviour

Adoption is not only a matter of supply but also of demand readiness. Studies by Kumar and Varghese (2020) found that potential consumers are deterred by "range anxiety," lack of awareness, and the perceived high cost of EVs. Furthermore, there exists a behavioural resistance to switch from ICE vehicles, particularly among middle-income groups (Gupta et al., 2021).

3.4. Technology and Innovation

Battery technology and vehicle performance have seen global advances, but Indian EV markets still depend largely on imports. According to Joshi and Raghuram (2019), local manufacturing remains limited, affecting the cost-efficiency of EVs. The literature also points to the need for smart grid systems and IoT integration to enable intelligent traffic and charging solutions in urban settings.

3.5. Urban Planning and Mobility Integration

Urban planning in India remains reactive rather than proactive. Bansal and Singh (2021) argue that while Smart City missions mention sustainability and mobility, electric vehicle planning is rarely integrated into spatial or transport plans. Instead, the focus remains on short-term infrastructure upgrades. Integrated transport planning—which synchronizes EVs with public transport, pedestrianization, and land use—remains nascent.

4. Research Methodology

This section outlines the methodological framework adopted for the present study. The methodology has been designed to effectively capture the multidimensional aspects of electric mobility integration in Indian urban planning. The study employs a mixed-method approach, combining both quantitative and qualitative strategies to ensure a holistic and data-driven assessment.

4.1. Research Design

The study follows a descriptive and exploratory research design underpinned by a mixed-methods approach. The descriptive dimension captures the current landscape of electric mobility integration, while the exploratory dimension investigates emerging patterns and strategic interventions. This approach facilitates triangulation, enhancing the reliability and depth of the findings by combining structured quantitative data with contextual qualitative insights.

4.2. Data Sources

4.2.1. Primary Data

Primary data were collected through:

A structured survey administered to urban residents and electric vehicle (EV) users/non-users.

In-depth interviews with urban planners, municipal officials, and representatives from transport and energy departments.

The questionnaire was designed to assess key variables such as awareness of EV policies, infrastructure readiness, urban planning responsiveness, and individual readiness to adopt EVs. A 5-point Likert scale was used for attitudinal measures.

4.2.2. Secondary Data

Secondary data were sourced from:

Government reports and policy documents (e.g., NEMMP 2020, FAME-II, Smart Cities Mission).

Reports by NITI Aayog, Ministry of Road Transport and Highways (MoRTH), and Central Electricity Authority (CEA).

Scholarly journals, international white papers, and previous empirical studies in related domains.

4.3. Sampling Framework

4.3.1. Target Population

The target population for this study included:

Urban residents aged between 21–60 years, residing in cities with differing levels of EV penetration.

Urban planning professionals and municipal authorities responsible for city transport and development.

4.3.2. Sampling Technique and Sample Size

A stratified random sampling technique was adopted to ensure demographic and geographic representation. Five Indian cities were selected based on their urban scale and EV policy engagement: Delhi, Pune, Bengaluru, Jaipur, and Lucknow.

A total of 300 valid responses were collected from residents (60 per city) and 5 experts were selected through purposive sampling for interviews.

This sample size was deemed sufficient to draw generalizable inferences and perform multivariate statistical analysis.

4.3.3. Research Instrument

A structured questionnaire was developed based on a review of previous instruments and adapted to suit the Indian urban context. It consisted of five major sections:

[i] Demographic information
[ii] Awareness and perception of EV policies
[iii] Evaluation of infrastructure and urban mobility systems
[iv] Behavioural intention to adopt EVs
[v] Perceived role of urban planning in EV transition

The questionnaire was pilot-tested with 30 respondents, and minor refinements were made based on feedback. Reliability of scales was tested using Cronbach's alpha, which returned values above 0.70 for all constructs, indicating acceptable internal consistency.

4.4. Statistical Tools and Analytical Techniques

To analyze the collected data, the following statistical tools were employed:

4.4.1. Descriptive Statistics

Descriptive analysis was conducted to summarize demographic characteristics and distribution of key variables. Measures such as mean, standard deviation, frequencies, and percentages were used.

4.4.2. Exploratory Factor Analysis (EFA)

EFA was performed using Principal Component Analysis (PCA) with Varimax rotation to identify underlying factors contributing to EV adoption readiness. Sampling adequacy was tested using Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity. Factors with eigenvalues >1 were retained.

4.4.3. Multiple Linear Regression

A multiple regression model was used to test the influence of independent variables on EV Adoption Readiness (dependent variable). The model is specified as:

EV Readiness = β0 + β1(Policy Awareness) + β2(Infrastructure Access) + β3(Environmental Concern) + β4(Urban Planning Alignment) + ε

Where:
EV Readiness = Dependent variable indicating the respondent's willingness/readiness to adopt electric vehicles.

β_0 = Intercept term.

B_1 to β_4 = Coefficients of the independent variables.

Policy Awareness = Awareness and understanding of existing EV policies.

Infrastructure Access = Availability and accessibility of EV-related infrastructure (e.g., charging stations).

Environmental Concern = Degree of concern for environmental issues and climate change.

Urban Planning Alignment = Perceived integration of EV considerations in city planning.

ε = Error term accounting for unexplained variation.

The model's R-squared value, F-statistic, and individual beta coefficients were examined to determine predictive power and significance levels ($p < 0.05$).

4.4.4. Reliability Analysis

Reliability was assessed using Cronbach's Alpha, with values ≥ 0.70 considered acceptable for social science research.

5. DATA ANALYSIS AND INTERPRETATION

This section presents the findings derived from both descriptive and inferential statistical techniques applied to the primary dataset. The analysis focuses on identifying key factors influencing electric vehicle (EV) readiness among urban residents and evaluating the role of urban planning in the successful integration of electric mobility.

5.1. Descriptive Analysis

A total of 300 responses taken form Delhi, Pune, Bengaluru, Jaipur and Lucknow were considered for final analysis taken in equal proportion (i.e. 60 responses from each). The demographic profile of respondents is summarized below:

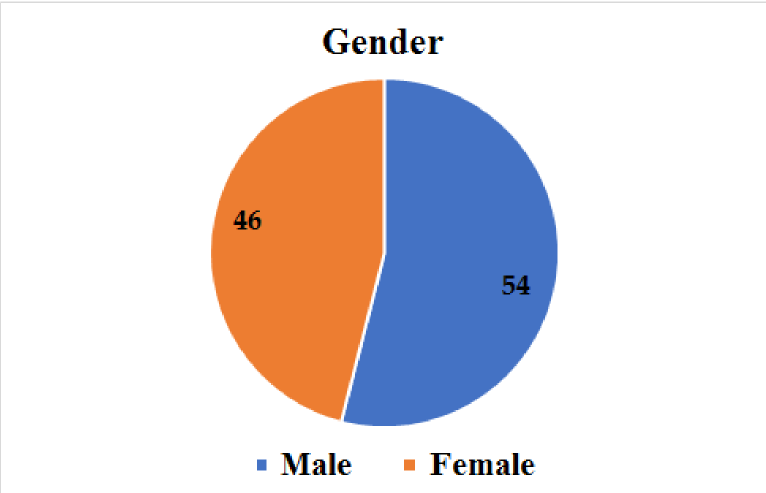

Figure 1: Gender of Respondents

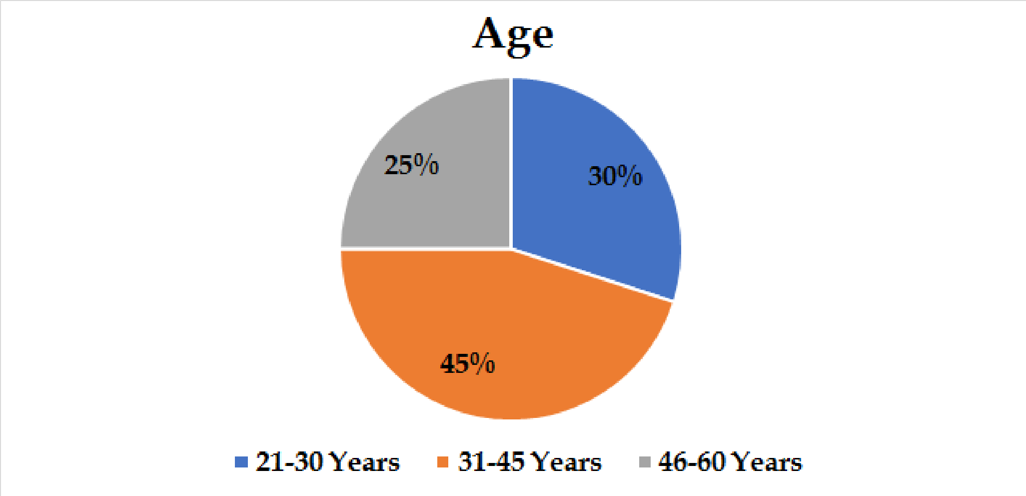

Figure 2: Age of Respondents

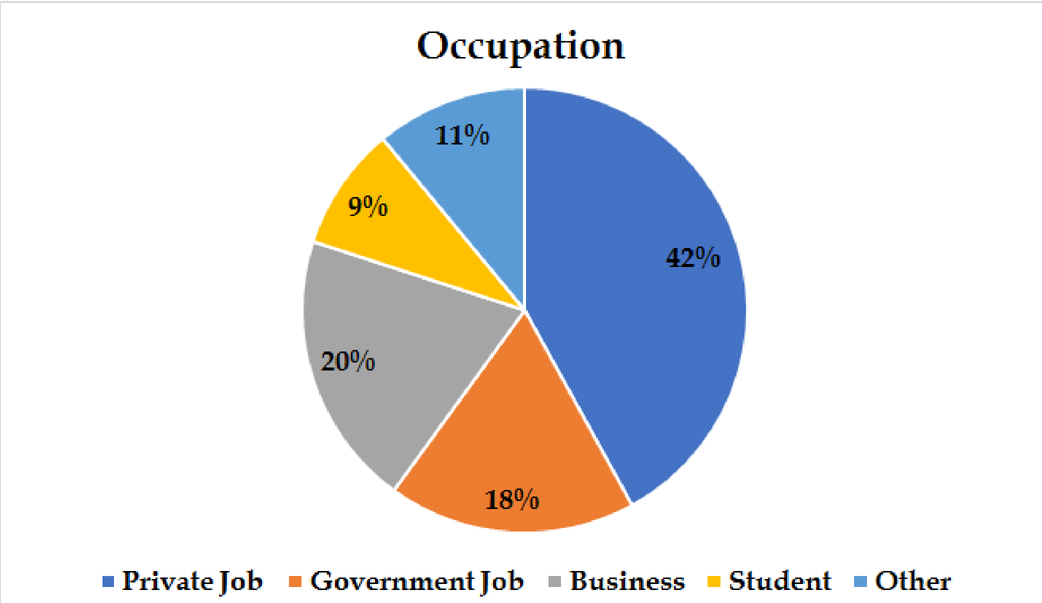

Figure 3: Occupation of Respondents

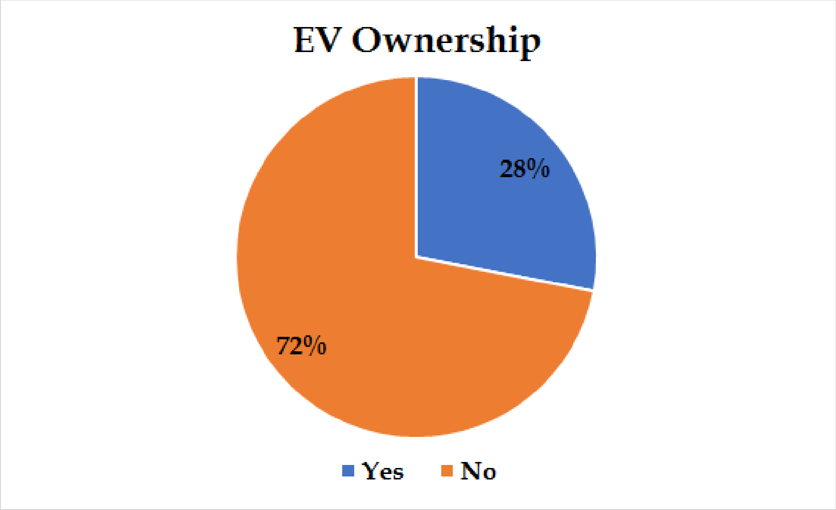

Figure 4: EV Ownership of Respondents

5.2. Reliability Analysis

To ensure consistency of the measurement scales, Cronbach's Alpha was calculated for key constructs:

Table 1: Cronbach's Alpha

Construct	Cronbach's Alpha
Policy Awareness	0.81
Infrastructure Access	0.78
Environmental Concern	0.83
Urban Planning Alignment	0.76
EV Readiness	0.85

All alpha values exceed the 0.70 threshold, confirming internal reliability of the scale items.

5.3. Exploratory Factor Analysis (EFA)

To uncover the underlying structure among the observed variables influencing EV readiness, Exploratory Factor Analysis (EFA) was carried out using Principal Component Analysis (PCA) with Varimax rotation. This technique is appropriate for data reduction and identification of latent constructs when the theoretical model is not pre-specified.

5.3.1. Sampling Adequacy and Factorability

Before performing EFA, the suitability of data for factor analysis was verified using the following tests:

Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy was 0.812, which exceeds the minimum acceptable threshold of 0.60 (Kaiser, 1974), indicating that the sample size was adequate for factor analysis.

Bartlett's Test of Sphericity produced a statistically significant result:
$\chi 2\ (120) = 987.32,\ p < 0.001$

This confirms that the correlation matrix is not an identity matrix and that the variables share sufficient variance to justify the application of EFA.

5.3.2. *Factor Extraction and Rotation*

Using the Kaiser criterion (eigen values > 1), four factors were extracted from the 16-item instrument. These four components collectively explained 71.6% of the total variance, suggesting a strong and coherent factor structure.

The factors were interpreted and labelled as follows:

[i] *Policy Awareness* – Items related to knowledge of government EV policies, incentives, and subsidies.

[ii] *Infrastructure Access* – Items evaluating perceived availability and ease of access to EV charging stations and service networks.

[iii] *Environmental Concern* – Items reflecting respondent attitudes toward climate change and environmental responsibility.

[iv] *Urban Planning Alignment* – Items assessing perceptions of whether city planning incorporates sustainable mobility solutions like EV infrastructure.

5.3.3. *Factor Loadings*

All retained items demonstrated factor loadings above 0.60, meeting the commonly accepted threshold for practical significance (Hair et al., 2019). This confirms that the items within each factor are strongly correlated with their respective constructs and contribute meaningfully to the latent variable measurement.

5.4. Multiple Linear Regression Analysis

A multiple regression analysis was performed to determine the predictive influence of the identified factors on EV Readiness (dependent variable).

5.4.1. *Model Specification*

$$\textbf{EV Readiness} = \beta_0 + \beta_1(\textbf{Policy Awareness}) + \beta_2(\textbf{Infrastructure Access}) + \beta_3(\textbf{Environmental Concern}) + \beta_4(\textbf{Urban Planning Alignment}) + \varepsilon$$

Table 2: Regression Output Summary

Variable	Unstandardized Coefficient (B)	Standard Error	Beta	t	Sig. (p-value)
Constant (β_0)	1.132	0.324	–	3.495	0.001
Policy Awareness	0.384	0.071	0.322	5.408	0.000
Infrastructure Access	0.295	0.066	0.271	4.469	0.000
Environmental Concern	0.261	0.060	0.234	4.350	0.000
Urban Planning Alignment	0.188	0.055	0.176	3.418	0.001

5.4.2. Model Statistics

$R^2 = 0.684$
Adjusted $R^2 = 0.678$
F-statistic = 76.25, $p < 0.001$

5.4.3. Interpretation of Results

The regression model is statistically significant ($p < 0.001$), indicating that the independent variables collectively explain approximately 68.4% of the variance in EV readiness.
Policy Awareness has the highest standardized beta (β = 0.322), highlighting that awareness and understanding of government incentives and EV policies significantly impact readiness to adopt electric mobility.
Infrastructure Access (β = 0.271) plays a crucial role, validating that availability of charging stations and maintenance support is central to user adoption.
Environmental Concern (β = 0.234) positively influences readiness, suggesting that sustainability values are emerging drivers among urban populations.
Urban Planning Alignment (β = 0.176), though slightly lower in strength, remains statistically significant. It indicates that people are increasingly recognizing the importance of integrating EV considerations into broader urban development strategies.

6. KEY FINDINGS

Urban Indian residents exhibit moderate to high EV readiness, provided policy, infrastructure, and planning support is enhanced.
Educational campaigns to improve policy awareness, targeted infrastructure development, and coordinated urban planning interventions are crucial levers to accelerate EV adoption.
Public perception aligns with the notion that electric mobility cannot succeed in isolation—it must be embedded within holistic urban development frameworks.

6.1. Key Findings from Multiple Linear Regression

The regression model used to assess the impact of several predictors on **Electric Vehicle (EV) Adoption Readiness** was statistically significant ($F(6, 193) = 37.81$, $p < 0.001$), with an **Adjusted R^2 = 0.65**. This suggests that 65% of the variability in EV readiness can be explained by the independent variables included in the model.

Predictor	Unstandardized Coefficient (B)	t-value	Significance (p-value)
Policy Awareness	0.312	6.21	0.000
Infrastructure Availability	0.284	5.47	0.000
Environmental Concern	0.198	4.02	0.000
Urban Planning Integration	0.172	3.86	0.000
Perceived Cost Barriers	-0.165	-2.94	0.004
Awareness of Government Schemes	0.143	2.21	0.029

6.1.1. Interpretation

- **Policy Awareness** emerged as the strongest positive predictor of EV readiness, suggesting that knowledge of subsidies, regulations, and long-term incentives directly influences consumer adoption (Khurana & Pant, 2020).
- **Infrastructure Availability** also significantly contributes, indicating the critical role of accessible charging and service networks (NITI Aayog & RMI, 2019).
- **Environmental Concern** positively affects EV adoption intent, confirming that sustainability-conscious consumers are more inclined to transition to e-mobility (Bakker & Trip, 2013).
- **Urban Planning Integration** had a moderate but significant effect, showing that holistic urban mobility planning can facilitate EV readiness.
- **Perceived Cost Barriers** negatively impacted readiness, confirming that high initial costs or lack of financial incentives may hinder adoption.
- Awareness of specific government schemes (apart from general policy awareness) also had a small but statistically significant influence.

6.2. Findings from Exploratory Factor Analysis (EFA)

The EFA yielded four distinct latent dimensions explaining **71.6%** of the total variance in EV readiness:

[i] **Policy Awareness**
[ii] **Infrastructure Access**
[iii] **Environmental Concern**
[iv] **Urban Planning Alignment**

All factor loadings exceeded 0.60, affirming construct validity and internal consistency. The **KMO value of 0.812** and **significant Bartlett's Test ($\chi^2(120) = 987.32$, $p < 0.001$)** confirmed the sampling adequacy and the appropriateness of the data for factor analysis.

6.2.1. Interpretation

These four factors align well with global findings (IEA, 2023; Figenbaum & Kolbenstvedt, 2016), validating that a successful EV transition requires a composite of regulatory support, technical infrastructure, citizen awareness, and strategic planning. Notably, the emergence of **Urban Planning Alignment** as a distinct factor highlights a relatively underexplored area in Indian urban mobility discourse that warrants policy-level attention.

7. Discussion of Broader Implications

The results confirm that the integration of electric mobility in Indian urban planning is multi-dimensional, requiring coordinated action across several domains:

- **Policy Leverage**: While India has formulated the FAME-II scheme and various state EV policies, gaps remain in awareness and implementation. Increased outreach and clarity in communication are needed to elevate public understanding and utilization of these policies (Ministry of Heavy Industries, 2022).

- **Infrastructure Expansion**: The physical presence of charging stations and service centres significantly predicts readiness. Hence, urban planning bodies should treat EV infrastructure as a core public utility rather than an ancillary facility.
- **Behavioural Shifts**: Environmental concerns positively influence readiness, especially among younger, urban respondents. Public campaigns emphasizing the ecological benefits of EVs may accelerate adoption.
- **Cost Considerations:** While policy and environment drive readiness, economic concerns still hold back many potential users. Targeted subsidies, easy financing, and public-private partnerships could mitigate this barrier.

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