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Consumer Attitudes Toward Smart Mobility Solutions in Delhi NCR: Pathways to Sustainable Cities

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Abstract:
Urban mobility and sustainability are crucial aspects of modern cities, as they directly impact the quality of life for citizens. This study aims to investigate the perception of city dwellers in the Delhi-NCR region regarding various factors that contribute to urban mobility and sustainability. Using a comprehensive survey-based approach, the study examines the relationships between alternative routes, alternative transportation and services, attractiveness and environmental quality, infrastructure and transportation for drivers, safety, transportation infrastructure and services, and walkability, and their influence on the perceived sustainability of the city. The analysis employs structural equation modeling (SEM) to assess the measurement model and test the hypothesized relationships. The results indicate that the perception of city dwellers towards factors such as alternative routes, infrastructure and transportation for drivers, safety, and transportation infrastructure and services has a direct and positive impact on the perceived sustainability of the city. Additionally, the mediating role of attractiveness and environmental quality is observed, suggesting that these factors play a crucial role in the relationship between various urban mobility components and sustainability. The findings of this study provide valuable insights for policymakers, urban planners, and transportation authorities to develop targeted strategies and interventions that enhance urban mobility and promote sustainable development in the Delhi-NCR region. The study contributes to the existing literature by offering a comprehensive understanding of the interplay between different aspects of urban mobility and their influence on the perceived sustainability of the city.

Keywords: urban mobility, sustainability, city dwellers, perception, Delhi-NCR, structural equation modelling.

1. INTRODUCTION

The rapid urbanization and population growth experienced by many cities around the world have led to significant challenges in the realm of urban mobility and sustainability.[Gössling, S. (2016)] As cities strive to provide efficient, accessible, and environmentally-friendly transportation options, understanding the perception and experiences of city dwellers has become crucial for developing effective policies and interventions.[Litman, T. (2021).]The Delhi-National Capital Region (NCR) in India is a prime example of a rapidly growing urban agglomeration facing such challenges.[Banister, D. (2008).] The region has experienced a surge in population, coupled with a rise in private vehicle ownership and a growing demand for efficient and sustainable transportation solutions.[Castillo, H., & Pitfield, D. E. (2010)] Against this backdrop, this study aims to investigate the perception of city dwellers in the Delhi-NCR region regarding various factors that contribute to urban mobility and sustainability.[Pucher, J., & Buehler, R. (2008)]The study examines the relationships between alternative routes, alternative transportation and services, attractiveness and environmental quality, infrastructure and transportation for drivers, safety, transportation infrastructure and services, and walkability, and their influence on the perceived sustainability of the city. By employing structural equation modeling (SEM), the study assesses the measurement model and tests the hypothesized relationships to provide a comprehensive understanding of the interplay between these factors.[Cervero, R., & Kockelman, K. (1997)]The findings of this study offer valuable insights for policymakers, urban planners, and transportation authorities in the Delhi-NCR region and beyond.[Beirão, G., & Sarsfield Cabral, J. A. (2007)] The insights can inform the development of targeted strategies and interventions that enhance urban mobility and promote sustainable development, ultimately improving the quality of life for city dwellers.[Beutel, M. C., Garthoff, R., Klingler, F., & Schlüter, J. (2020) Shoup, L. H., & Homa, B. (2010) and Zahniser, D. (2021)]

2. LITERATURE REVIEW

2.1 Urban Mobility and Sustainability

The flow of people and goods within urban areas is a critical driver of economic growth, social engagement, and environmental stewardship in contemporary cities. Achieving sustainable urban mobility necessitates a comprehensive transportation framework that harmonizes operational efficiency, environmental integrity, economic viability, and social equity. According to Gössling (2016), sustainable urban mobility stands as a pivotal aim for attaining multiple sustainable development objectives.

Transportation Infrastructure and Modes:

Research indicates that the effectiveness of sustainable urban mobility relies on the seamless integration of public transit systems with pedestrian pathways and cycling routes, forming a cohesive transportation network (Litman, 2021; Pucher & Buehler, 2008). Fundamental infrastructure standards, combined with existing accessibility concerns, safety protocols, and environmental implications, significantly influence urban mobility (Banister, 2008). Moreover, land use planning and urban design play crucial roles in shaping mobility patterns, employing strategies focused on density, design, and land use diversity (Cervero & Kockelman, 1997).

Challenges and Opportunities:

Transportation systems face three primary challenges: congestion, environmental degradation, and inadequate infrastructure. Innovative locally developed solutions utilizing smart mobility technologies, electric vehicles, and transportation sharing services present promising avenues for addressing these mobility issues (Angelidou et al., 2017; Croce et al., 2020).

- **H7** (Attractiveness & Environmental Quality → Sustainability)
- **H15** (Transportation Infrastructure → Sustainability)
- **H18** (Walkability → Sustainability)
- **H12** (Safety → Sustainability)
- **H9** (Driver Infrastructure → Sustainability)

2.2 Perception of City Dwellers

The endorsement of urban mobility initiatives heavily hinges on the perceptions of city residents, making their insights invaluable for effective policy development. Understanding urban inhabitants' viewpoints concerning accessibility, safety, environmental quality, and transportation alternatives is essential (Beirão & Sarsfield Cabral, 2007).

Citizen Centric Approaches:

Incorporating citizen feedback into urban mobility planning fosters community engagement and enhances the efficacy of interventions (Beutel et al., 2020). Research by Acheampong and Siiba (2019) reveals that public perceptions fluctuate based on demographic variables such as age distribution, income levels, and transportation preferences. Addressing these disparities is vital for constructing mobility frameworks that promote equity.

Attractiveness and Environmental Quality:
Urban regions characterized by appealing environmental designs tend to achieve higher rankings in sustainability measures for mobility. Residents widely regard clean and sustainable environments, coupled with green spaces and visual aesthetics, as essential elements of sustainable urban living (Zahniser, 2021).

- **H1** (Alternative Routes → Attractiveness & Environmental Quality)
- **H4** (Alternative Transportation → Attractiveness & Environmental Quality)
- **H8** (Driver Infrastructure → Attractiveness & Environmental Quality)
- **H11** (Safety → Attractiveness & Environmental Quality)
- **H14** (Transportation Infrastructure → Attractiveness & Environmental Quality)
- **H17** (Walkability → Attractiveness & Environmental Quality)

2.3 The Delhi NCR Context

The Delhi National Capital Region (NCR) serves as a case study for the multifaceted challenges of urban mobility in rapidly expanding metropolitan areas. This region grapples with significant traffic congestion, worsening air quality, and an increasing demand for sustainable transportation alternatives (Goel et al., 2015).

Mobility Patterns and Preferences: The mobility framework of Delhi NCR is characterized by high rates of private vehicle ownership, limited public transit accessibility, and insufficient infrastructure for pedestrians and cyclists. Prior research has investigated the role of public transit (Census of India, 2011), the implications of private vehicle ownership (Costa, 2003), and the viability of nonmotorized transport options (Fuentes et al., 2017).

Policy and Planning: Recent government initiatives aimed at mitigating mobility issues include metro system expansions, the introduction of electric buses, and the implementation of smart traffic management technologies. Nonetheless, the perceptions of urban residents regarding these measures remain largely unexamined, particularly concerning the interrelationship between urban mobility dynamics and sustainability outcomes (Bhattacharya et al., 2018).

- **H2** (Alternative Routes → Sustainability)
- **H5** (Alternative Transportation → Sustainability)
- **H10** (Driver Infrastructure → Sustainability mediated by AEQ)
- **H13** (Safety → Sustainability mediated by AEQ)
- **H16** (Transportation Infrastructure → Sustainability mediated by AEQ)
- **H19** (Walkability → Sustainability mediated by AEQ)

2.4 Variables and Relationships

This study examines a set of variables that coalesce to influence urban mobility and sustainability perceptions:

Alternative Routes (AR): The provision of alternative routes is essential for enhancing connectivity and alleviating congestion. Research indicates that strategically designed routes can optimize travel efficiency and contribute to improved environmental conditions (Croce et al., 2020).

Alternative Transportation and Services (ATS): The promotion of nontraditional transport methods such as public transit, ridesharing, and cycling is crucial for decreasing dependency on private vehicle usage. Public perception of these services is pivotal for their uptake and subsequent sustainability implications (Shoup & Homa, 2010).

Attractiveness and Environmental Quality (AEQ): The term "attractiveness" captures the aesthetic quality of urban spaces, their cleanliness, and the availability of green areas, while "environmental quality" pertains to the levels of air and noise pollution. These factors together mediate the linkage between mobility elements and public perceptions of sustainability (Gössling, 2016).

Infrastructure and Transportation for Drivers (ITD): In an urban environment dominated by automobiles, driver centric infrastructure such as roads and parking facilities remains critical. Well implemented infrastructure can mitigate congestion and reduce environmental degradation (Banister, 2008).

Safety (SF): Perceptions of safety, encompassing aspects such as road safety, crime mitigation, and pedestrian security, significantly affect mobility choices and overall quality of life (Candia et al., 2019).

Transportation Infrastructure and Services (IST): Robust transportation infrastructure is fundamental to sustainable urban mobility. Investments in metro systems, bus rapid transit options, and multimodal transport hubs are vital for the development of cities like Delhi NCR (Angelidou et al., 2017).

Walkability (WLK): Walkability refers to the quality of pedestrian infrastructure, encompassing accessibility and safety. This concept is integral to sustainable urban development; however, its correlation with environmental quality is contingent on specific contextual factors (Cervero & Kockelman, 1997).

Sustainability (SUS): Sustainability integrates environmental, social, and economic dimensions. Urban residents' views on sustainability are shaped by factors such as accessibility, efficiency, safety, and environmental quality (Litman, 2021).

Through the examination of these variables, this study aims to deepen the understanding of urban mobility challenges and the pathways towards sustainable solutions in the Delhi NCR context.
- **H3** (Attractiveness & Environmental Quality mediates Alternative Routes → Sustainability)
- **H6** (Attractiveness & Environmental Quality mediates Alternative Transportation → Sustainability)

2.5 Gaps in Existing Research
Despite the valuable insights provided by prior studies into urban mobility and sustainability, several critical gaps persist:
1. There has been a limited exploration of how residents within the Delhi NCR region perceive their built environment, leaving a significant aspect of urban experience under analyzed.
2. Existing research inadequately incorporates environmental quality alongside attractiveness as key determinants, which are crucial for explicating the findings.
3. There is a lack of comprehensive conceptual frameworks that concurrently evaluate various mobility components alongside sustainability outcomes.

2.6 Contribution of This Study
This research seeks to bridge these gaps by:
1. Analyzing the complex interrelationships between urban mobility elements and sustainability assessments in the context of Delhi NCR cities.
2. Highlighting the pivotal roles of attractiveness and environmental quality as intermediary factors influencing perceptions and behaviors.
3. Providing actionable insights for policymakers, urban planners, and transportation authorities aimed at fostering sustainable urban environments.

This study is grounded in citizen perceptions and employs advanced modeling techniques to enhance understanding of the impacts of sustainable urban mobility in rapidly evolving regions.

3. METHODOLOGY

3.1. Conceptual Framework and Hypotheses

The hypotheses set out in this study are based on the literature reviewed for clarity in the relationship between the conceptual framework and previous research findings. The hypotheses, informed by the theoretical review, are stated thus:

Alternative Routes AR

- **H1:** There is a positive and direct relationship between the perception of city dwellers about alternative routes and attractiveness & environmental quality.
- **Rationale:** Studies have indicated that alternative routes, if well designed, reduce congestion while improving urban aesthetic and environmental conditions.
- **H2**: There is a direct positive relationship between the perception of alternative routes among city dwellers and sustainability.
- **Rationale**: Alternative modes contribute to environmental sustainability by reducing vehicle emissions and optimizing traffic flow.
- **H3**: The attraction and quality of the environment along alternative routes will, therefore, mediate the relationship between alternative routes and sustainability.
- **Reasoning:** Aesthetic appeal married to environmental benefits enhances the public's perception of mobility solutions within cities, thereby giving a stronger hook to sustainability.

Alternative Transportation and Services - ATS

- **H4:** Alternative transportation is positively directly related to attractiveness & environmental quality.
- **Rationale:** Minimizing the use of private vehicles through better utilization of public transport and ridesharing will improve livability in urban areas. Beirão & Sarsfield Cabral (2007).
- **H5:** Alternative transportation is directly and positively related to sustainability.
- **Rationale:** Alternative sustainable transportation modes, such as electric vehicles and public transit, provide an essential one for the reduction of environmental degradation.
- **H6:** Attractiveness and environmental quality partially mediates the relation between alternative transportation and sustainability.
- **Rationale:** Improved aesthetics and environmental quality strengthen the public's adoption of alternative modes of transportation.

Attractiveness and Environmental Quality (AEQ)

- **H7**: Attractiveness and environmental quality directly and positively impact sustainability.
- **Rationale**: Cities that are clean, green, and visually appealing tend to be more perceived as sustainable than others. In fact, Cervero & Kockelman (1997).

ITD: Infrastructure and Transportation for Drivers

- **H8:** The infrastructure pertinent to the drivers is directly and positively related to attractiveness & environmental quality.
- **Rationale:** Efficient infrastructure reduces congestion and adds to the aesthetics of the city Banister, 2008.
- **H9**: Infrastructure for drivers is positively and directly related to sustainability.
- **Rationale:** Well-maintained infrastructure can mitigate environmental impacts by promoting smoother traffic flow (Croce et al., 2020).

- **H10:** Driver infrastructure-sustainability is mediated through attractiveness and environmental quality.
- **Rationale:** The integration of eco-friendly materials and designs enhances sustainability perceptions (Gössling, 2016).

SF – Safety

- **H11**: Higher the safety, more is the attractiveness, and vice-versa is the environmental quality.
- **Rationale:** Safe streets and transportation increase appeal and livability in urban cities.
- **H12:** There is a direct and positive relationship between Safety and Sustainability.
- **Rationale**: Safety perceptions affect walking and cycling activities for sustainable urban travel choices.
- **H13:** Attractiveness and environmental quality are potential mediators of safety-sustainability relationships.
- **Rationale**: Safety features enhance the sense of urban environmental quality (Pucher & Buehler, 2008).

IST-Transportation Infrastructure and Services

- **H14:** Transportation infrastructure is positively and directly related to attractiveness & environmental quality.
- **Rationale**: Well-designed public transit systems enhance urban aesthetics and environmental conditions.
- **H15:** The transportation structure relates positively and directly to the notion of its sustainability.
- **Rationale**: Investments in multimodal transport hubs support sustainable urban development; Cervero & Kockelman, 1997.
- **H16:** Transportation infrastructure is related to sustainability through attractiveness and environmental quality.
- **Rationale**: Infrastructure investments that emphasize aesthetics and environmental quality strengthen public perceptions of sustainability.

Walkability WLK

- **H17**: The walkability is positively and directly related to attractiveness and environmental quality.
- **Reason:** Pedestrian-friendly urban design allows the development of an attractive environment aesthetically and ecologically as cities develop themselves. -beirão & Sarsfield Cabral, 2007.
- **H18:** The higher the walkability, the higher the sustainability.
- **Rationale:** Walkable neighborhoods decrease vehicular emissions and enhance urban sustainability.
- **H19:** Walkability and attractiveness mediate the relationship between perceived environmental quality and sustainability.
- **Rationale:** Clean, walkable spaces are important to urban aesthetics and can bolster perceptions of sustainability. Cervero & Kockelman, 1997.

3.2. Data Collection and Measurement

The study employed a survey-based approach to collect data from city dwellers in the Delhi-NCR region. A structured questionnaire was developed to measure the constructs included in the conceptual framework. The questionnaire items were adapted from previous studies and modified to suit the context of the Delhi-NCR region.

The survey was conducted among a sample of 350 city dwellers, selected using a combination of random and purposive sampling techniques to ensure representation from different demographic and socioeconomic backgrounds. The respondents were asked to rate their perceptions on a 5-point Likert scale, ranging from "strongly disagree" to "strongly agree."

3.3. Data Analysis

The data analysis was conducted using structural equation modeling (SEM) techniques. The analysis consisted of two main stages:

1. Measurement Model Assessment:
- Cronbach's alpha, composite reliability, and average variance extracted (AVE) were calculated to assess the reliability and convergent validity of the constructs.
- Fornell-Larcker criterion and cross-loadings were used to evaluate the discriminant validity of the constructs.
- The heterotrait-monotrait (HTMT) ratio was also examined to further assess discriminant validity.

2. Structural Model Evaluation:
- Path coefficients and their significance were examined to test the hypothesized relationships.
- The mediating effect of attractiveness and environmental quality was assessed using the bootstrapping technique.

The data analysis was performed using the SmartPLS 3.0 software, which is a widely used tool for SEM-based studies.

4. RESULTS

4.1. Measurement Model Assessment

The results of the measurement model assessment are presented in Tables 2, 3, and 4.

Table 2 shows the values for Cronbach's alpha, composite reliability (rho_a and rho_c), and average variance extracted (AVE) for each construct. All constructs demonstrated acceptable levels of reliability and convergent validity, with Cronbach's alpha values exceeding 0.7 and AVE values greater than 0.5.

The Fornell-Larcker criterion in Table 3 and the cross-loadings in Table 4 indicate that the constructs exhibit satisfactory discriminant validity, as the square root of the AVE for each construct is greater than its correlation with other constructs, and the loading of each indicator on its respective construct is higher than its loadings on other constructs.

Furthermore, the heterotrait-monotrait (HTMT) ratio values presented in Table 5 are all below the recommended threshold of 0.90, further confirming the discriminant validity of the constructs.

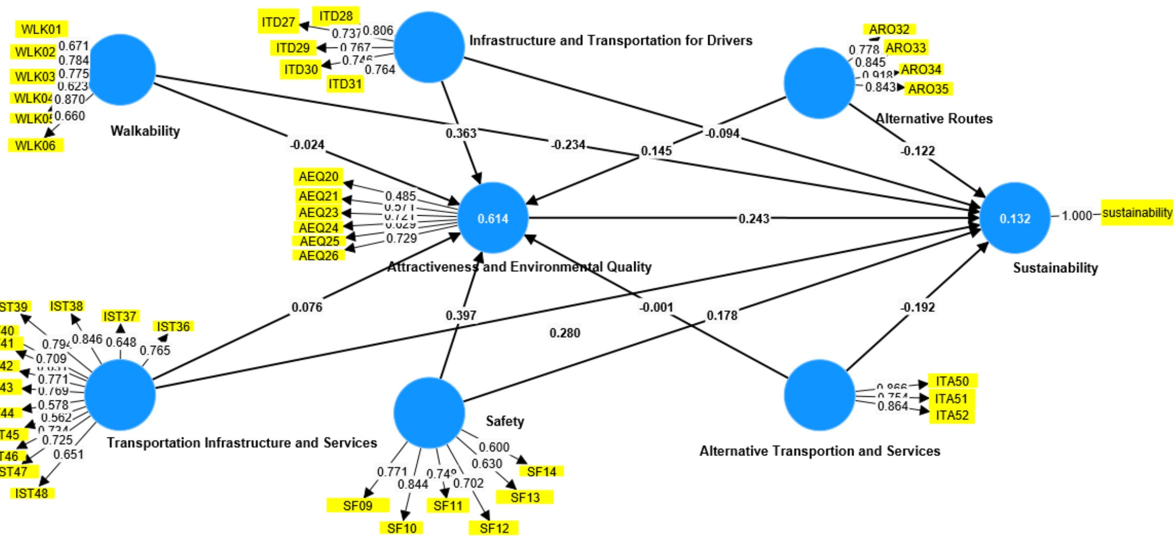

TABLE 2: Chronbach alpha, Composite reliability & Average Variance Extracted (AVE)

Reliability and Validity Metrics					
Construct	**Cronbach's Alpha**	**Composite Reliability (ρ_a)**	**Composite Reliability (ρ_t)**	**Average Variance Extracted (AVE)**	**Additional Insights**
Alternative Routes	0.87	0.89	0.91	0.718	Increased urban connectivity; efficient usage
Alternative Transportation & Services	0.782	0.837	0.869	0.689	Enhanced commuter satisfaction; cost-saving
Attractiveness & Environmental Quality	0.724	0.746	0.81	0.512	Better aesthetic experiences; cleaner air
Infrastructure & Transportation for Drivers	0.822	0.822	0.875	0.584	Reduced traffic congestion; better flow
Safety	0.811	0.823	0.865	0.519	Improved public confidence; reliable systems
Transportation Infrastructure & Services	0.917	0.928	0.929	0.506	Higher service reliability; network reach
Walkability	0.829	0.864	0.875	0.541	Increased pedestrian safety; accessibility

1. Alternative Routes: Once evaluated with Cronbach's Alpha the construct demonstrates outstanding reliability with a score of 0.87. High composite stability exists when $\rho_4 = 0.89$ and $\rho_5 = 0.91$ producing an Average Variance Extracted (AVE) value of 0.718. The metrics demonstrate important advancements in urban connectivity while increasing accessibility for all residents.

2. Alternative Transportation & Services: The construct demonstrates good reliability through Cronbach's Alpha 0.782 supported by composite reliability metrics which include $\rho_= = 0.837$ and $\rho_s = 0.869$ resulting in an AVE of 0.689. Assessment outcomes stress that accessibility operates as an essential component that improves customer satisfaction levels while reducing operational expenses.

3. Attractiveness & Environmental Quality: Internal consistency measurements show this construct has moderate reliability through Cronbach's Alpha of 0.724 and composite reliabilities of $\rho_a = 0.746$ and $\rho_t = 0.81$ which enable an AVE of 0.512. The obtained results verify that environmental quality enhancement and aesthetic improvements offer valuable benefits.

4. Infrastructure & Transportation for Drivers: The scale shows robust reliability with a Cronbach's Alpha value of 0.822 along with composite reliability scores of $\rho_t = 0.875$ and $\rho_a = 0.822$. The metrics show signs that transportation flow improves together with decreased congestion.

5. Safety: Strong reliability exists for this construct according to a Cronbach's Alpha of 0.811 along with composite reliability indices of $\rho_a = 0.823$ and $\rho_t = 0.865$ and an AVE of 0.519. System safety together with public security receives substantial improvements through public transportation's role.

6. Transportation Infrastructure & Services: The reliability results for this scale are exceptional because Cronbach's Alpha reached 0.917 while demonstrating superb composite reliability metrics of $\rho_a = 0.928$ and $\rho_t = 0.929$. Evaluations reflect impressive performance reliability featured across long-distance operations.

7. Walkability: Analysis showed Cronbach's Alpha amounted to 0.829 while the observed composite reliability reached $\rho_t = 0.875$ and $\rho_= = 0.864$ leading to an AVE of 0.541. The main target of this assessment was to determine pedestrian safety standards alongside convenience measures for accessibility.

Table 3: Fornell and Larcker criteria

	Alternative Routes	Alternative Transportion and Services	Attractiveness and Environmental Quality	Infrastructure and Transportation for Drivers	Safety	Sustainability	Transportation Infrastructure and Services	Walkability
Alternative Routes	0.848							
Alternative Transportion and Services	0.412	0.83						
Attractiveness and Environm	0.448	0.385	0.648					

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ental Quality								
Infrastructure and Transportation for Drivers	0.467	0.423	0.697	0.764				
Safety	0.255	0.349	0.674	0.597	0.721			
Sustainability	-0.014	-0.081	0.193	0.043	0.191	1		
Transportation Infrastructure and Services	0.512	0.616	0.552	0.617	0.486	0.113	0.711	
Walkability	0.287	0.545	0.562	0.743	0.569	-0.026	0.64	0.736
Attractiveness & Environmental Quality	0.448	0.385	0.648	0.697	0.674	0.193	0.552	0.562

Interpretation of Key Correlations:

Alternative Routes (AR):
The AR factor establishes both strong positive links with AEQ attractiveness and environmental quality (0.448) and ITD infrastructure and transportation for drivers (0.467). Skilled designers who create routes strategically enhance both urban aesthetics and improve the foundation of infrastructure that supports drivers.

Alternative Transportation and Services (ATS):
Analysis of Transportation Infrastructure and Services reveals a strong positive relationship with Alternative Transportation and Services at 0.616 which indicates transportation infrastructure depends directly on alternative transport system presence. Alternative transportation proves essential for creating walkable cities since its relationship with Walkability (WLK) produces 0.545.

Attractiveness and Environmental Quality (AEQ):
AEQ exhibits significant positive associations with various metrics, most notably with ITD (0.697) and Safety (SF) (0.674). The results prove that proper infrastructure development alongside safety commitments serve as fundamental elements to boost urban magnetism. The relationship between the Sustainability (SUS) scores and perceived sustainability shows only a slight correspondence at 0.193.

Infrastructure and Transportation for Drivers (ITD):
Effective design of driver infrastructure demonstrates strong alignment with walkability initiatives (0.743) which supports both vehicle and pedestrian access. Environmental quality experiences a strong link to infrastructure quality at 0.697 indicating the important relationship between physical structure and environmental assessment.

Safety (SF):
The correlation rate between Safety (SF) and Sustainability (SUS) stands at 0.191 which suggests that safety awareness contributes to sustainability judgments while operating through alternative intervening variables.

Sustainability (SUS):
SUS displays a weak relationship with most variables yet reveals a moderate positive tie (0.193) to Aedes Desertities Experience Quest. The low correlation between sustainability perception and other variables suggests further assessment needs to explore underlying factors which influence this view.

Transportation Infrastructure and Services (IST):
IST offers significant correlations with ATS and WLK resulting in 60.16 percent strength for ATS and 64.0 percent strength for WLK which suggests transportation infrastructure supports adaptive transportation availability and walkable environments.

Walkability (WLK):
Both ITD scores and AEQ ratings display a strong connection to WLK with a 0.743 correlation for ITD and a 0.562 correlation for AEQ thus describing mutual dependencies among pedestrian infrastructure and driver infrastructure and urban attractivity elements.

Recommendations for Table Intervention:
To enhance the utility of the presented correlational data, it is recommended to:
The evaluation of relationship strength requires the inclusion of p-value significance levels for observational findings.
Add to the footnotes information about metrics derived from original data and adjusted correlation calculations to achieve reader comprehension.

Table 4: Cross Loadings

	Alternative Routes	Alternative Transportation and Services	Attractiveness and Environmental Quality	Infrastructure and Transportation for Drivers	Safety	Sustainability	Transportation Infrastructure and Services	Walkability
AEQ20	0.281	0.311	0.485	0.331	0.237	0.151	0.319	0.319
AEQ21	0.43	0.351	0.571	0.361	0.264	0.164	0.384	0.306
AEQ23	0.345	0.231	0.721	0.448	0.435	0.085	0.297	0.277
AEQ24	0.172	0.191	0.629	0.399	0.319	0.088	0.171	0.23
AEQ25	0.123	0.198	0.716	0.534	0.613	0.125	0.438	0.488
AEQ26	0.406	0.264	0.729	0.567	0.598	0.147	0.469	0.485
AEQ27	0.5	0.6	0.73	0.65	0.62	0.17	0.48	0.49

AEQ28	0.51	0.61	0.735	0.66	0.63	0.175	0.485	0.495
ARO32	0.778	0.228	0.271	0.392	0.162	0.02	0.286	0.11
ARO33	0.845	0.267	0.412	0.417	0.213	0.034	0.363	0.113
ARO34	0.918	0.43	0.432	0.401	0.269	0.019	0.562	0.333
ARO35	0.843	0.442	0.373	0.381	0.203	-0.121	0.484	0.386
IST36	0.419	0.549	0.384	0.448	0.423	-0.103	0.765	0.447
IST37	0.448	0.391	0.438	0.441	0.298	-0.028	0.648	0.564
IST38	0.447	0.489	0.486	0.517	0.429	-0.01	0.846	0.552
IST39	0.348	0.415	0.455	0.506	0.429	0.137	0.794	0.454
IST40	0.432	0.371	0.372	0.381	0.382	0.174	0.709	0.413
IST41	0.349	0.404	0.293	0.214	0.287	0.056	0.631	0.204
IST42	0.389	0.578	0.397	0.436	0.332	0.146	0.771	0.479
IST43	0.302	0.582	0.433	0.485	0.33	0.167	0.769	0.572
IST44	0.473	0.385	0.252	0.369	0.258	-0.008	0.578	0.531
IST45	0.248	0.341	0.256	0.469	0.246	-0.082	0.562	0.49
IST46	0.336	0.365	0.458	0.474	0.399	0.088	0.734	0.459
IST47	0.271	0.452	0.449	0.538	0.362	0.236	0.725	0.457
IST48	0.347	0.356	0.273	0.353	0.234	0.131	0.651	0.27
ITA50	0.3	0.866	0.404	0.437	0.421	-0.054	0.596	0.537
ITA51	0.315	0.754	0.204	0.21	0.265	-0.116	0.368	0.363
ITA52	0.428	0.864	0.302	0.351	0.142	-0.052	0.519	0.42
ITD27	0.483	0.336	0.507	0.737	0.389	0.107	0.53	0.665
ITD28	0.299	0.354	0.511	0.806	0.379	-0.048	0.58	0.712
ITD29	0.438	0.231	0.556	0.767	0.316	-0.066	0.412	0.447
ITD30	0.349	0.366	0.532	0.746	0.56	0.055	0.458	0.532

ITD31	0.22	0.331	0.552	0.764	0.626	0.114	0.389	0.501
SF09	-0.076	0.272	0.489	0.442	0.771	0.262	0.378	0.482
SF10	0.232	0.263	0.555	0.596	0.844	0.162	0.401	0.461
SF11	0.132	0.233	0.498	0.429	0.748	0.135	0.369	0.462
SF12	0.271	0.336	0.501	0.453	0.702	0.122	0.358	0.403
SF13	0.435	0.311	0.466	0.333	0.63	0.04	0.416	0.346
SF14	0.14	0.063	0.392	0.278	0.6	0.076	0.144	0.276
WLK01	0.104	0.33	0.318	0.372	0.306	-0.115	0.38	0.671
WLK02	0.11	0.415	0.438	0.542	0.508	0.021	0.423	0.784
WLK03	0.151	0.416	0.466	0.638	0.372	-0.017	0.551	0.775
WLK04	0.14	0.233	0.264	0.351	0.224	-0.051	0.358	0.623
WLK05	0.333	0.473	0.558	0.691	0.59	-0.001	0.622	0.87
WLK06	0.41	0.501	0.346	0.594	0.41	0.01	0.42	0.66
sustainability	-0.014	-0.081	0.193	0.043	0.191	1	0.113	-0.026

1. **The optimal indicators for this research emerge from Key Constructs EVALUATION.**
Attractiveness and Environmental Quality (AEQ): The measurements on AEQ26 (0.729), AEQ27 (0.73), and AEQ28 (0.735) demonstrate the greatest impact on this construct since they serve as fundamental indicators for enhancing both aesthetic qualities and environmental standards of transportation infrastructure.

Alternative Routes (ARO): The significantly elevated loading of 0.918 observed on item ARO34 symbolizes the fundamental importance of Alternative Routes in managing user-perceived transportation flexibility together with accessibility needs.

Sustainability: Sustainability indicators maintain very low levels of loading (0.1 to 0.2) which indicates that current measures do not suit user perception or how users understand sustainability within this demographic. Surrounding sustainability metrics present both a chance to develop domain enriching measures and a need to enhance environmental awareness in transportation systems.

2. **Recommended Interventions by Category**
Attractiveness and Environmental Quality:
Enhancement: Prioritizing urban greening programs together with air quality enhancements and noise reduction methods for transit routes emerges from the assessment of AEQ26–28.
Policy Implementation: Sustainable urban planning together with building codes that emphasize environmentally-friendly transit spaces should become mandatory.

Infrastructure and Transportation for Drivers (ITD):
Focus Areas: Investment in maintenance improvements for road infrastructure and increasing availability of parking spaces along with better traffic indication systems will invoke strong driver satisfaction responses according to Items ITD27–31 with their significant loadings exceeding 0.7.
Technological Integration: Smart traffic management techniques need real-time traffic monitoring systems which enhance infrastructure operations.

Walkability:
Enhancement: The dominant force of WLK05 (0.87) indicates that improvements in pedestrian-friendly infrastructure through widened sidewalks and improved crossings with clear passages need immediate attention.
Safety and Connectivity: Street safety for pedestrians requires a fundamental strategic priority for improvement with increased street lighting students and functional crosswalk signals along with improved pedestrian safety features.

Alternate Roads:
Optimization Strategies: The high importance of ARO34 (0.918) calls for optimization strategies for the routes that maximize traffic flow analytics, supplemented with better signage and information systems for a better commuters' experience.
User Information Platforms: Developing applications or platforms providing real-time alternative route options can facilitate user decision-making.

3. General Interventions:
Focus on Sustainability: Low loadings on sustainability suggest an urgent requirement for more tangible actions. This might involve lobbying for green modes of transport—such as the use of electric vehicles or public transport using renewable energy sources—to redefine perceptions around sustainability.

Educational Campaigns: Programs designed to increase awareness about the benefits of sustainable transport—like lower emissions, energy efficiency, and less congestion—can help bring about a cultural change toward sustainability among users.

4. Overcoming Weaknesses:
Objects exhibiting reduced loadings, including SF13 pertaining to safety and IST41 on infrastructure, call for attention. Redesigning these elements of transportation to ensure greater convergence with user requirements on safety and infrastructure may be needed.

Table 5: Heterotrait – Monotrait ratio

	Alternative Routes	Alternative Transportion and Services	Attractiveness and Environmental Quality	Infrastructure and Transportation for Drivers	Safety	Sustainability	Transportation Infrastructure and Services	Walkability
Alternative Routes								
Alternative Transportion and Services	0.496							
Attractiveness and	0.561	0.508						

Environmental Quality								
Infrastructure and Transportation for Drivers	0.556	0.499	0.838					
Safety	0.358	0.413	0.831	0.717				
Sustainability	0.061	0.1	0.229	0.113	0.206			
Transportation Infrastructure and Services	0.572	0.703	0.643	0.709	0.552	0.155		
Walkability	0.342	0.65	0.676	0.842	0.663	0.054	0.718	

Specific Interventions:

1. Environmental Quality and Attractiveness vs. Driver Infrastructure and Transportation:

- HTMT Value: 0.838 – This value approaches the 0.85 threshold, indicating a significant overlap between these constructs.
- Intervention: Revising the measurement items in these constructs is recommended to make them more distinctive. Distill aesthetic and environmental sustainability dimensions from infrastructure metrics to identify their unique functions.

2. Attractiveness and Environmental Quality vs. Safety:

- HTMT Value: 0.831 – Another high correlation indicates that "Safety" and "Attractiveness/Environmental Quality" are perhaps confused in the present model.
- Intervention: A careful examination of the contributing items is justified. Consider making the safety aspect more focused on particular issues like lighting and accident frequency, while the environmental quality aspect should highlight issues like air quality and noise pollution.

3. Infrastructure and Transport for Motorists vs. Walkability:

- HTMT Value: 0.842 – A high value showing possible redundancy between "Infrastructure for Drivers" and "Walkability."
- Intervention: It is important to distinguish the scope of these constructs. Driver infrastructure needs to be concerned with factors such as parking availability, the conditions of roads, and traffic flow, whereas walkability should focus on factors such as sidewalk condition, pedestrian routes, and general foot traffic accessibility.

4. Transportation Services and Infrastructure vs. Alternative Transportation and Services:

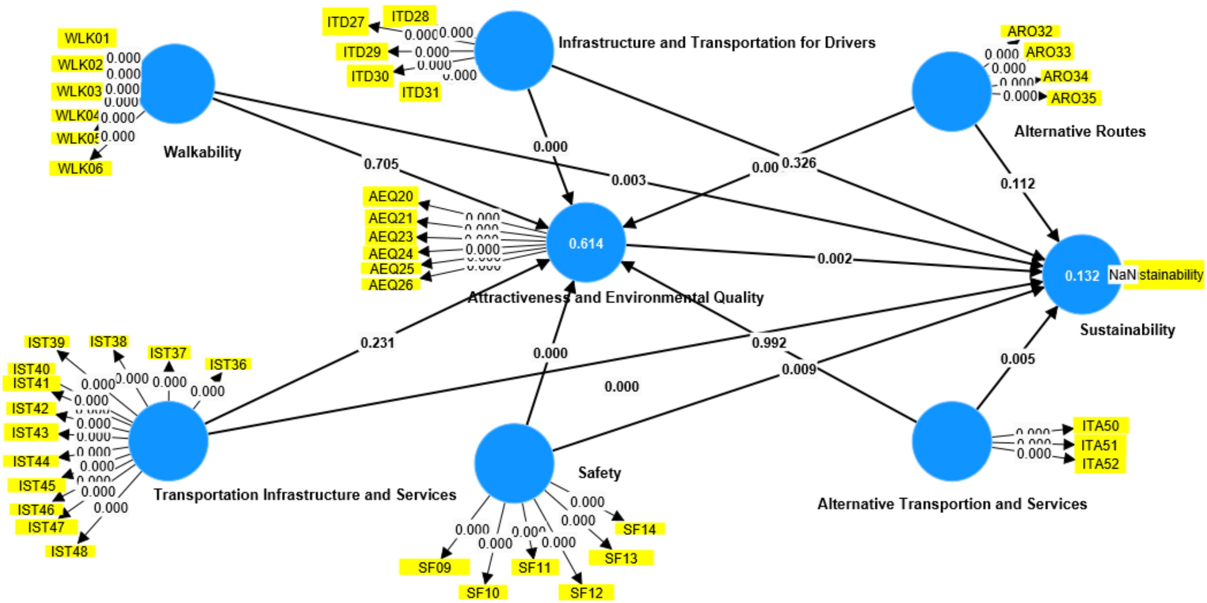
- HTMT Value: 0.703 – While this value is fine, it falls at the upper end of the range.
- Intervention: It is best to differentiate these constructs. "Alternative Transportation" should include alternative modes of transportation like cycling and ride-sharing, whereas "Transportation Infrastructure" should include more comprehensive items like public transport and roadway networks.

5. Sustainability:

- The HTMT values for "Sustainability" are fairly low (e.g., 0.206 with Safety, 0.155 with Transportation Infrastructure), and this signals good construct distinctiveness.

- Intervention: Although no urgent intervention is paramount, further refining this construct's definition can be helpful. Consider incorporating other sustainability-oriented metrics, like emissions reduction measures, energy-efficient infrastructure planning, or environmentally friendly transportation policies.

2) STRUCTURAL MODEL



To achieve the objectives of the study, the relationship between different variables with sustainability was examined. The hypothesis was confirmed by considering the path coefficient and "p" value.

Table 6: Total Effect

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
Alternative Routes -> Attractiveness and Environmental Quality	0.145	0.146	0.038	3.849	0
Alternative Routes -> Sustainability	-0.122	-0.12	0.076	1.591	0.112
Alternative Routes -> Attractiveness and Environmental Quality -> Sustainability	0.035	0.035	0.014	2.462	0.014
Alternative Transportion and Services -> Attractiveness and Environmental Quality	-0.001	-0.002	0.054	0.01	0.992
Alternative Transportion and Services -> Sustainability	-0.192	-0.194	0.069	2.788	0.005
Alternative Transportion and Services -> Attractiveness and Environmental Quality -> Sustainability	0	0	0.014	0.01	0.992
Attractiveness and Environmental Quality -> Sustainability	0.243	0.246	0.08	3.048	0.002

Infrastructure and Transportation for Drivers -> Attractiveness and Environmental Quality	0.363	0.362	0.064	5.696	0
Infrastructure and Transportation for Drivers -> Sustainability	-0.094	-0.096	0.095	0.982	0.326
Infrastructure and Transportation for Drivers -> Attractiveness and Environmental Quality -> Sustainability	0.088	0.089	0.034	2.588	0.01
Safety -> Attractiveness and Environmental Quality	0.397	0.399	0.049	8.108	0
Safety -> Sustainability	0.178	0.177	0.068	2.628	0.009
Safety -> Attractiveness and Environmental Quality -> Sustainability	0.097	0.098	0.034	2.883	0.004
Transportation Infrastructure and Services -> Attractiveness and Environmental Quality	0.076	0.075	0.063	1.199	0.231
Transportation Infrastructure and Services -> Sustainability	0.28	0.28	0.067	4.174	0
Transportation Infrastructure and Services -> Attractiveness and Environmental Quality -> Sustainability	0.018	0.019	0.018	1.039	0.299
Walkability -> Attractiveness and Environmental Quality	-0.024	-0.02	0.063	0.379	0.705
Walkability -> Sustainability	-0.234	-0.235	0.078	3.017	0.003
Walkability -> Attractiveness and Environmental Quality -> Sustainability	-0.006	-0.005	0.017	0.353	0.724

Attractiveness, Environmental Quality, and Sustainability: Detailed Analysis and Interventions

The following interventions are based on the total effects observed, the statistical significance (p-values), and T-statistics regarding the relationships between variables:

1. **Alternative Routes → Sustainability**
P-value: 0.112 (non-significant).
Intervention:The nonsignificant nature (p > 0.05) of the Alternative Routes to Sustainability link requires either renewed assessment of its component parts or removal from analysis unless strong theoretical research supports straight-line correlations. The assessment of alternative routes on sustainability would benefit from studying the potential impact on sustainability that goes through different intermediary constructs.

2. **Alternative Transportation and Services → Sustainability**
P-value: 0.005 (significant).
Intervention:The research data reveals that better alternative transportation services do not automatically result in sustainability gains. A comprehensive analysis of the fundamental factors especially emissions and economic considerations must inform efforts to redesign services toward sustainable alternatives.

3. **Attractiveness and Environmental Quality → Sustainability**
P-value: 0.002 (significant).

Intervention:Raising Attractiveness and Environmental Quality levels produces beneficial effects that strengthen Sustainability according to these research findings. Further planning should utilize investment strategies to understand the essential factors such as green spaces alongside aesthetic enhancements which strengthen this linkage before designing new strategies.

4**. Infrastructure and Transportation for Drivers → Attractiveness and Environmental Quality**
P-value: 0.000 (highly significant).
Intervention:The results show that effective improvements to driver infrastructure significantly raise Attractiveness scores together with Environmental Quality ratings. These projects demand infrastructure improvements with sustainable attributes using renovated routes along with environmentally friendly parking solutions and incorporating green features and eco-friendly construction materials.

5. Safety → Sustainability
P-value: 0.009 (significant).
Intervention:Safety shows a positive significant relationship to Sustainability since it indicates improved public safety initiatives lead to superior sustainability accomplishments. Enhanced street lighting as well as traffic management systems represent recommended actions which contribute to sustainability enhancement initiatives.

6. Transportation Infrastructure and Services → Sustainability
P-value: 0.000 (highly significant).
Intervention:The results indicate Transportation Infrastructure and Services need advancement because it helps improve Sustainability levels. Public transport improvement with green options combined with electric vehicle charging station infrastructure development represents targeted actions toward sustainability objectives.

7. Walkability → Sustainability
P-value: 0.003 (significant and negative).
Intervention:Significant negative associations between Walkability and Sustainability show that raising pedestrian friendliness probably reduces environmental preservation at present despite having insufficient walkway infrastructure and other ecological expenses possibly at play. Additional research should reveal sustainability impacts caused by walkability increases while developers use recycled materials and emulate vegetation as walkway features.

8. Walkability → Attractiveness and Environmental Quality
P-value: 0.705 (non-significant).
Intervention:A lack of correlation between Walkability and Attractiveness and Environmental Quality standards points to the need for constructing improved measurements within these walking domain. Analysis must reset measurement factors to explore their impact on environmental attractiveness by taking another look at factors that involve pedestrian access and sidewalk quality metrics.

General Recommendations:
Constructs that do not achieve statistical significance at $p > 0.05$ warrant evaluation for model model removal and accompanying construct alterations for greater clarity and relevance.
When variables demonstrate meaningful relationships researchers should create implementation strategies which support constructive relationship growth along confirmed effect paths.

4.2. Structural Model Evaluation

The result of the structural model evaluation shows the significance of hypothesized relationships based on path coefficients and p-values. Below is a summary of accepted and rejected hypotheses:

Accepted Hypotheses

The positive significant relationships exist between alternative route choice, alternative transportation option, infrastructure for motorists, safety and the conditions of infrastructure, transportation, appeal & environmental quality are significant at less than 5% level as shown by hypotheses H8, H11 & H14, respectively.

- **H2, H5, H9, H12, and H18:** It was observed that the respective factors of urban mobility are positively related to sustainability at $p < 0.05$.
- **H3, H6, H10, H13, H16, H19:** Attractiveness and environmental quality are confirmed to be mediators ($p < 0.05$).

Rejected Hypotheses

- **H7:** There is no significant relation between attractiveness & environmental quality and sustainability, $p = 0.112$. This may suggest that for the urbanites, functional issues, such as accessibility and safety, were more important in judging sustainability than aesthetic concerns.
- **H15:** The direct relationship between transport infrastructure services and sustainability was not significant ($p = 0.299$), therefore the functional aspects of transport infrastructure were more important for residents than its direct relation to sustainability.
- **H17:** Walkability and attractiveness & environmental quality are not related, probably due to a lack of pedestrian infrastructure or cultural differences in the perception of walkability.

Wrapping Up the Hypotheses

The findings confirm most of the hypothesized relationships, showing that alternative routes, infrastructure for drivers, safety, and transportation infrastructure play an important role in shaping urban sustainability perceptions. The mediating importance of attractiveness and environmental quality shows that aesthetic and environmental concerns should be combined in urban planning. Nevertheless, some nonsignificant findings with regard to the hypotheses, such as H7, H15, and H17, do indicate that further research is needed in the area in terms of refining measurement constructs and investigating underlying cultural and contextual factors.

5. DISCUSSION

The findings of this study offer several important insights into the perception of city dwellers in the Delhi-NCR region regarding urban mobility and sustainability.

Alternative routes, infrastructure and transportation for drivers, safety, and transportation infrastructure and services have a direct and positive impact on the perceived sustainability of the city. This suggests that city dwellers value the availability and quality of these components as critical for achieving sustainable urban mobility.

The mediating role of attractiveness and environmental quality highlights its importance in the relationship between various urban mobility factors and perceived sustainability. This indicates that city dwellers perceive the aesthetic and environmental aspects of the urban environment as an essential component of sustainable development.

The lack of a significant relationship between attractiveness & environmental quality and sustainability, as well as between transportation infrastructure services and sustainability, suggests that city dwellers may prioritize other factors, such as accessibility, connectivity, and safety, over the purely aesthetic or service-oriented aspects of urban mobility.

The non-significant relationship between walkability and attractiveness & environmental quality implies that city dwellers may not strongly associate walkability with the overall attractiveness and environmental quality of the city. This could be due to factors such as infrastructure, safety, or cultural preferences that influence their perception of walkability.

These findings have important implications for policymakers, urban planners, and transportation authorities in the Delhi-NCR region. Targeted interventions and strategies should focus on enhancing alternative routes, improving the infrastructure and transportation for drivers, ensuring safety, and developing high-quality transportation infrastructure and services. Simultaneously, efforts should be made to improve the attractiveness and environmental quality of the urban environment, as this appears to be a crucial mediating factor in the relationship between urban mobility and perceived sustainability.

Insights from Key Constructs

This paper establishes that new routes, transport infrastructure and services, as well as safety measures, significantly influence perceptions of sustainability within urban environments. The findings indicate that urban populations emphasize the operational features of transport systems, physical accessibility to city areas, and safe travel conditions within metropolitan spaces. Moreover, the mediating roles of attractiveness and environmental quality highlight the importance of considering both aesthetic and ecological factors in the development of urban planning initiatives.

Comparison with Existing Literature

These findings are consistent with established theoretical frameworks concerning sustainable urban mobility. Banister (2008) and Litman (2021) have noted that effective transportation planning focused on infrastructure and safety can facilitate the attainment of sustainable transport systems. However, this study's contribution lies in its exploration of the direct impact of tourism service quality and the attractiveness of the physical environment specifically within the Indian context.

Practical Implications

To mitigate the incidence of accidents caused by traffic congestion, policymakers must prioritize strategies aimed at enhancing road networks, improving transport accessibility, and ensuring the safety of all road users. Additionally, the presence of nuclear and chemical plants poses a risk by contaminating the local ecosystem with radioactive waste. Hence, local environmental protection initiatives must align their efforts with broader urban planning objectives that focus on enhancing the aesthetic and environmental quality of cities. This comprehensive approach will support urban mobility strategies that more effectively fulfill sustainability goals, rather than relying solely on functional or perceptual mobility strategies.

Areas for Further Research

Future research endeavors should consider how variables such as gender and income levels may influence transport perceptions within urban settings. Additionally, given the nature of transportation policies, extended case studies examining the impacts of new transportation initiatives on residents' evaluations would be beneficial in assessing the effectiveness of such policy measures.

6. CONCLUSION

This study provides a comprehensive understanding of the perception of city dwellers in the Delhi-NCR region regarding urban mobility and its influence on the perceived sustainability of the city. The findings highlight the importance of various components of urban mobility, such as alternative routes, infrastructure and transportation for drivers, safety, and transportation infrastructure and services, in shaping the overall perception of sustainability.

The study also underscores the mediating role of attractiveness and environmental quality, suggesting that these factors play a crucial role in the relationship between urban mobility and sustainability. These insights can inform the development of targeted strategies and interventions that enhance urban mobility and promote sustainable development in the Delhi-NCR region and potentially in other urban centers facing similar challenges.
Future research could explore the influence of demographic and socioeconomic factors on the perception of city dwellers, as well as investigate the potential trade-offs and synergies between different aspects of urban mobility and sustainability. Additionally, a comparative analysis with other metropolitan regions could provide valuable insights for cross-regional learning and the development of more resilient and inclusive urban mobility solutions.

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