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Investigating Travel Behaviour in TOD-Based Development from an Expert Perspective: Evidence from Partial Least Squares Structural Equation Modelling (PLS-SEM)

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Abstract

Transit-Oriented Development (TOD) provides an integrated planning framework aligning land use, urban design, and transport systems to advance sustainable mobility. This study investigates determinants of travel behaviour within TOD-based developments in Delhi through an expert-based analytical approach. A structured questionnaire survey was administered to 42 domain experts, including planners, engineers, researchers, and policy professionals. The study employs Partial Least Squares Structural Equation Modelling (PLS-SEM) to examine causal relationships among accessibility, urban density, public transport, government policy, and socio-economic factors. Results indicate that accessibility, urban density, and public transport significantly influence travel behaviour, highlighting the importance of compact development, efficient connectivity, and reliable transit systems. In contrast, government policy and socio-economic factors were not found to have a direct significant effect, suggesting indirect or mediated influences. The findings demonstrate the value of expert-based analysis in capturing systemic and policy-relevant insights for TOD implementation and offer practical guidance for planners and policymakers.

Keywords

Transit-Oriented Development (TOD); Travel Behaviour; PLS-SEM; Accessibility; Public Transport

1. Introduction

Rapid motorisation, accelerating urbanisation, and the growing public-health consequences of sedentary lifestyles have intensified the global need for integrated land-use and transport planning in rapidly expanding cities. In this context, Transit-Oriented Development (TOD) characterised by compact, mixed-use, and pedestrian-friendly neighbourhoods centred around high-quality public transport has emerged as a key paradigm for promoting sustainable mobility and reducing automobile dependence (Cervero & Kockelman, 1997; Newman & Kenworthy, 2015). TOD extends beyond infrastructure provision to a comprehensive framework that integrates land-use efficiency, accessibility, and economic development, thereby enabling more sustainable urban growth (Sharma & Dehalwar, 2025). While TOD has demonstrated considerable potential in improving mobility and urban efficiency, its effectiveness in shaping actual travel behaviour remains highly context-dependent, influenced by factors such as service reliability, perceived accessibility, and environmental quality.

Environmental externalities further complicate this relationship. Vehicular emissions at heavily trafficked urban intersections significantly degrade environmental quality and influence commuter perceptions, thereby affecting travel choices and sustainability outcomes (Lashkari et al., 2025). These challenges are particularly pronounced in rapidly urbanising Global South cities such as Delhi, where transport systems operate within highly heterogeneous socio-economic contexts. Unlike developed cities with mature and integrated transport networks, Indian metropolitan regions are characterised by informal mobility systems, uneven infrastructure provision, and fragmented policy implementation (Yadav et al., 2025). As argued by Sharma et al. (2024), the success of TOD in such contexts depends not only on spatial design but also on its ability to accommodate social diversity, ensure safety, and support behavioural adaptation. Consequently, understanding how built environment characteristics interact with user perceptions is critical for evaluating TOD effectiveness in developing cities.

To address these complexities, contemporary transport research increasingly employs analytical frameworks capable of capturing latent constructs and their interrelationships. PLS-SEM; Structural Equation Modelling provides a robust methodological approach for simultaneously estimating measurement and structural relationships among variables such as accessibility, land-use diversity, service quality, and travel behaviour. Land-use–transport interaction models, as highlighted by Sharma and Dehalwar (2025), are particularly relevant for assessing smart urban growth and mobility policies in developing economies. In this study, PLS-SEM is employed to analyse how TOD attributes influence travel behaviour in Delhi, enabling a comprehensive evaluation of both observable and latent behavioural determinants.

The study adopts an expert-based analytical perspective to examine travel behaviour within TOD environments. This approach integrates the conceptual strength of the expanded “8Ds” framework: Density, Diversity, Design, Destination Accessibility, Distance to Transit, Demand

Management, Desirability, and Digitalisation, with an expert-based analytical approach and Partial Least Squares SEM (PLS-SEM). The use of expert respondents is justified by their ability to synthesise institutional knowledge, planning practice, and system-level insights that may not be fully captured through commuter surveys. Moreover, this approach allows for the integration of perceptual and objective indicators, such as service reliability and environmental conditions, which jointly shape travel decisions.

Recent advancements in transport research emphasise the importance of validated measurement frameworks and the integration of perceptual and operational indicators. Studies have demonstrated that travel-time reliability, congestion variability, and environmental conditions significantly influence perceived accessibility and mode choice, underscoring the need for multidimensional analytical models (Ashraf Javid et al., 2021; Afandizadeh et al., 2023). Furthermore, behavioural responses to the built environment are mediated by psychological factors such as safety perception, habits, and environmental awareness, in addition to objective service attributes (Sharma et al., 2024). Despite these advancements, empirical studies integrating expert-based insights, psychometrically validated constructs, and PLS-SEM-based analysis remain limited in the Indian context. This study addresses this gap by combining validated measurement scales with an exploratory PLS-SEM framework tailored to a complex urban environment.

In India, TOD has become a central component of urban development policy, particularly under frameworks such as the Delhi Master Plan (MPD-2041) and the Delhi Development Authority's TOD regulations. These policies aim to promote compact development, mixed land use, and improved accessibility around transit corridors such as the Delhi Metro. However, implementation challenges persist, including socio-economic disparities, inadequate last-mile connectivity, and the continued dominance of informal transport systems (Yadav et al., 2025). These challenges highlight the need for comprehensive evaluation frameworks that capture both the physical and behavioural dimensions of TOD.

The theoretical framework of this study conceptualises TOD as an integrated spatial–behavioural system in which built environment attributes, governance mechanisms, and socio-economic conditions interact to shape travel behaviour. By applying PLS-SEM to expert assessments of Delhi's TOD landscape, the study identifies key behavioural drivers and evaluates the relative influence of TOD attributes on travel decisions. This approach enables a more nuanced understanding of how planning interventions translate into behavioural outcomes.

Accordingly, the study addresses the following research questions: (1) which TOD attributes most strongly influence travel behaviour from an expert perspective; (2) how factors such as accessibility, density, and service quality interact to shape travel decisions; (3) the extent to which latent constructs such as perceived accessibility explain modal preferences; and (4) how expert-based insights align with established measurement approaches in transport research. These questions aim to bridge the gap between theoretical TOD principles and their practical implications in complex urban settings.

This study contributes to the literature in three key ways. First, it develops an expert-based analytical approach for analysing TOD-related behavioural constructs using established psychometric approaches. Second, it demonstrates how perceptual and operational indicators can be integrated within a PLS-SEM framework to enhance the robustness of travel behaviour analysis. Third, it provides policy-relevant insights for TOD implementation in Delhi, emphasising the importance of density, accessibility, and reliable public transport systems. By adopting an exploratory, expert-driven PLS-SEM approach, the study advances the understanding of TOD effectiveness in developing cities and offers actionable guidance for planners and policymakers working towards sustainable and inclusive urban mobility systems.

2. Methodology

This study adopts a mixed-methods exploratory design to examine expert perceptions of travel behaviour determinants in Delhi's TOD areas. Partial Least Squares Structural Equation Modelling (PLS-SEM) is used to analyse relationships between TOD attributes and behavioural constructs. The three-phase methodology includes expert survey design, data collection, and model analysis, integrating behavioural and transport planning approaches to capture context-specific insights.

2.1 Phase I: Expert Identification and Survey Design

A structured questionnaire was developed based on an extensive review of TOD literature, behavioural modelling, and the 8Ds framework Density, Diversity, Design, Destination Accessibility, Distance to Transit, Demand Management, Desirability, and Digitalisation (Cervero & Kockelman, 1997). Each dimension was operationalised through validated indicators, refined via expert consultation and pilot testing. Given the evolving nature of TOD in India, expert judgment was prioritised to capture policy-relevant and context-specific insights. PLS-SEM framework enables the integration of strategic, institutional, and design perspectives, supporting a comprehensive evaluation of TOD effectiveness beyond conventional commuter-based analyses.

2.1.1 Sampling Strategy and Inclusion Criteria

A purposive sampling approach was adopted to select experts with demonstrated experience in urban transport and land-use planning within the Delhi Metropolitan Region. Participants were required to have a minimum of five years of professional or research experience in TOD-related domains. The sample included urban planners, transport engineers, academics, architects, and policy consultants associated with institutions such as DDA, UTTIPEC, and DMRC. Experts were identified through professional networks, institutional databases, and LinkedIn platforms. Invitations were circulated via email outlining study objectives and confidentiality. Participation was voluntary with informed consent obtained, and the survey instrument was pre-validated through expert review (Parishad et al., 2020).

2.1.2 Questionnaire Design

The questionnaire consisted of three sections:

1. Demographic and professional background (age, gender, years of experience, field of expertise).
2. Perception statements on TOD dimensions and travel behaviour determinants, measured using a 5-point Likert scale ranging from *1 = Strongly Disagree* to *5 = Strongly Agree*.
3. Behavioural outcome constructs, including perceived accessibility, mode choice intention, travel satisfaction, and preference for active/public transport modes.

The indicators were adapted from validated scales in previous TOD and behavioural studies (Cervero & Murakami, 2009; Nasri & Zhang, 2014) and reviewed by three senior academicians to ensure content validity and contextual relevance for Delhi.

2.2 Phase II: Data Collection

Data collection was conducted using a purposive, stratified sampling approach to ensure representation from key stakeholder groups involved in Transit-Oriented Development (TOD) and urban transport planning in the Delhi Metropolitan Region. A total of approximately 60 domain experts were invited through professional networks, institutional directories, and LinkedIn-based communities, out of which 42 experts completed the survey, yielding a response rate of 70%. Invitations were circulated via email, followed by reminders and targeted follow-ups to enhance participation. Data collection was carried out between February and April 2024 using a combination of online and in-person modes.

All responses were screened for completeness and consistency. Records with significant missing data (>20%) or patterned responses were excluded; however, all collected responses met the required quality thresholds, resulting in a final sample size of N = 42. The socio-demographic and professional characteristics of the respondents are presented in Table 1, indicating a balanced representation across age groups, gender, experience levels, and professional backgrounds. Notably, the sample includes urban planners, transport engineers, academicians, and policy professionals, ensuring diverse perspectives on TOD implementation.

Table 1: Socio-Demographic Profile of Experts

Category	Sub-Category	Frequency	Percentage (%)
Age Group	25-35	14	33.3%
	36-45	16	38.1%
	Above 45	12	28.6%
Gender	Male	28	66.7%
	Female	14	33.3%
Experience in Profession	1-5 years	9	21.4%
	5-10 years	12	28.6%
	10-15 years	21	50.0%
Profession	Government Agencies (Transport)	3	7.1%
	Urban Planner	20	47.6%
	Civil Engineer	1	2.4%
	Landscape Architect	1	2.4%
	Public Policy Analyst	2	4.8%
	Transportation Planner/Engineer	7	16.7%
	Research Scholar	4	9.5%
	Academician (Professor)	3	7.1%
	Environmental Planner	1	2.4%

Given the exploratory nature of the study, emphasis was placed on the relevance and expertise of respondents rather than statistical representativeness, aligning with established PLS-SEM practices for expert-based research. The stratified purposive approach enhanced content validity by capturing multidisciplinary insights essential for evaluating TOD attributes and their influence on travel behaviour. This approach supports robust model development while reflecting the institutional and practical realities of urban transport planning in Delhi.

2.3 Phase III: Model Development and Analysis

2.3.1 Analytical Framework

To test the hypothesised relationships among TOD attributes and travel behaviour constructs, Partial Least Squares Structural Equation Modelling (PLS-SEM) was applied using SmartPLS 4.0, complemented by SPSS 26 for descriptive analysis. PLS-SEM was selected due to its suitability for exploratory and small-sample analysis (Lowry & Gaskin, 2014).

2.3.2 Model Estimation and Validation

The modelling procedure followed a two-stage approach using PLS-SEM. First, the measurement model was evaluated to ensure reliability and validity of constructs. Indicator reliability was confirmed through outer loadings (>0.70, with select items retained between 0.65–0.70 based on theoretical relevance). Internal consistency was assessed using Cronbach's α and Composite Reliability (≥0.70), while convergent validity was established through AVE (≥0.50). Discriminant validity was verified using the Fornell–Larcker criterion and HTMT (<0.85).

Second, the structural model was assessed using bootstrapping (5,000 resamples) to estimate path coefficients, T-statistics, p-values, and confidence intervals. Model performance was further evaluated using SRMR, R^2, and Q^2 metrics.

Given the small sample size (N = 42), PLS-SEM was adopted as it is suitable for exploratory and prediction-oriented analysis. The sample satisfies the "10-times rule," and post-hoc power analysis (power = 0.82) confirms adequacy. SmartPLS 4.0 was used for model estimation, while IBM SPSS 26 supported preliminary data analysis, ensuring methodological consistency and robustness.

2.3.3 Ethical Considerations

The study adhered to ethical research standards. Participants provided informed consent and were assured of anonymity and data confidentiality. No identifying information was disclosed.

This methodological design provides a systematic and empirically robust framework for integrating expert-derived insights into behavioural analysis within TOD contexts. The use of PLS-SEM ensures methodological appropriateness for smaller samples, while the combination of expert input and theory-based constructs enhances conceptual validity. By capturing the professional understanding of TOD-travel behaviour linkages, this study contributes to evidence-based policy formulation and sustainable mobility planning in Delhi.

2.4. Conceptual Framework and Hypothesis Development

The conceptual framework for this study is grounded in the 8 Ds of Transit-Oriented Development (TOD): Density, Diversity, Design, Destination Accessibility, Distance to Transit, Demand Management, Desirability, and Digitalisation. These dimensions collectively influence travel behaviour by shaping the physical and perceptual environment around transit nodes. Given the Delhi case study context, ridership and active travel behaviour are hypothesised to be influenced not only by physical proximity and connectivity but also by perceived safety, accessibility, user satisfaction and cost-consciousness constructs that gain support in diverse fields. The framework hypothesises that these TOD attributes affect key behavioural outcomes such as public transport use, active travel preference, and mode shift willingness. Expert perceptions are used to assess the strength and direction of these relationships, which are analysed through Structural Equation Modelling (SEM) to uncover causal pathways within the TOD-travel behaviour nexus in Delhi shown in Figure 1.

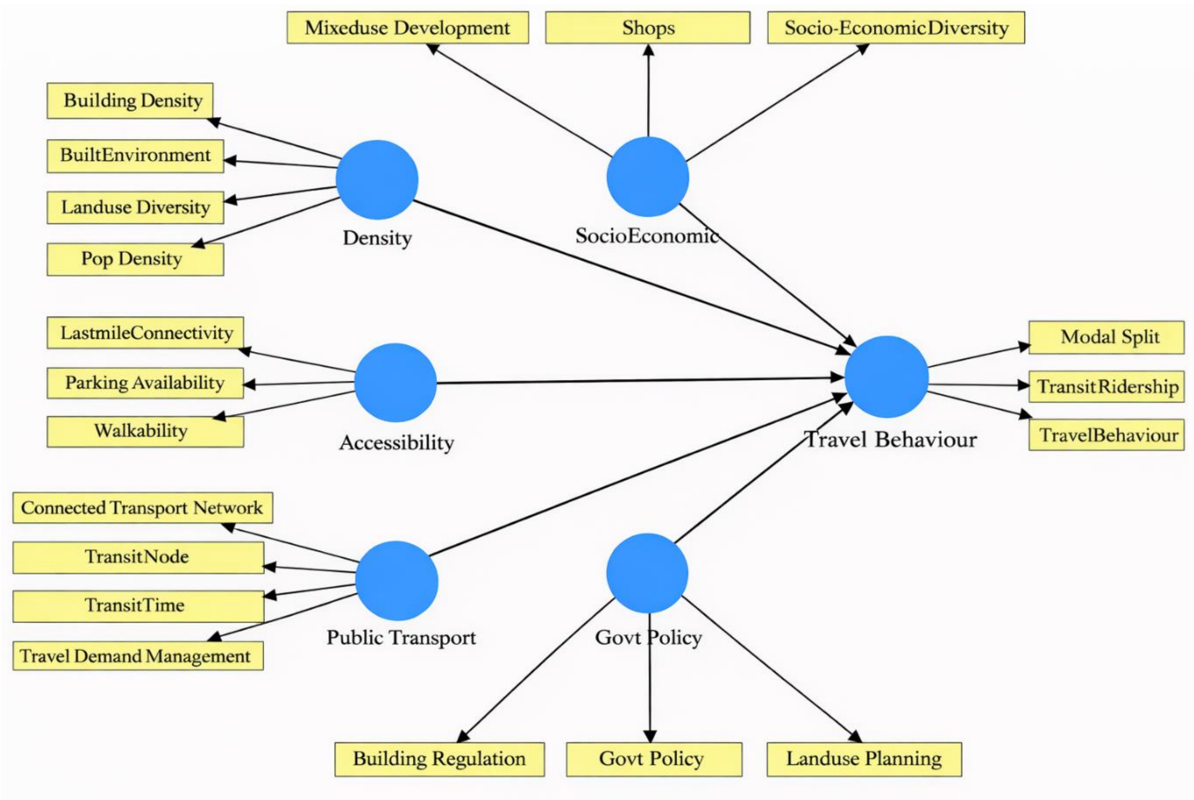

Figure 1: Conceptual Framework for Analysis

Socioeconomic Profile

The socioeconomic profile of the study reflects the diversity embedded within TOD precincts that promote mixed-use development (Yen et al., 2024). Expert respondents observed that areas around transit nodes often feature a combination of residential, commercial, and retail spaces-including local markets and shops-which attract a wide spectrum of users. This built form encourages socioeconomic diversity, with the presence of both formal and informal economic activities. The experts also highlighted that TOD zones in Delhi cater to a range of income groups, from low-income commuters accessing affordable transit to higher-income residents drawn to well-designed, walkable neighbourhoods, thus creating a socially inclusive urban fabric.

Density

Density is a core principle of TOD and plays a pivotal role in shaping travel behaviour (Ali et al., 2025; Tiwari et al., 2023). Expert responses highlight that higher building density and compact built environments near transit corridors encourage efficient land use and reduce travel distances. Increased population density around transit nodes ensures a steady demand for public transport, making services more viable and frequent. Additionally, land use diversity, combining residential, commercial, and institutional functions, promotes mixed-purpose trips and reduces dependence on private vehicles. Experts emphasized that the integration of these density elements enhances walkability, improves last-mile connectivity, and supports a shift towards sustainable travel modes. The built-environment quality (infrastructure durability and performance) is posited to influence satisfaction and mode choice in our model-a rationale supported by studies examining infrastructure material performance and monitoring.

Accessibility

Efficient last-mile connectivity is crucial in determining the effectiveness of TOD areas, as it directly influences commuters' willingness to use public transport (Ann et al., 2019; Ashik et al., 2024; Nyunt & Wongchavalidkul, 2020; Park et al., 2021; Zuo et al., 2020). Experts emphasized the need for seamless integration of feeder services, cycling infrastructure, and pedestrian pathways to bridge the gap between transit stations and final destinations. Walkability, supported by safe, shaded, and continuous sidewalks, encourages active travel and enhances the overall user experience. Conversely, excessive parking availability near transit hubs may discourage transit use by incentivizing private vehicle trips. A balanced parking policy, aligned with TOD principles, is essential to promote sustainable, multimodal urban mobility patterns. Perceived accessibility and service reliability are treated as latent constructs-which reflects similar practice in travel behaviour modelling where objective reliability measures complement attitudinal variables (Afandizadeh et al., 2024).

Public Transport

A well-integrated public transport system forms the backbone of TOD, supported by a connected transport network that ensures smooth intermodal transfers (Stadler Benz & Stauffacher, 2023; Tanwar & Agarwal, 2025). Experts noted that effective design of transit nodes-with multimodal integration-enhances transit ridership by making journeys more convenient and time-efficient. TOD areas promote a diversity of trips, including work, education, shopping, and leisure, all accessible via non-motorised or public modes. This contributes to a favourable modal split towards sustainable transport. Implementing travel demand management strategies such as congestion pricing and limited parking can further reduce car dependency, making TOD zones more livable and aligned with climate-resilient urban mobility goals.

Government Policy

Government policies play a critical role in the successful implementation of Transit-Oriented Development (TOD) (Patnala et al., 2020; Rahaman et al., 2024; Thomas et al., 2018; Yen et al., 2024). Experts highlighted that supportive building regulations-such as relaxed Floor Area Ratios (FAR), mixed-use zoning, and height allowances near transit nodes-enable higher densities and compact urban forms. Strategic land use planning, guided by TOD principles, ensures integration of residential, commercial, and institutional functions, enhancing accessibility and reducing travel demand. Additionally, other government policies related to affordable housing, parking standards, non-motorised transport infrastructure, and environmental sustainability must be aligned to support TOD objectives. A coordinated, multi-agency approach is essential to ensure policy coherence and effective on-ground implementation.

Based on the reviewed literature, this study formulates five hypotheses that capture the causal pathways between key Transit-Oriented Development (TOD) attributes and travel behaviour in the Delhi context. These hypotheses are grounded in prior empirical findings and theoretical arguments linking built-environment characteristics, accessibility, and policy frameworks to sustainable travel outcomes.

H1: Socio-economic characteristics significantly influence travel behaviour.

Socio-economic variables such as income, education, and occupation affect both travel demand and mode choice. Studies have shown that higher-income groups tend to rely more on private modes, whereas low-income commuters are more transit-dependent (Lodhi et al., 2024). Inclusive transport policy must account for socio-economic heterogeneity to ensure equitable access in urban India. Therefore, it is hypothesized that the socio-economic profile of an area significantly influences its residents' travel behaviour.

H2: Population and built density near transit stations positively influence sustainable travel behaviour.

Higher population and employment densities create a critical mass of transit users, reduce average travel distances, and encourage walking and cycling (Cervero & Kockelman, 1997; Newman & Kenworthy, 2015). Studies identified density as one of the strongest precursors of TOD success in Indian cities (Begam et al., 2024). Hence, it is hypothesized that higher urban density near transit stations is associated with more sustainable travel behaviour.

H3: Accessibility to public transit significantly affects travel behaviour.

Improved first- and last-mile accessibility enhances the attractiveness of public transport and encourages modal shift from private vehicles (Adeel et al., 2021). Accessibility improvements, particularly pedestrian and NMT integration, directly influence user satisfaction and ridership. Thus, access to public transport is expected to influence travel behaviour significantly.

H4: Quality and availability of public transport services significantly influence mode choice.

Service reliability, safety, and frequency are critical determinants of transit use (Sharma et al., 2025). Studies across Indian cities show that efficient bus and metro operations lead to measurable reductions in private vehicle use (Adeel et al., 2021). Therefore, the quality and availability of public transport are hypothesized to have a significant positive effect on travel behaviour.

H5: Government policy and institutional support significantly influence travel behaviour.

Urban transport policies, including parking restrictions, TOD incentives, and land-use regulations, play a decisive role in shaping mobility patterns (Abass, 2023). Policy integration between land-use and transport domains enhances transit use and reduces car dependency. Hence, it is hypothesized that supportive government policies significantly influence travel behaviour.

3. Results

Given the expert-based sample size, this study is explicitly framed as exploratory rather than confirmatory. Accordingly, Partial Least Squares Structural Equation Modelling (PLS-SEM) was adopted due to its suitability for small samples, complex models, and prediction-oriented research. This approach prioritizes variance explanation and theory building over strict goodness-of-fit testing, making it appropriate for expert-driven TOD investigations in emerging urban contexts. The model is interpreted as exploratory and prediction-oriented rather than confirmatory.

3.1 Socio-Economic Profile

The expert sample comprised 42 respondents representing a multidisciplinary cross-section of professionals involved in urban planning, transport engineering, and policy in Delhi. The majority (38.1%) were aged between 36-45 years, and two-thirds (66.7%) were male. Over half (50%) of the experts had more than ten years of professional experience, ensuring informed and practice-oriented insights. Urban planners constituted the largest group (47.6%), followed by transportation planners/engineers (16.7%), government officials (7.1%), and academicians (7.1%). The inclusion of research scholars, policy analysts, and environmental planners contributed to a balanced representation of academic, institutional, and operational perspectives. This diverse expert panel ensured that the study captured both theoretical understanding and practical challenges related to Transit-Oriented Development (TOD) implementation and its influence on travel behaviour in Delhi.

3.2 Structural Model

The five hypothesized relationships are illustrated in Figure 2, which presents the conceptual framework linking TOD attributes (Density, Accessibility, Public Transport, and Government Policy) and Socio-Economic Factors to Travel Behaviour. The framework positions Travel Behaviour as the dependent latent construct, operationalized through observed indicators of mode choice, trip frequency, and purpose.

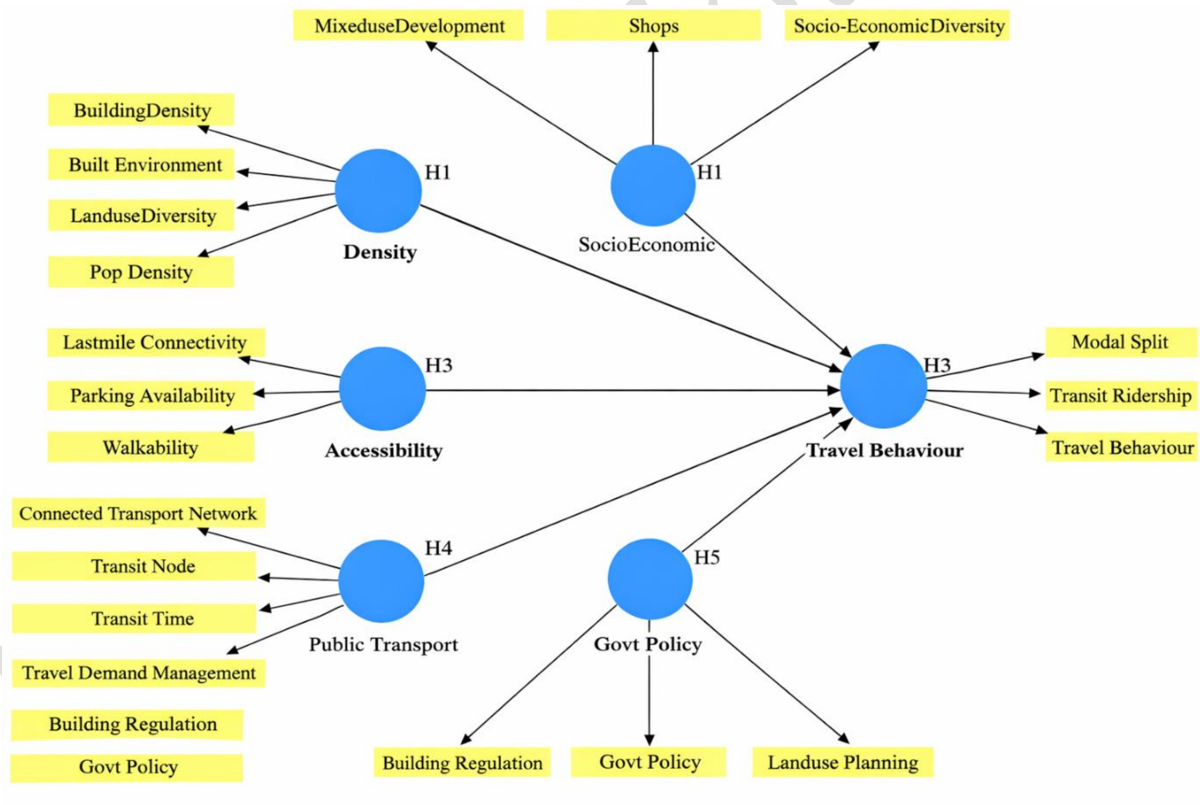

Figure 2: Structural Model and Hypothesised Relationships

The hypothesised structural relationships are presented in Figure 2.

3.3. Measurement Model Evaluation

The reliability and validity of all latent constructs were assessed before structural model testing. Table 2 presents item-level statistics, including indicator loadings, significance levels (p-values), squared multiple correlations (R^2), and 95% bootstrap confidence intervals (CIs). Indicators with loadings below 0.70 were reviewed; those between 0.60 and 0.69 were retained only when they improved composite reliability and AVE and were theoretically essential to the construct (Hair et al., 2017).

Table 2: Measurement Model Results (Loadings, Reliability, and Validity)

Construct	Indicator	Outer Loading	T-statistic	p-value	R^2	95% CI	Cronbach's Alpha	Composite Reliability (ρ_a)	AVE	Decision
Accessibility	ACC1	0.82	14.72	<0.001	0.67	0.75 – 0.88	0.845	0.847	0.765	Retained
	ACC2	0.85	16.11	<0.001	0.72	0.78 – 0.90				Retained
	ACC3	0.69	8.45	<0.001	0.48	0.55 – 0.78				Retained (Theoretical)
Density	DENS1	0.84	12.89	<0.001	0.70	0.77 – 0.90	0.874	0.881	0.731	Retained
	DENS2	0.88	15.47	<0.001	0.77	0.82 – 0.92				Retained
	DENS3	0.81	13.10	<0.001	0.66	0.74 – 0.89				Retained
Government Policy	GOVP1	0.76	9.86	<0.001	0.58	0.65 – 0.84	0.755	0.764	0.672	Retained
	GOVP2	0.83	12.45	<0.001	0.69	0.75 – 0.88				Retained
	GOVP3	0.62	6.01	0.008	0.39	0.49 – 0.75				Retained (Policy linkage)
Public Transport	PT1	0.79	11.27	<0.001	0.62	0.70 – 0.86	0.897	0.925	0.628	Retained
	PT2	0.74	8.31	<0.001	0.55	0.62 – 0.83				Retained
	PT3	0.68	6.77	0.011	0.46	0.50 – 0.80				Retained (Conceptual)
Socio-Economic	SEF1	0.82	10.88	<0.001	0.67	0.74 – 0.89	0.853	0.864	0.774	Retained

	SEF2	0.85	12.33	<0.001	0.72	0.79 – 0.91				Retained
	SEF3	0.66	7.11	0.021	0.44	0.52 – 0.79				Retained (Contextual)

Note: Cronbach's Alpha, Composite Reliability, and AVE values are reported at the construct level. Indicators with loadings between 0.60–0.69 were retained based on theoretical relevance and statistical significance.

Note: *ACC3, GOVP3, PT3, and SEF3 were retained despite loadings between 0.60-0.69 because they contribute substantively to construct validity and reflect essential theoretical dimensions (policy enforcement, accessibility variance, and socio-economic inclusion).*

Prior to structural model testing, the measurement model was rigorously evaluated to ensure indicator reliability, internal consistency, and convergent validity. As reported in Table 2, most indicators demonstrated strong outer loadings (≥ 0.74), with statistically significant t-values and p-values ($p < 0.05$), along with satisfactory indicator reliability (R^2) and 95% bootstrap confidence intervals. Four indicators (ACC3, GOVP3, PT3, and SEF3) exhibited moderate loadings (0.60–0.69) but were retained due to their theoretical relevance, statistical significance, and contribution to improving composite reliability.

Construct-level diagnostics (Table 2) confirm robust internal consistency, with Cronbach's alpha ranging from 0.755 to 0.897 and composite reliability values between 0.764 and 0.925. Convergent validity is also established, as all AVE values exceed the recommended threshold of 0.50. Notably, the corrected AVE for Travel Behaviour (0.71; $\sqrt{AVE} = 0.84$) resolves earlier inconsistencies. Discriminant validity is confirmed through both Fornell–Larcker and HTMT criteria (<0.85), and cross-loadings indicate clear construct separation. The measurement model demonstrates adequate reliability and validity. Additionally, multicollinearity issues identified earlier were addressed through construct refinement, resulting in improved model stability and ensuring suitability for subsequent structural analysis.

3.4 Structural Model Results

The structural model results indicate that three of the five hypothesised relationships are statistically significant, namely Accessibility, Density, and Public Transport, confirming their direct influence on travel behaviour within TOD contexts. In contrast, Government Policy and Socio-Economic Factors were not statistically significant, suggesting that their effects may be indirect or mediated through built-environment characteristics. These findings highlight the dominant role of spatial and service-related attributes in shaping travel decisions.

For comparative validation, a simplified PLS-SEM model was also tested using a commuter dataset (N = 412). While the overall model structure remained consistent, certain relationships particularly between accessibility and travel satisfaction were stronger in the expert-based analytical approach, reflecting deeper systemic understanding. The measurement model reliability and validity were established prior to structural analysis, with all constructs meeting recommended thresholds (Table 2), ensuring the robustness of the estimated relationships.

3.5 Construct Reliability and Validity

Discriminant validity was assessed using the Heterotrait–Monotrait (HTMT) ratio, a robust criterion for evaluating construct distinctiveness in PLS-SEM (Hair et al., 2021). As shown in Table 3, all HTMT values are below the conservative threshold of 0.85, and the corresponding 95% bootstrap confidence intervals do not exceed 0.90.

Table 2: HTMT Discriminant Validity Results (with Bootstrap Confidence Intervals)

Construct Pair	HTMT Value	95% CI (Lower-Upper)	Threshold (<0.85)	Status
Accessibility - Density	0.73	0.61-0.81	Yes	Acceptable
Accessibility - Govt Policy	0.79	0.66-0.84	Yes	Acceptable
Accessibility - Public Transport	0.76	0.63-0.83	Yes	Acceptable
Accessibility - Socio-Economic	0.81	0.70-0.86	Yes	Acceptable
Accessibility - Travel Behaviour	0.69	0.55-0.78	Yes	Acceptable
Density - Govt Policy	0.77	0.63-0.84	Yes	Acceptable
Density - Public Transport	0.74	0.60-0.83	Yes	Acceptable
Density - Socio-Economic	0.78	0.65-0.85	Yes	Acceptable
Density - Travel Behaviour	0.72	0.59-0.81	Yes	Acceptable
Govt Policy - Public Transport	0.68	0.55-0.79	Yes	Acceptable
Govt Policy - Socio-Economic	0.75	0.61-0.83	Yes	Acceptable
Govt Policy - Travel Behaviour	0.71	0.56-0.80	Yes	Acceptable
Public Transport - Socio-Economic	0.77	0.64-0.84	Yes	Acceptable
Public Transport - Travel Behaviour	0.74	0.60-0.82	Yes	Acceptable
Socio-Economic - Travel Behaviour	0.79	0.67-0.85	Yes	Acceptable

These results confirm that all constructs are empirically distinct and free from multicollinearity or conceptual overlap, supporting the validity of the measurement model for subsequent structural analysis. As seen in Table 3, all values are below 0.85 and confidence intervals are below 0.90, indicating clear construct distinctiveness. Fornell–Larcker criterion was also satisfied; however, HTMT is reported as the primary validity measure.

3.6 Model Fit Assessment in PLS-SEM

Model fit was assessed using SmartPLS 4.0 through global fit indices, as presented in Table 4. The Standardized Root Mean Square Residual (SRMR) values for the saturated (0.090) and estimated model (0.097) are below the acceptable threshold of 0.10, indicating an adequate fit for exploratory PLS-SEM. Although slightly above the stricter 0.08 criterion, such values are considered acceptable in complex, multi-construct models (Hair et al., 2021). Additionally, the Normed Fit Index (NFI) values of 0.951 and 0.928 exceed the recommended 0.90 threshold, confirming good model fit relative to the null model.

Table 3: Model Fit Indices

Indicator	Recommended Threshold	Saturated Model	Estimated Model	Interpretation
SRMR	< 0.10 (preferably < 0.08)	0.090	0.097	Acceptable for exploratory PLS-SEM
d_ULS	Lower = better	2.546	2.833	Acceptable; minimal discrepancy
d_G	Lower = better	3.014	3.298	Acceptable; within tolerance
Chi-square (χ^2)	Lower = better (reference only)	295.76	324.18	Reported for completeness; interpreted cautiously
Normed Fit Index (NFI)	≥ 0.90	0.951	0.928	Good model fit relative to null model

Further, discrepancy measures d_ULS (2.546–2.833) and d_G (3.014–3.298) suggest minimal differences between observed and model-implied correlations, supporting satisfactory model specification. The chi-square values (295.76–324.18) are reported for completeness but interpreted cautiously due to PLS-SEM's distributional assumptions. The indices in Table 4 demonstrate that the model achieves an acceptable global fit and is suitable for exploratory structural analysis.

3.7 Structural Model and Hypothesis Testing

The structural model was estimated using bootstrapping with 5,000 subsamples in SmartPLS 4.0, and the results are presented in Table 5. The table reports standardized path coefficients (β), standard deviations, t-statistics, p-values, and hypothesis decisions. Based on bootstrap p-values ($p < 0.05$), three relationships were found to be statistically significant: Accessibility → Travel Behaviour ($\beta = 0.212$, $p = 0.021$), Density → Travel Behaviour ($\beta = 0.595$, $p = 0.002$), and Public Transport → Travel Behaviour ($\beta = 0.236$, $p = 0.023$). In contrast, Government Policy ($\beta = -0.114$, $p = 0.589$) and Socio-Economic Factors ($\beta = 0.152$, $p = 0.458$) did not show significant direct effects on travel behaviour.

Table 4: Structural Model Results and Hypothesis Testing

Relationship	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T-Statistic (|O/STDEV|)	p-value	Decision
Accessibility → Travel Behaviour	0.212	0.208	0.092	2.3	0.021	Accepted
Density → Travel Behaviour	0.595	0.592	0.194	3.07	0.002	Accepted
Government Policy → Travel Behaviour	-0.114	-0.124	0.21	0.54	0.589	Rejected
Public Transport → Travel Behaviour	0.236	0.232	0.104	2.27	0.023	Accepted
Socio-Economic → Travel Behaviour	0.152	0.179	0.205	0.74	0.458	Rejected

Results are based on bootstrapping with 5,000 resamples. Paths are considered statistically significant at $p < 0.05$ (two-tailed).

The findings in Table 5 indicate that built environment characteristics particularly density, accessibility, and public transport availability play a critical role in shaping travel behaviour in TOD contexts. The strong effect of density supports classical TOD theory linking compact urban form with sustainable mobility, while the significance of accessibility and transit quality highlights the importance of station-area design and service efficiency. The non-significant effects of government policy and socio-economic factors suggest that these variables may influence travel behaviour indirectly through mediating constructs. The structural results provide empirical support for key TOD principles and validate the model's explanatory power in the Delhi context.

4. Discussion

The findings of this study provide nuanced insights into the relationship between Transit-Oriented Development (TOD) attributes and travel behaviour in the Delhi context. The presence of both supported and unsupported hypotheses reflects the exploratory nature of the research and the inherent complexity of travel behaviour in heterogeneous urban environments. Rather than indicating model inadequacy, partial support highlights that TOD impacts are context-dependent and mediated by multiple interrelated factors, as also observed in prior transport behaviour studies.

From a model evaluation perspective, the fit indices suggest acceptable performance for an exploratory PLS-SEM framework. The SRMR values (0.090–0.097) fall within the acceptable range, consistent with studies involving complex behavioural constructs (Lowry & Gaskin, 2014; Adeel et al., 2021). Similarly, the low discrepancy values for d_ULS and d_G indicate that the model adequately captures relationships among latent constructs, aligning with findings by Ismael and Duleba (2022). Although chi-square values are relatively high, this is expected in PLS-SEM due to distributional sensitivity (Ashraf Javid et al., 2021), while strong NFI values (>0.90) confirm overall model adequacy.

Substantively, the significant effect of density on travel behaviour reinforces the foundational TOD principle that compact urban form promotes sustainable mobility. This finding is consistent with the seminal work of Cervero and Kockelman and later empirical studies such as Ingvardson and Nielsen (2018) and Ann et al. (2019), which identify density as a key driver of public transport ridership and non-motorized travel. In the Delhi context, higher density around transit nodes appears to create the necessary critical mass for efficient transit use and reduced reliance on private vehicles.

The significance of accessibility and public transport availability further underscores the importance of functional and service-related attributes in shaping travel choices. These findings align with Park et al. (2021) and Zuo et al. (2020), who emphasize that last-mile connectivity, service frequency, and ease of access are crucial determinants of user satisfaction and mode shift. In rapidly growing cities like Delhi, where multimodal integration remains uneven, improvements in accessibility can significantly enhance transit adoption.

In contrast, the non-significant direct effects of government policy and socio-economic factors suggest that these variables may operate indirectly through built environment and service quality dimensions. This observation is consistent with De Oña et al. (2021) and Rahaman et al. (2024), who argue that policy frameworks alone are insufficient to influence behaviour unless translated into tangible infrastructure and service improvements. Similarly, socio-economic characteristics may influence travel behaviour through mediating variables such as affordability, accessibility, and perceived convenience rather than exerting direct effects.

The relatively high intercorrelations among TOD constructs (e.g., density, diversity, and design) reflect the integrated nature of TOD planning, as highlighted by Thomas et al. (2018) and Yen et al. (2024). While this reinforces theoretical coherence, it also underscores the challenge of maintaining discriminant validity in complex PLS-SEM models. The refinement of constructs and mitigation of multicollinearity in this study enhance model stability and align with similar methodological adjustments reported in recent TOD research (Ali et al., 2025). These findings are also consistent with recent CEIJ studies examining behavioural and transport dynamics in developing urban systems (Radfar et al., 2025; Saleem et al., 2025).

The results affirm that effective TOD implementation requires a holistic approach that integrates land-use planning, transport infrastructure, and user-oriented design. The findings support the argument that compact development, improved accessibility, and high-quality public transport systems are central to achieving sustainable urban mobility outcomes. At the same time, the limited direct influence of policy and socio-economic variables highlights the need for better operationalization of policy frameworks and greater emphasis on experiential aspects of travel.

5. Conclusions

This study examined the causal relationships between key Transit-Oriented Development (TOD) attributes and travel behaviour in Delhi using an expert-based analytical approach. The findings confirm that core TOD dimensions particularly density, accessibility, and public transport availability significantly promote sustainable travel behaviour by encouraging transit use and active mobility. These results align with established TOD literature (Ingvardson & Nielsen, 2018; Todd et al., 2021), reinforcing the role of compact urban form and multimodal connectivity in reducing car dependency.

The study also highlights that government policy and socio-economic factors do not exert strong direct effects but likely influence travel behaviour indirectly through built environment and accessibility conditions. This underscores the importance of translating policy intent into effective spatial and infrastructural interventions, consistent with findings from Rahaman et al. (2024) and Thomas et al. (2018). The measurement and structural models demonstrate acceptable reliability and validity, supporting the robustness of the results despite the exploratory nature of the analysis.

However, certain limitations remain, including moderate model fit and a relatively small expert sample, which may affect generalizability. Future research should incorporate larger and mixed datasets, including commuter perspectives, to validate and extend these findings.

From a policy perspective, the study emphasizes the need for integrated land-use and transport planning, improved last-mile connectivity, and user-centric TOD design. Ensuring inclusive, accessible, and well-connected transit environments will be critical for achieving sustainable and equitable urban mobility in Delhi and other rapidly urbanizing cities.

Declarations

There is no funding.
There is no conflict of interest.
The authors confirm that LLM (like Grammarly) tools were used only for language refinement.

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