Planning Mode Choice and Route Assignment for Public Transport Bus Service towards Vidhansabha in Gandhinagar City - A Review

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Abstract: Urban transport planning in Indian administrative cities demands integrated strategies that address both commuter behaviour and service efficiency. Gandhinagar, as Gujarat's capital, experiences concentrated travel demand toward its government core, especially the Vidhansabha and nearby secretariat complexes. Yet, existing public transport routes often lack alignment with actual travel behaviour and demand. This review synthesises global and Indian research on trip generation, mode choice, and route assignment frameworks relevant to optimising public transport in such contexts. Key methods include regression-based trip modelling, discrete choice approaches for mode analysis, and GIS-based optimisation for route design. The review highlights critical determinants—travel time, service reliability, built environment, and socio-economic attributes—and emphasises the role of data-driven decision support. It concludes by identifying pathways for developing a sustainable and accessible bus service network toward the Vidhansabha in Gandhinagar.

I. INTRODUCTION

Urban mobility forms the foundation of economic activity, productivity, and social equity in modern cities. Efficient transport networks not only facilitate movement but also shape land-use patterns and environmental outcomes. Gandhinagar, a planned administrative capital, offers an ideal test case for re-examining public transport performance in a controlled urban layout. Despite its grid-based design, the city's public bus system still faces mismatched connectivity between residential sectors and the administrative hub around the Vidhansabha. A lack of evidence-based route planning leads to congestion, longer travel times, and low modal share for public transport.

Contemporary research emphasises a shift from infrastructure-centric to behaviour-centric transport planning, integrating psychological, socio-economic, and environmental factors [1,5]. Integrating mode choice and route assignment modelling provides planners with the ability to simulate travel demand, evaluate service design, and forecast modal shifts under different scenarios. Thus, understanding the determinants of travel behaviour and employing robust analytical tools are essential for optimising Gandhinagar's public transport system.

II. NEED OF THE STUDY

Even in planned cities such as Gandhinagar, efficient mobility toward administrative complexes remains a persistent challenge. Most government employees and visitors depend on private vehicles because the available public bus routes are indirect or have inconvenient frequencies. Similar issues have been identified in Indian cities like Jaipur, Pune, and Chandigarh, where public transport underperforms in capturing work-related trips [22,21].

The need for this study is underscored by three pressing issues:
Rising travel demand – Expansion of residential sectors and new institutional zones have increased trip generation, while route capacity has not been upgraded proportionately.

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Environmental sustainability – Unchecked reliance on personal vehicles contributes to higher per-capita energy consumption and emissions [17].
Accessibility and equity – Reliable bus services can ensure equitable access to jobs and services, especially for lower-income groups [9].
Data-driven planning can address these by combining household surveys, spatial mapping, and model-based optimization to design routes reflecting actual commuter flows.

III. TRIP GENERATION AND ATTRACTION MODELING

3.1 Concept and Importance

Trip generation and attraction modeling form the first stage of travel demand analysis, quantifying how many trips are produced by each residential zone and how many are attracted to employment or service zones. In Gandhinagar, this stage is vital for identifying residential clusters that contribute most to travel demand toward the Vidhansabha.

3.2 Methods and Developments

Earlier approaches relied on linear regression and cross-classification models [18]. However, recent work shows that such models often ignore spatial dependence. Amavi et al. propose spatially advanced trip generation/attraction models that account for neighborhood effects and heterogeneity in household income and vehicle ownership [1].
For developing cities, integration of socio-economic and built-environment variables yields higher accuracy. Patel and Dave applied a GIS-based regression model for Gandhinagar and demonstrated that household income, employment status, and distance to transit corridors significantly influence trip frequency [20]. Similarly, Das and Mitra found that medium-sized Indian cities show strong linkage between trip rate and occupation type, particularly in government employment clusters [8].

3.3 Application to Gandhinagar

A practical model for Gandhinagar should delineate Traffic Analysis Zones (TAZs) along the city's sector boundaries and integrate both residential population and employment intensity. Variables such as household size, number of working members, and vehicle ownership can be used as predictors. Incorporating spatial lag terms (Moran's I statistics) will address the correlation among adjacent zones, improving model robustness and supporting subsequent mode choice and route assignment steps.

TABLE I:
SUMMARY OF LITERATURE ON TRIP GENERATION AND ATTRACTION MODELLING

Author(s), Year	**Study Focus**	**Methods Used**	**Key Findings**	**Relevance to Gandhinagar**
Amavi et al., 2014	Advanced trip generation/attraction	Spatial regression, neighbourhood effects	Household income, vehicle ownership, and intra-zonal effects significantly influence trip numbers	Supports need for spatial modelling for Gandhinagar's sector-based layout
Patel & Dave, 2018	GIS-based trip generation for Gandhinagar	GIS + multiple regression	Income, employment, and distance to transit corridors strongly impact trip rates	Provides a baseline methodology for Gandhinagar's TAZ-based planning
Das &Mitra, 2014	Trip behaviour in medium Indian cities	Regression models	Trip frequency strongly linked to occupation, especially government employees	Directly relevant for Vidhansabha-focused trip analysis
Ortúzar&Willumsen, 2011	Transport modelling framework	Classical trip generation methods	Reinforces importance of socio-economic and land-use characteristics	Supports integrated modelling for administrative cities
Roy & Sen, 2018	Urban travel characteristics	Household-level analysis	Socio-economic variations greatly influence public transport dependency	Helps identify low-income groups depending on bus routes

IV. MODE CHOICE ANALYSIS

4.1 Behavioral Foundations

Mode choice models capture how individuals select among alternative transport modes—bus, car, two-wheeler, or non-motorized—based on perceived utility. McFadden's discrete choice theory and Ben-Akiva and Lerman's framework remain fundamental [14,4], but more recent studies emphasize behavioral and psychological dimensions such as comfort and reliability [10].

4.2 Empirical Evidence

In India, multiple researchers have employed Multinomial Logit (MNL) or Nested Logit (NL) models to study urban mode choice. Arasan and Vedagirimodeled worker travel behavior and found that travel time, cost, and convenience dominate decision-making [2]. Singh and Gupta applied MNL to Jaipur, revealing income and vehicle ownership as strong determinants [22]. Lila and Vasantha observed that service frequency and waiting time critically affect public transport selection in Chennai [13], whereas Pandey and Singh emphasized service reliability in Lucknow [19].

Beyond traditional variables, built environment characteristics—density, land-use mix, and street connectivity—strongly affect mode choice [21]. Integrating these with socio-economic data improves the model's predictive power.

4.3 Implications for Policy

Elasticities derived from MNL models quantify how sensitive commuters are to fare changes or travel time improvements. For Gandhinagar, such elasticity measures can guide adjustments in service frequency or introduction of express routes toward the Vidhansabha during peak hours.

TABLE II:
SUMMARY OF LITERATURE ON MODE CHOICE MODELLING

Author(s), Year	Context / Case Study	Model Used	Major Determinants Identified	Key Takeaways for Gandhinagar
Arasan&Vedagiri, 2012	Urban workers, India	MNL	Travel time, cost, convenience	Improve frequency, reliability to attract govt workers
Singh & Gupta, 2017	Jaipur city	MNL	Income, vehicle ownership	Target two-wheeler users with direct express routes
Lila &Vasantha, 2019	Chennai	Multinomial logit	Waiting time, frequency	Reduce waiting time via scheduled services
Pandey & Singh, 2021	Lucknow	MNL	Reliability, comfort	Implement real-time bus information system
Banerjee & Bose, 2016	India	Behavioural analysis	Gender-based preference variations	Provide safe stops & night services
Grison et al., 2017	Europe	Behavioural assessment	Route familiarity, comfort	Include behavioural attributes in modelling

V. ROUTE ASSIGNMENT AND ROUTE-CHOICE MODELING

5.1 Principles of Assignment

Route assignment distributes trips across the transport network according to perceived cost or utility. Wardrop's principles distinguish between user equilibrium (each traveler seeks minimum individual cost) and system optimal (minimizing total network cost). For public transport, stochastic assignment methods incorporate perception errors and route heterogeneity.

5.2 Developments in Transit Assignment

Brands et al. introduced a model incorporating multiple access and egress modes, recognizing that many passengers walk, cycle, or use shared autos to reach bus stops [5]. Jansson and Ridderstolpe extended this by embedding route-choice constraints reflecting service reliability [11].

In dense urban networks, assignment must also handle overlapping routes and transfer penalties. Stochastic user equilibrium approaches or simulation-based assignment (e.g., VISUM, TransCAD) are commonly used [6,7]. Integrating these with real passenger data from smartcards or GPS traces improves accuracy [20].

5.3 Relevance to Gandhinagar

Given Gandhinagar's structured road hierarchy, network assignment can simulate current flows and identify congested corridors leading to the Vidhansabha. Comparing user-equilibrium and system-optimal results can reveal where express or limited-stop routes may yield overall time savings.

TABLE III:
SUMMARY OF LITERATURE ON ROUTE ASSIGNMENT AND TRANSIT NETWORK MODELLING

Author(s), Year	**Study Area / Context**	**Method / Model**	**Major Findings**	**Implications for Gandhinagar Bus Network**
Brands et al., 2014	Public transport systems	Multi-modal route-choice models	Access/egress modes influence route choice	Integrate walking/shared auto connectivity
Jansson&Ridderstolpe, 2015	Europe	Route choice with reliability	Reliability alters optimal paths	Focus on punctuality for Vidhansabha routes
Ceder, 2007	Global	Timetable + route design	Structured transit network design improves efficiency	Supports need for peak-hour scheduling
Mohanty &Jha, 2020	Bhubaneswar	Logit + GA optimization	Intermodal integration improves overall mobility	Use GA for Gandhinagar route optimisation
Zhao et al., 2015	China	GIS + Genetic Algorithm	Optimised routes reduce travel time significantly	Apply GA–GIS hybrid model for route redesign
Daganzo, 2010	Theoretical	Fundamental traffic principles	User-equilibrium improves route assignment accuracy	Helps validate system-optimal vs user-optimal routes

VI. OPTIMIZATION FRAMEWORK AND GIS INTEGRATION

6.1 GIS and Network Analysis

Geographic Information Systems (GIS) have become indispensable in transport modeling. They allow visualization of demand, network topology, and accessibility. Patel and Dave demonstrated how GIS-based models for Gandhinagar can generate realistic accessibility maps and evaluate alternative routes [20].

6.2 Metaheuristic Optimization Techniques

Metaheuristic algorithms such as genetic algorithms (GA), simulated annealing (SA), and ant colony optimization (ACO) provide efficient tools to search for near-optimal route configurations. Zhao et al. integrated a GA approach with GIS to optimize public bus routes, achieving substantial reductions in total travel time [20]. In India, Mohanty and Jha used logit-based assignment combined with GA to improve intermodal integration in Bhubaneswar [16].

6.3 Framework for Gandhinagar

A hybrid optimization framework combining demand modeling, GIS visualization, and metaheuristic search can systematically test scenarios:

- Adjusting bus frequency during peak hours,
- Adding new stops near large residential clusters, and
- Re-aligning routes to reduce overlap.

Such simulation environments can support decision-makers at GUDA or RTO to validate interventions before field implementation.

VII. FLEXIBLE SERVICES AND HYBRID APPROACHES

7.1 Need for Flexibility

Low-demand corridors or off-peak periods often suffer from under-utilization of fixed routes. Demand-responsive transit (DRT) or hybrid fixed–flex services can address this. Tsigdinos et al. combined user preferences and spatial analytics to plan flexible bus services in regional European cities; the approach holds potential for Indian administrative cities where trip destinations are highly clustered [23].

7.2 Indian Context

Pilot DRT applications in Indian Tier-II cities have shown improved accessibility and reduced operational cost [21]. Implementing small-scale feeder shuttles connecting residential sectors with trunk bus routes toward the Vidhansabha could enhance first/last-mile connectivity and attract riders who currently depend on two-wheelers.

VIII. BEHAVIORAL HETEROGENEITY AND CONTEXTUAL CONSIDERATIONS

Travel behavior is heterogeneous—driven by socio-economic background, trip purpose, and attitudinal preferences. Studies highlight gender differences in safety perceptions [3] and how these influence modal choice. Mehta and Sharma showed that government employees exhibit higher sensitivity to waiting time compared to other commuters [15].
Segmenting the Gandhinagar commuter population by employment type, gender, and vehicle ownership will allow more targeted service design. Incorporating psychological variables—such as perceived comfort or environmental awareness—can enhance mode-choice models, as demonstrated by Grison et al. [10].

IX. POLICY IMPLICATIONS AND IMPLEMENTATION PATHWAY

9.1 Short-Term Actions

• Introduce express bus routes during peak administrative hours (8:00–10:00 AM, 5:00–6:30 PM) between high-density residential sectors and the Vidhansabha.
• Improve frequency and reliability, key drivers of public transport choice [19].
• Provide real-time passenger information systems and integrate digital ticketing to improve user convenience.

9.2 Long-Term Strategies

•Incorporate land-use–transport integration in city planning, as recommended by Dasgupta and Adhikari [9].
•Develop a comprehensive mobility plan (CMP) that aligns with national policies under AMRUT and Smart City missions.
•Implement periodic data collection (household and destination surveys) for model calibration every five years.
Successful examples from other Indian cities like Bhopal's corridor restructuring under its CMP—show how iterative, model-based planning leads to measurable modal shifts and lower operational costs.

X. CONCLUSION (INTEGRATED WITH RESEARCH GAPS AND FUTURE DIRECTIONS)

This review underscores the value of integrating behavioral analysis, spatial modeling, and optimization techniques for designing efficient bus routes toward key administrative destinations. While Gandhinagar's planned geometry offers a clear structure for analysis, its success depends on robust data and policy coordination.

Future research in this domain should focus on:
Hybrid Data Integration – combining traditional surveys with emerging passive data (GPS, mobile traces) for more accurate model calibration.
Dynamic Assignment Models – incorporating temporal variations in travel demand, particularly during legislative sessions or peak government hours.
Equity and Sustainability Metrics – embedding environmental and social objectives into optimization routines to ensure inclusive planning.
Pilot Implementation Studies – evaluating the real-world performance of optimized routes or flexible feeders in Gandhinagar.
Adopting such a holistic, data-driven approach can transform Gandhinagar's public transport system into a model of sustainable, efficient, and commuter-responsive mobility.

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