ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Volume 13, Issue 06, June 2026

Improvisation of Public Transport System in Ahilyanagar City

[1] Ar. Ankit Bhagwan Avhad, [2] Dr. S. G. Sonar

[1] [2] Department of Planning, COEP Technological University, Pune, Maharashtra, India
Corresponding Author Email: [1] ankitbavhad@gmail.com, [2] sgs.civil@coeptech.ac.in

Abstract— ***Due to the legacy of radial network topologies and fast, uncontrolled urban development, public transportation in India's mid-tier cities is frequently characterized by systemic inefficiencies. The serious transit deficiencies in Ahilyanagar City, Maharashtra, which presently depends on an unsustainable modal share of 53.7% for private two-wheelers, are the focus of this study. Using Geographic Information Systems (GIS) for Catchment Area Analysis (CAA) and primary Origin-Destination (O-D) surveys to identify significant "Transit Deserts" where 79.3% of the population lives beyond the 500-meter statutory Service Level Benchmark (SLB) accessibility buffer, the study uses a mixed-methods approach to diagnose these inefficiencies.***

By using demographic forecasting alongside density-based coefficients, the research identifies a 50% spatial and operational shortfall across the existing municipal transit fleet. To mitigate this, the study suggests a phased shift from the current hub-and-spoke radial setup, toward a more decentralized, integrated "Trunk-and-Feeder" network. In that approach, the deployment of newly sanctioned Electric Buses, or E-Buses, is handled via dynamic headway analytics t `hat lean on density rules, with a Cd application included. It also sort of formalizes how Intermediate Public Transport, IPT, gets woven in, to cover the last mile connectivity gaps that always pop up. Overall, the results lay out a framework that other mid-tier cities can reuse, so they can align ecological sustainability with operational efficiency, and still give municipal corporations clear action steps over a 10-year planning horizon.

Keywords— ***Ahilyanagar, Electric Mobility, GIS Spatial Modeling, Trunk-and-Feeder Network Service Level Benchmarking, Urban Transit Planning.***

I. INTRODUCTION

Ahilyanagar, serving as the district headquarters in the central part of Maharashtra state, is geographically positioned as a pivotal regional node. Located approximately 156 kilometers from Nashik and 120 kilometers from Pune, its strategic location along National Highway 50 endows the city with critical connectivity that heavily influences its economic and social development trajectories. The district's economy exhibits wide diversification, integrating traditional sugarcane agriculture with an expanding manufacturing sector and a robust educational infrastructure.

Demographically, Ahilyanagar hosts approximately 350,000 residents, with a youthful population skewed heavily toward those below 25 years of age (35%). Economic surveys indicate that roughly 70% of the population subsists on monthly incomes below ₹25,000, amplifying the vital role of affordable public transportation as an enabler of social equity.

Despite this, the city's transport landscape is characterized by severe infrastructural constraints. The public transport services, predominantly operated by the Maharashtra State Road Transport Corporation (MSRTC), experience significant demand-supply mismatches exacerbated by fleet reductions and insufficient service frequencies. This has forced a growing dependence on personal motor vehicles, leading to an unsustainable 53.7% reliance on private two-wheelers.

Furthermore, the existing network suffers from a systemic "Radial Flaw," functioning on an inefficient hub-and-spoke model where all cross-city trips are forced to converge at the historic Central Bus Stand (CBS). This research aims to develop an actionable, data-driven plan to improve Ahilyanagar city's public transport system, addressing these localized bottlenecks and preparing for future capacity demands over a medium-term 10-year horizon.

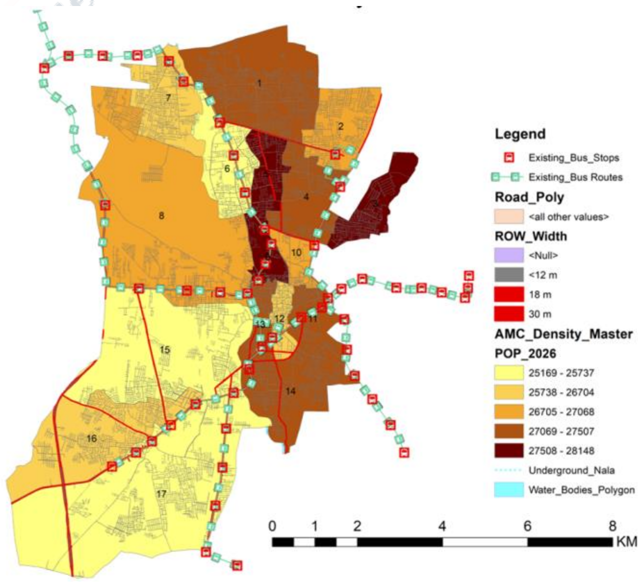

Figure 1(a). Existing Hub-and-Spoke Radial Bottleneck

ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Volume 13, Issue 06, June 2026

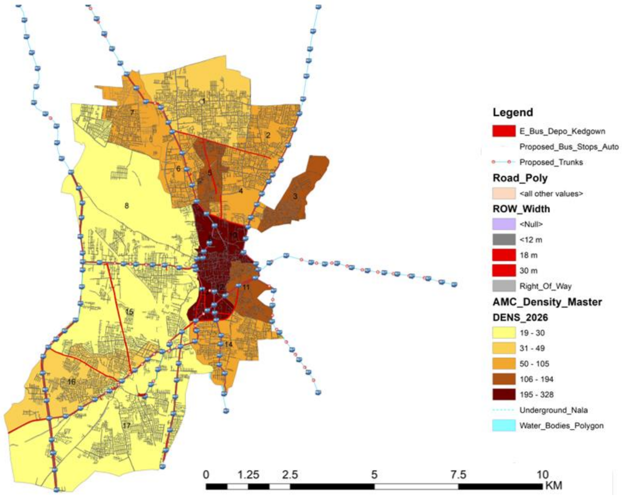

Figure 1(b). Proposed Ring-and-Radial Flow

II. METHODOLOGY AND STUDY AREA

The spatial scope of this research covers the core urban area and immediate peripheral regions of Ahilyanagar, utilizing municipal wards as formal Traffic Analysis Zones (TAZs). A mixed-methods approach was adopted, combining spatial geographic mapping with rigorous primary data collection.

To ensure statistical validity for the user perception and Origin-Destination (O-D) surveys, Cochran's Formula for large populations was applied at a 95% confidence level and a 5% margin of error.

$$n = \frac{Z^2 . p . q}{e^2} \quad (1)$$

Where
Z = % confidence level (1.96)
p =estimated proportion (0.5)
q =0.5
e =acceptable margin of error (0.05)

This calculation established a target of 384 statistically significant samples.

Data collection utilized structured methodologies across five stratified municipal zones. A User Satisfaction Survey assessed acceptable walking distances and modal preferences, while an O-D survey established empirical "Desire Lines" indicating the origins and terminations of internal trips. Simultaneously, manual volumetric Traffic Movement Counts (TMC) were conducted at critical arterial junctions during peak hours (08:30–10:30 AM and 17:00–19:00 PM) to quantify physical kinetic friction.

III. SPATIAL GAP AND DEMAND ANALYSIS

The fundamental basis of this transit Master Plan is the precise quantification of both current and future mobility demands against statutory national guidelines.

A. Demographic Forecasting

Ahilyanagar is experiencing rapid spatial expansion characteristic of mid-tier industrial hubs. To accurately project the population over a medium-term horizon, the Geometric Increase Method was employed.

$$P_n = P_0 \left(1 + \frac{r}{100}\right)^n \quad (2)$$

Where:
P_n = The projected future population after n decades or years.
P_0 = The baseline (current) population of the study area.
r = The assumed constant percentage growth rate per decade/year.
n = The number of decades or years into the future being projected.

Applying this methodology strictly to the AMC municipal wards, the baseline population for the immediate operational horizon (2026) was established at 457,028 residents, with a long-term projection of 533,795 by 2036.

Table I. Demographic Forecasting of Ahilyanagar (AMC LIMITS)

Year	Forecasting Horizon	Projected Population	Estimated Growth Rate
2026	Baseline (Current)	457,028	-
2031	Short-Term (5 Years)	493,923	16.8% per decade
2036	Medium-Term (10 Years)	533,795	16.8% per decade

B. Spatial Equity and Catchment Area Analysis (CAA)

According to the Ministry of Housing and Urban Affairs (MoHUA), the standard acceptable pedestrian walking distance to a transit node is defined as 0.5 kilometers (500 meters). Areas falling completely outside of this pedestrian buffer are formally classified as "Transit Deserts".

To audit the existing Ahilyanagar Municipal Corporation (AMC) bus network against this Service Level Benchmark (SLB), the coordinates of all active legacy bus stops were mapped within ArcMap, and a strict 0.5 km spatial buffer was generated. The spatial overlay yielded severe diagnostic results: the 500-meter catchment shadows were heavily clustered around the historic central core, leaving 79.3% of the surveyed residents in completely unserved Transit Deserts. This immense lack of physical accessibility is the direct causative factor driving the city's heavy reliance on private transport.

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Volume 13, Issue 06, June 2026

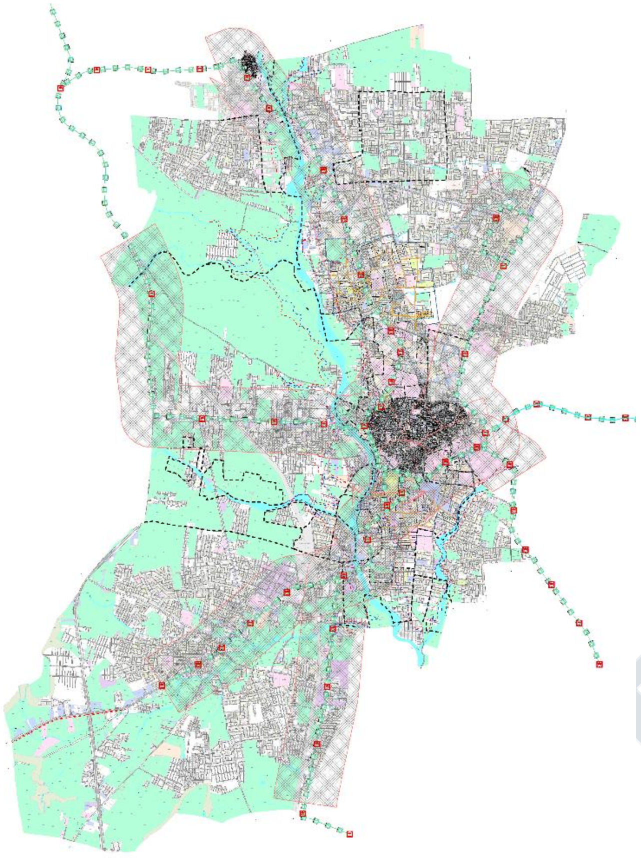

Figure 2. Existing 500m Walkability Buffer revealing the 79.3% Transit Desert gap

IV. STRAFFIC VOLUME AND JUNCTION CAPACITY

For a proposed high-capacity transit network to maintain reliable dynamic headways, buses must navigate the city's arterial network without succumbing to severe intersection delays. A detailed Level of Service (LOS) evaluation was conducted at primary arterial junctions, including Sakkar Chowk, Bhistabag Chowk, Kinetic Chowk, and DSP Chowk.

The physical volume-to-capacity assessment revealed that the approaching arms at these critical junctions ranging from 12 meters to 24 meters in Right-of-Way (ROW) currently operate at an LOS ranging from B-C to C. An LOS of C indicates highly restricted maneuverability. Forcing an electric bus fleet through these bottlenecks without route rationalization will inevitably result in schedule degradation, dragging the commercial speed below the target 20 km/h SLB threshold and accelerating battery depletion.

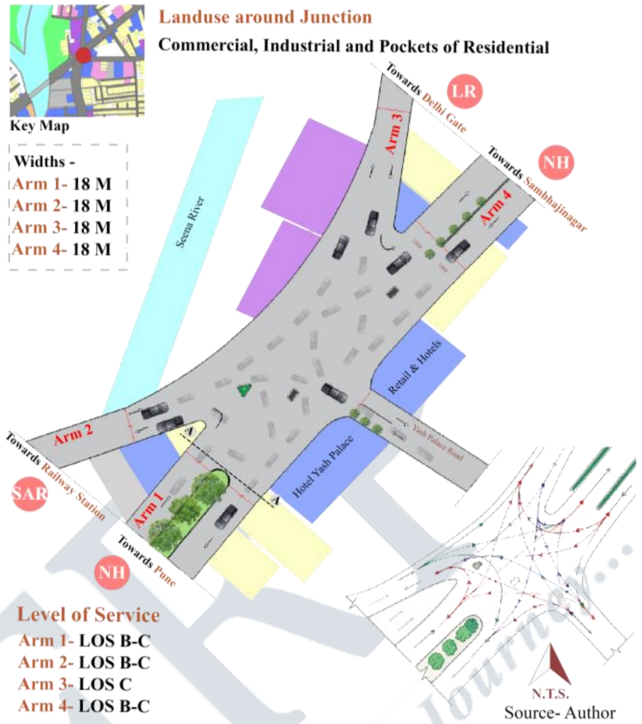

Figure 3. Level of Service (LOS) Assessment at Critical Arterial Junctions

V. OPERATIONAL DEFICIT AND FLEET SIZING

Translating raw demographic demand into physical infrastructural requirements is the most critical mathematical derivation of the Master Plan.

A. Peak Hour Load

Because Ahilyanagar falls within the 1 to 5 Lakh demographic tier, statutory benchmarks mandate a minimum public transport modal share of 15%. Intersecting the 2026 baseline population (457,028) with this target yields a daily demand of 68,554 transit trips.

Applying the IRC:106-1990 standards for urban road capacity, the design Peak Hour Factor is established at 10%, condensing demand to a peak hourly load of 6,855 trips. Accounting for tidal commuter flows, a strict 60/40 directional split was applied, establishing an absolute peak directional load of 4,113 passengers per hour.

B. Fleet Sizing Formulation

Utilizing a combined seating and standing capacity of 50 passengers per mid-sized urban bus, the network requires an absolute dispatch rate of 83 buses per hour in the peak direction. Because the AMC is transitioning to an Electric Vehicle (EV) fleet, a mandatory 15% rotational maintenance and charging reserve must be integrated.

The total operational fleet requirement is derived by multiplying the hourly dispatch rate by the calculated average Round Trip Time (RTT = 0.6451 hours) and factoring in the 15% EV reserve multiplier:

ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Volume 13, Issue 06, June 2026

$$Total\ Fleet = (83 \times 0.6451) \times 1.15 = 61.57 \approx 62 \quad (3)$$

The AMC requires an operational fleet of 62 buses to achieve the statutory 15% modal share. With a current operational potential of only 55 buses, the municipality faces a significant 11% numerical supply deficit, compounding the existing 79% spatial deficit.

Table II. SLB Gap And Operational Deficit Analysis

Parameter	Statutory Target / Required	Current AMC Status	Identified Deficit / Gap
Spatial Accessibility (500m Buffer)	100% Coverage	20.7% Coverage	**79.3%** (Transit Deserts)
Public Transport Modal Share	15% Minimum	Negligible Formal PT	Unmet (53.7% Private 2W reliance)
Target Daily Transit Trips	68,554 Trips	Sub-optimal / Unmet	Major Demand-Supply Mismatch
Total Operational Fleet	62 Buses	55 Buses (40 EVs + 15 Existing)	**7 Buses** (To be mitigated via IPT)

VI. DYNAMIC SCHEDULING AND HEADWAY ANALYTICS

Static scheduling is a primary driver of operational inefficiency. To prevent the municipal fleet from hemorrhaging energy, the system utilizes Density-Based Headway Analytics.

The operational foundation is the calculated Round-Trip Time (T) for each transit corridor to maintain a 20 km/h commercial speed (V):

$$T = \left(\frac{L}{V}\right) \times 60 + (n \times d) \quad (4)$$

Where:

T = The total Round-Trip Time (cycle time) in minutes.

L = The total loop length (route distance) in kilometers, extracted via GIS spatial geometry.

V = The target commercial kinetic speed in km/h (standardized at 20 km/h as per Service Level Benchmarks).

n = The total number of scheduled passenger stops along the route.

d = The average dwell time per stop in minutes (standardized at 2 minutes to account for high-density passenger onboarding).

Headways are dynamically throttled based on a municipal Density Coefficient (C_d). The target headway (H_r) is derived from the base 10-minute service headway (H_b):

$$H_r = \frac{H_b}{C_d} \quad (5)$$

Where:

H_r = The final target (throttled) service headway for the specific route in minutes.

H_b = The base ideal service headway in minutes (set at 10 minutes for optimal high-frequency trunk service).

C_d = The Density Coefficient assigned to the specific municipal ward (e.g., 1.0 for Tier 1 High-Density Core, 0.66 for Tier 2 Transition zones, and 0.5 for Tier 3 Peripheral zones).

Core Trunk routes in high-density Tier 1 wards (C_d = 1.0) receive the mandatory 10-minute headway to maximize throughput. Transition connectors in Tier 2 wards (C_d = 0.66) operate at 15-minute intervals, while Peripheral Feeders in Tier 3 wards (C_d = 0.5) are throttled to 20 minutes to prevent the wasteful operation of high-capacity electric buses in low-demand zones.

Table III. Density-Based Headway Throttling (C_d)

Route Classification	Ward Density Tier	Density Coefficient (Cd)	Target Headway (Hr)
Core Trunks	Tier 1 (High Density)	1.0	10 Minutes
Transition Connectors	Tier 2 (Medium Density)	0.66	15 Minutes
Peripheral Feeders	Tier 3 (Low Density)	0.50	20 Minutes

VII. INTEGRATED PUBLIC TRANSPORT SYSTEM PROPOSALS

To systematically resolve the CBS radial bottleneck and bridge the 500-meter catchment gap, the network is restructured into a strict Trunk-and-Feeder hierarchy.

A. The Trunk Network

The 40 new AMC electric buses will be deployed exclusively on linear, high-density arterial corridors possessing a Right-of-Way (ROW) greater than 18m. These Core Trunks bypass the historic CBD, connecting peripheral residential wards directly to employment nodes and educational campuses at reliable 10-to-15-minute frequencies.

B. Intermediate Public Transport (IPT) Integration

To eradicate the Transit Deserts, formalized E-rickshaws (IPT) will be deployed as capillary feeder networks in narrow inner-city TAZs with ROWs under 12m. These vehicles are mathematically suited to bridge the 0.5 km gap, funneling passengers to formal "Mid-Hub" interchanges along the Trunk routes without forcing them to travel to the central

IFERP
Explore Your Research Journey...
ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Volume 13, Issue 06, June 2026

core.

C. Zero-Dead-Mileage Depot Placement

The primary E-Bus depot is strategically placed in Kedgaon (Ward 17). By aligning the start and end of high-capacity trunk routes with this southern facility, the network eliminates "dead mileage," ensuring the fleet remains in a revenue-generating state while integrating the mandatory 15% charging reserve.

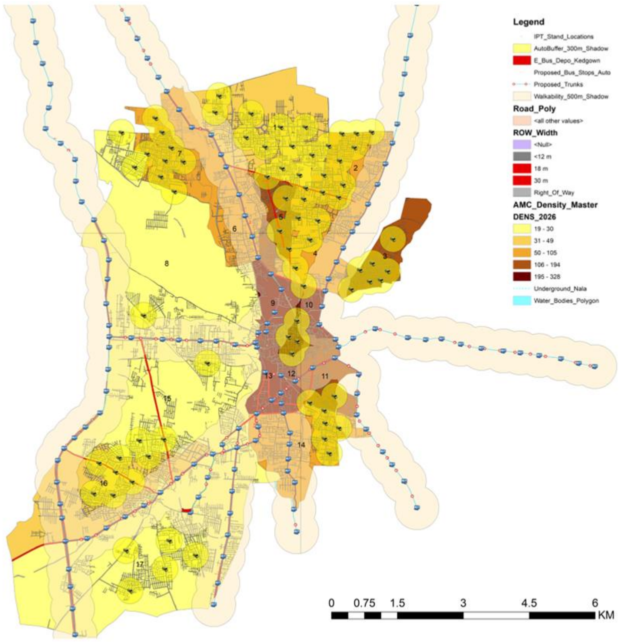

Figure 4. Proposed Trunk-and-Feeder Transit Corridors intersecting with 250m IPT Nodes

VIII. CONCLUSION

This analysis proves that Ahilyanagar's public transport deficit cannot be solved merely by the linear acquisition of rolling stock. By transitioning from a centralized hub-and-spoke model to a spatially engineered Trunk-and-Feeder hierarchy, the Ahilyanagar Municipal Corporation can bridge the critical 79.3% accessibility gap. The application of geometric demand forecasting, GIS spatial modeling, and density-based headway analytics provides a mathematically sound, replicable blueprint. This master plan ensures the optimal deployment of the incoming electric bus fleet, harmonizing statutory Service Level Benchmarks with long-term urban sustainability.

REFERENCES

[1] T. Banerjee, "Sustainable transportation infrastructure in Indian cities of different size-class: towards a research and policy agenda," Transport Policy, vol. 142, pp. 89-102, 2024.
[2] S. Dawda, "Towards a comprehensive framework for public transport planning in India," SSRN Electronic Journal, 2024.
[3] A. Fielbaum, "Improving public transportation via line-based integration of fixed and flexible services," Transportation Research Part A: Policy and Practice, vol. 182, 104537, 2024.
[4] T. Ghosh, "Enhancing inclusiveness and sustainability of public transport systems: A case study of Bengaluru," Case Studies on Transport Policy, vol. 11, pp. 234-248, 2023.
[5] G. Tiwari, "Development of public transport systems in small cities: A comparative study of Patiala and Bulandshahr," IATSS Research, vol. 45, no. 1, pp. 12-25, 2021.
[6] M. Kumar, "Informal public transport modes in India: A case study of intermediate public transport," IATSS Research, vol. 40, no. 2, pp. 83-89, 2016.
[7] A. B. Gaikwad and S. G. Sonar, "Integrated Public Transportation Planning for Pune Metropolitan Region," Proceedings of the Second National Online Conference on Planning, Design and Management 2022, pp. 333-344, 2022.