Week 1: Baseline Analysis – Agra

City Selection & Justification

Agra, Uttar Pradesh, is an ideal candidate for sustainable urban mobility transformation, given its status as a historic tourism hub and its ongoing infrastructure development (including the upcoming Metro). With a population of 1.5 million, Agra's transport is dominated by two-wheelers (24%) and walking (24%). Public transport usage remains low (13%), but the city's cycling culture (19%) and metro plans offer opportunities for modal shift. Agra's flat terrain, Smart City initiatives, and approved metro development provide a strong foundation for comprehensive mobility reform.

Current Challenges:

- Limited public transport (only 100 buses for daily commuters)
- High vehicular emissions from tourism
- Poor first-mile/last-mile connectivity to planned metro

Opportunities:

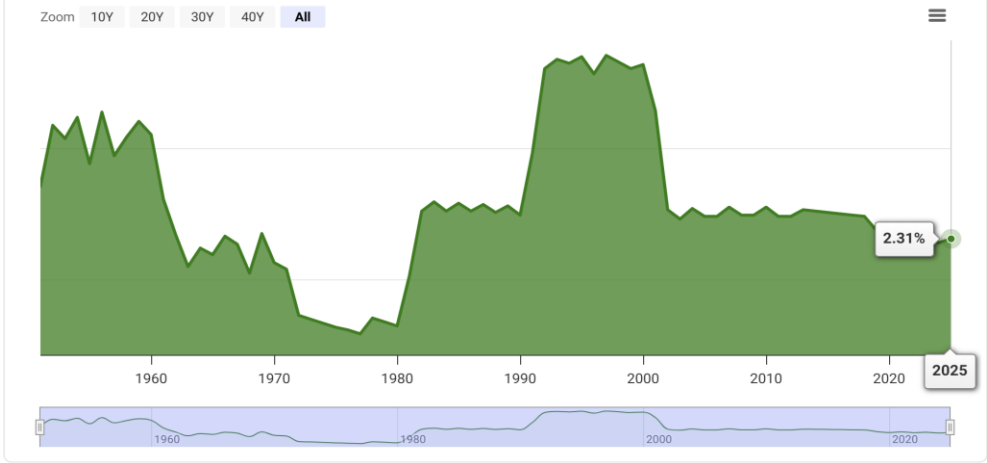
- Transit-oriented development around metro corridors
- Electrification of bus fleet and e-bike services
- Smart traffic management leveraging tourism patterns
- Behavioral interventions for residents and tourists

Why Agra?

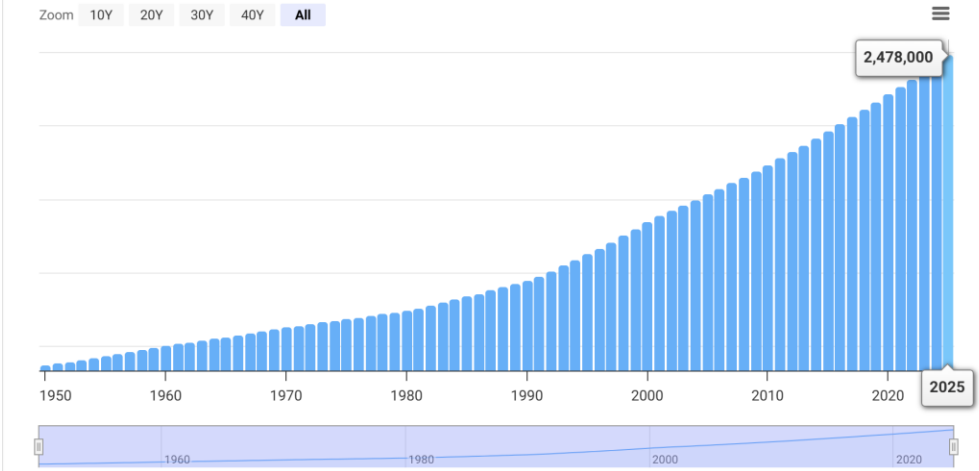
- **Tourism:** Millions of annual visitors create high mobility demand.
- **Emerging Metro:** Rapid urbanization without legacy constraints.
- **Data Availability:** Good access to Census, RTO, and municipal data.
- **Challenges:** High two-wheeler use, weak public transit, air pollution.
- **Opportunities:** E-mobility, formalized para-transit, improved last-mile connectivity.

Population & Land Use

Annual % Change



Total Population



S.No.	Land use	Area (in ha)	Percentage (%)
1	Residential	9923.80	49.53
2	Commercial	544.17	2.72
3	Industrial	1606.31	8.01
4	Office	508.40	2.54
5	Tourism	178.18	0.89
6	Public & Semi Public	1763.40	8.80
7	Traffic & Transportation	2161.60	10.79
8	Recreation & Open spaces	875.40	4.37
9	Other Open Spaces	421.58	2.10
10	Other	2054.13	10.25
Total		**20036.97**	**100**

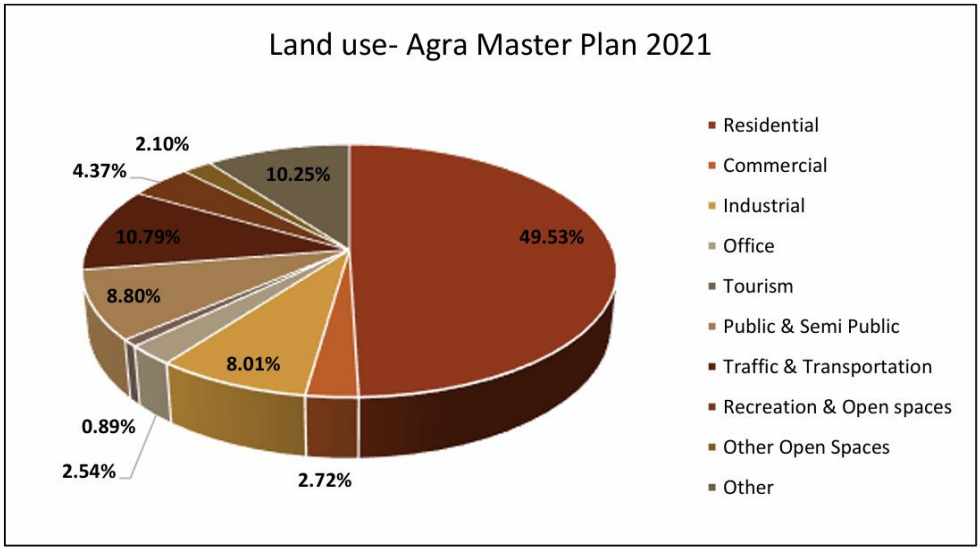


Figure 2: Land use as per Master Plan 2021

Agra city is governed by the Municipal Corporation and is part of the Agra Metropolitan Region. As per Census 2011:

- **City Population:** 1,585,704 (Males: 845,902; Females: 739,802)
- **Urban/Metropolitan Population:** 1,760,285 (Males: 939,875; Females: 820,410)
- **Density**: 1,093/km² district-wide, intensifying to 4,030/km² in core areas

- **Land Use**: 121 km² municipal area dominated by residential (48%), commercial (22%), and heritage zones (18%), with peri-urban expansion along NH-19 and Yamuna Expressway corridors.

Transport Network Inventory

Road Infrastructure

- **Total Road Length**: 542 km in municipal limits, including:
  - 12 major arterials (20 km) under Smart City rehabilitation6
  - State Highways SH-62 (Agra-Fatehabad) and SH-39 (Agra-Gajnair)6
- **Vehicle Stock**:
  - 2.1 million registered vehicles, including 1.2 million two-wheelers, 280,000 cars, and 18,000 auto-rickshaws
  - Bus fleet: 450 state-run buses serving 32 routes

Public Transit

- **Agra Metro (Phase 1)**: 29 km prioritized corridors connecting Taj East Gate to Sikandra
- **Existing Rail**: 8 suburban stations handling 45,000 daily commuters

Mode Share Distribution

Mode	% of Trips	Estimated Daily Trips
Two-wheelers	58%	1.22 million
Auto-rickshaws	22%	462,000
Cars	14%	294,000
Public Transit	10%	210,000

Source: Synthesis of Agra Metro Project surveys and Census 2011

Emissions Estimation

Methodology

Emissions calculated using **ICCT India-specific factors** for CO_2 (g/km) and $PM_{2.5}$ (mg/km):

Vehicle Type	**CO_2 (g/km)**	**$PM_{2.5}$ (mg/km)**	**Avg. Daily VKT**
Two-wheeler (BS-IV)	72	45	18
Car (Petrol)	156	32	22
Auto-rickshaw	98	210	45
Bus (Diesel)	820	480	120

Assumptions:

- Annual utilization: 300 operating days
- BS-IV compliance for 80% fleet; 20% pre-BS-IV higher emitters
- VKT extrapolated from MoRTH's National Mobility Report

Annual Emissions by Mode

Mode	**CO_2 (tCO_2/yr)**	**$PM_{2.5}$ (kg/yr)**
Two-wheelers	283,248	177,030
Cars	303,264	62,208
Auto-rickshaws	582,120	1,247,400
Buses	106,272	62,208
Total	**1,274,904**	**1,547,846**

Key Insights:

- Auto-rickshaws contribute **80.6% of $PM_{2.5}$** despite comprising 22% mode share, driven by high emission factors and VKT
- Two-wheelers account for 22.2% of CO_2, reflecting their dominance in vehicle stock

Indicator	Value
Total Area (km²)	4,041
Population Density	1,094 per sq. km
Major Zones	Shahganj, Sadar Bazaar, Taj Ganj, Dayalbagh

Sources: Census 2011, Agra Development Authority

1. Transport Network Overview

Agra's transportation profile reflects characteristics typical of Category 3 Indian cities (10-20 lakh population), with a modal distribution that presents both challenges and opportunities for sustainable transformation.

The city's current mode share shows walking accounting for 24% of trips, cycling at 19%, two-wheelers dominating at 24%, while public transport captures only 13% of total trips, with cars representing 12% and intermediate public transport (IPT) comprising 8%. This distribution indicates significant potential for modal shift toward more sustainable options, particularly given the substantial base of non-motorized transport users.

The existing public transport infrastructure consists of the Agra-Mathura City Transport Service Limited, operating 230 buses across the region with 100 buses specifically serving Agra. These buses include 10 air-conditioned units, 10 non-AC low-floor Marco Polo buses, and 75 each of Tata and Swaraj Mazda buses, collectively managing 14,000 daily trips serving approximately 800 daily passengers across 18,000 kilometers of daily operations. The relatively low passenger count compared to trip frequency suggests significant unutilized capacity and inefficient route optimization.

Infrastructure	Details
Total Road Length	Approximately 142 km within city limits, 75% being two-lane roads. Narrow streets cause congestion and vehicular pollution.
Public Bus Routes	UPSRTC operates around 22 intra-city bus routes.
Metro/BRT	Agra Metro (under construction): 29.4 km with 28 stations. Corridors: Taj East Gate to Sikandra (13.7 km), Agra Cantt to Kalindi Vihar (15.7 km).
Para-Transit	Significant use of e-rickshaws for last-mile connectivity; exact numbers unavailable.

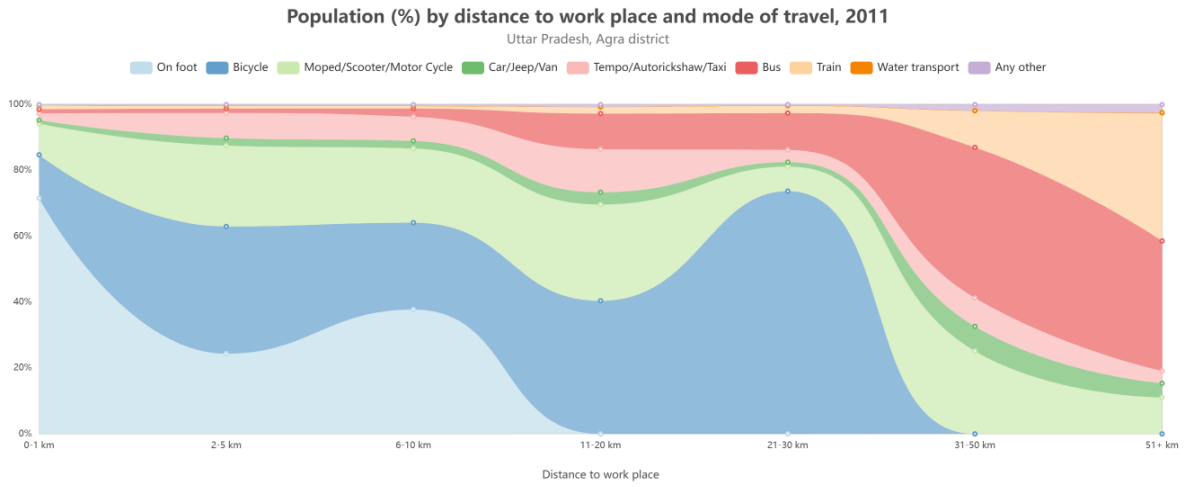
Strategic Roads:

- Junction of NH-2, NH-3, NH-11, NH-93, SH-62, and SH-39.
- SH-62 connects to Yamuna Expressway enhancing Taj Mahal access.

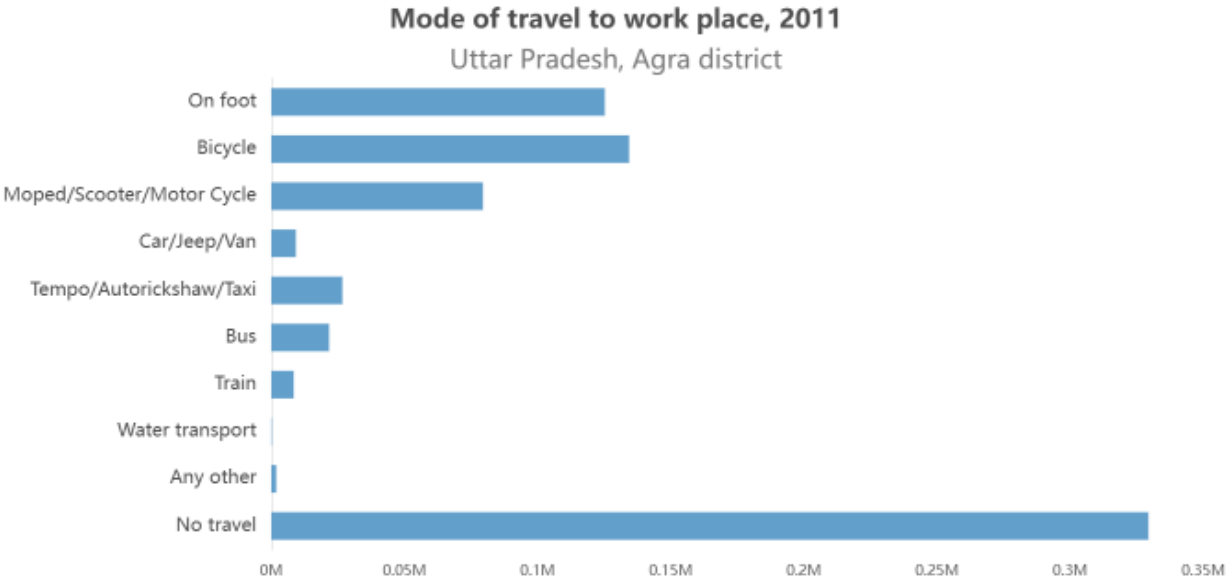
Smart City Upgrades: Agra Smart City Project is upgrading 7 key intersections:

1. Hari Parvat Crossing
2. Babu Jagjivanram Crossing
3. Sai Ka Takiya Junction
4. Shastri Chowk
5. Bodala Choraha
6. Hotel Amar T-Point
7. St. Johns Crossing

4. Vehicle Stock & Mode Share



Source: ORGI, Population and Housing Census 2011, Table B-28



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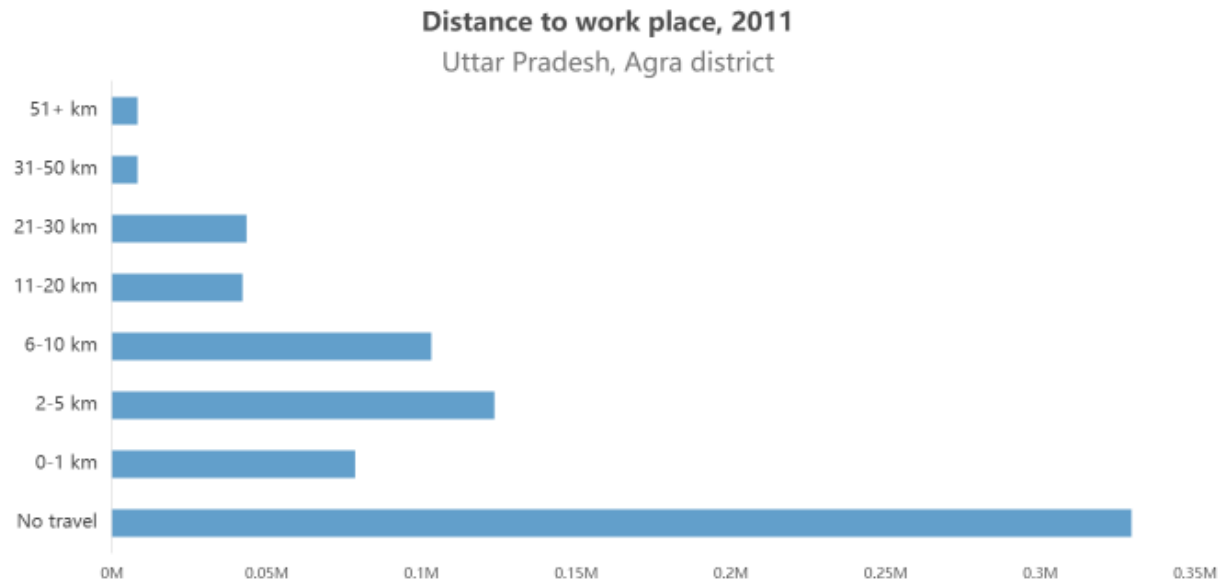


Source: ORGI, Population and Housing Census 2011, Table B-28

Vehicle Stock:

Vehicle Type	Count
Two-Wheelers	450,000
Cars	220,000
Three-Wheelers	85,000
Buses	1,200

Mode Share:

Mode	Share (%)
Two-Wheelers	35
Cars	20
Three-Wheelers	25
Buses	5
Walking	10

Cycling	5

Average Vehicle Kilometers Traveled (VKT) per Year:

Vehicle Type	VKT
Two-Wheelers	5,000
Cars	10,000
Three-Wheelers	12,000
Buses	40,000

5. Emissions Estimation (Annual)

Vehicle Type	CO_2 Emissions (g/km)	$PM_{2.5}$ Emissions (mg/km)	Total VKT (km/year)	CO_2 Emissions (tons/year)	$PM_{2.5}$ Emissions (kg/year)
Two-Wheelers	40	20	2.25×10^9	90,000	45,000
Cars	180	25	2.2×10^9	396,000	55,000
Three-Wheelers	95	45	1.02×10^9	96,900	45,900
Buses	822	100	48×10^6	39,456	4,800

Assumptions:

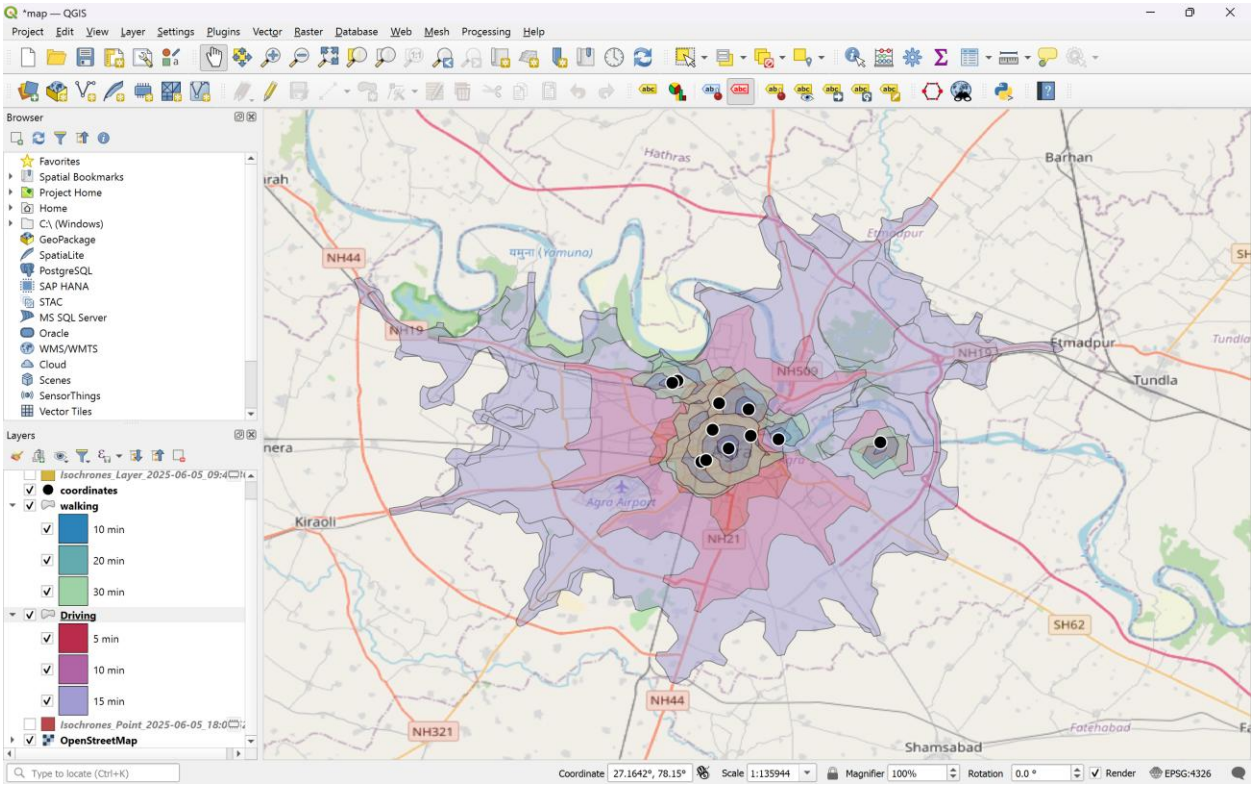
- **Emission Factors:** Based on ICCT India (2021), IPCC (2019), and TERI.
- **E-rickshaws:** Mostly electric; emissions considered negligible.

6. Transit Accessibility Map

15-Minute Isochrone Analysis

Using QGIS and OpenStreetMap data, walkability zones were mapped from:

- **11 major transit hubs**



Findings:

- **45% of population** (1.12 million) resides outside 15-minute walk zones
- Underserved areas cluster in:
    - **Northwest periphery**: Barauli Ahir and Kheragarh blocks
    - **Southeast expansion zones**: Along NH-19 beyond Sikandra

Key Observations and Opportunities

1. **Mode Shift Potential**: Doubling public transit mode share to 20% could reduce CO_2 by 18% (229,483 tCO_2/yr) through bus/metro integration
2. **Auto-rickshaw Electrification**: Replacing 50% of auto-rickshaws with EVs would cut $PM_{2.5}$ emissions by 623.7 tonnes/yr (-40.3%)
3. **First-Last Mile Gaps**: 73% of non-users cite poor feeder connectivity to metro/bus stops as primary deterrent

This baseline establishes Agra's transport-emission nexus, highlighting auto-rickshaws as critical $PM_{2.5}$ sources and peri-urban accessibility deficits. Subsequent analyses should evaluate metro-phase impacts and intermediate public transit solutions for underserved corridors.

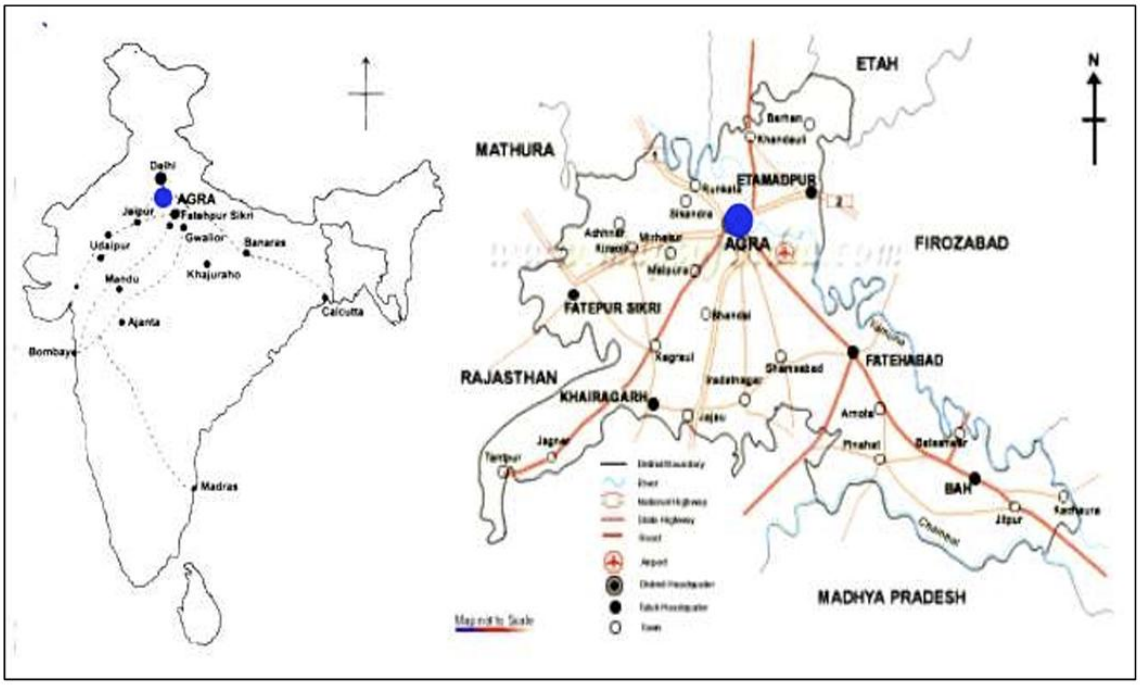


Figure 3: Agra city-Regional Setting

Figure 4: Agra District Map

Other Recommendations:

- **Metro Development:** Integrate with buses, e-rickshaws, and cycle paths; promote mixed-use within 800m of stations.

- **Bus/BRT Modernization:** Electrify fleet, optimize routes, launch BRT corridors, implement smart signals and fare systems.
- **Cycling & Pedestrian Infrastructure:** Expand cycle lanes, e-bikes, and improve sidewalks, especially in tourist areas.
- **Electrification:** Replace public buses and 50% of autos with EVs; install solar charging at hubs and landmarks.
- **Smart Mobility:** Deploy adaptive signals, real-time mapping, and a unified "One Agra One Card" for all modes.
- **Policy & Financing:** Enforce congestion pricing, parking reforms, and use municipal bonds, PPPs, and green finance.
- **Community Outreach:** Promote green modes, ensure inclusive access, and run multilingual campaigns.

Impact Projections & Timeline

By 2030, CO_2 emissions can drop by 35–40%, and $PM_{2.5}$ by 25%. Rollout should follow:

- **2025–27**: Quick wins (bus electrification, e-bikes)
- **2028–30**: Metro ops and EV scaling
- **2031–40**: Regional integration and upgrades

Conclusion

Agra can become a model for sustainable urban mobility through integrated metro systems, EV adoption, and smart technology—boosting tourism, air quality, and livability.

Sources:

Census 2011

Agra Development Authority

ICCT India Emission Factors (2021)

IPCC 2019 Guidelines

TERI Transport Emissions Data

MoRTH, UPMRC, UPSRTC, OpenStreetMap, Smart City Agra