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Planning Framework for Low Emission Zone (LEZ) in Core Areas of Indian Cities

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Abstract
The project on Planning Framework for Low Emission Zone (LEZ) in Core Areas of Indian Cities investigates an area-based approach to facilitate actions towards addressing transportation challenges and GHG emissions for the core area of Ahmedabad, India. The project explores interventions for the core area with the support of stakeholders and formulates strategies and action plans for implementation.

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Abbreviations/Acronyms

2W	Two-wheeler
3W	Three-wheeler
3W Cargo	Three-wheeler Cargo
4W	Four-wheeler
AAQM	Ambient Air Quality Monitoring
AIR	Air Information and Response
AJL	Ahmedabad Janmarg Limited
AMC	Ahmedabad Municipal Corporation
AMTS	Ahmedabad Municipal Transport Service
ANPR	Automatic Number Plate Recognition
APMC	Agricultural Produce Market Committee
AQI	Air Quality Index
AQMC	Air Quality Management Cell
ASI	Archaeological Survey of India
AUDA	Ahmedabad Urban Development Authority
AWHCT	Ahmedabad World Heritage City Trust
BAU	Business as Usual
BPMC	Bombay Provincial Municipal Corporations
BRTS	Bus Rapid Transit System
BS	Bharat Stage
CAQM	Commission for Air Quality Management
CBD	Central Business District
CC	Congestion Charge
CCTV	Closed Circuit Television
CEMS	City Electric Mobility Strategy
CMV	Central Motor Vehicle
CNG	Compressed Natural Gas

CoE-UT	Center of Excellence - Urban Transport
CPCB	Central Pollution Control Board
CRDF	CEPT Research and Development Foundation
CVC	Classified Vehicle Count
EC	Elemental Carbons
ECS	Equivalent Car Space
EP Act	Environmental Protection Act 1986
e-Rickshaw	Electric Rickshaw
EV	Electric Vehicle
FCDO	Foreign, Commonwealth and Development Office
FGD	Focus Group Discussion
GBP	Great British Pound
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIDC	Gujarat Industrial Development Corporation
GIZ	Gesellschaft fuer Internationale Zusammenarbeit
GLA	Greater London Authority
GMRCL	Gujarat Metro Rail Corporation
GPCB	Gujarat Pollution Control Board
GSRTC	Gujarat State Road Transport Corporation
GST	Goods and Services Tax
GTPUDA	Gujarat Town Planning and Urban Development Act 1976
GVW	Gross Vehicle Weight
HH	Household
HCV	Heavy Commercial Vehicle
HGV	Heavy Goods Vehicle
ICCT	International Council on Clean Transport
ICE	Internal Combustion Engine

IITM	Indian Institute of Tropical Meteorology
INR	Indian Rupee
IPT	Intermediate Public Transport
IRC	Indian Road Congress
kmph	Kilometre per hour
KPI	Key Performance Indicators
LCV	Light Commercial Vehicle
LEZ	Low Emission Zone
LIC	Low Income Country
LOS	Level of Service
LPG	Liquefied Petroleum Gas
MCV	Medium Commercial Vehicle
MoEFCC	Ministry of Environment, Forest and Climate Change
MoHUA	Ministry of Housing and Urban Affairs
MoRTH	Ministry of Road Transport and Highways
NAAQS	National Ambient Air Quality Standards
NAMP	National Air Quality Monitoring Programme
NCAP	National Clean Air Programme
NCR	National Capital Region
NDC	Nationally Determined Contributions
NDC	Nationally Determined Contributions
NEV	New Energy Vehicle
NMT	Non-Motorised Transport
OECD	Organization for Economic Cooperation and Development
PCU	Passenger Car Unit
PM	Particulate Matter
PT	Public Transport
RIVM	Dutch National Institute for Public Health and the Environment

RoW	Right of Way
RTO	Regional Transport Office
SAFAR	System of Air Quality and Weather Forecasting and Research
SAMP	State Air Quality Monitoring Programme
SDA	State Department of Archaeology
SLB	Service Level Benchmark
SMG	Seoul Metropolitan Government
SPCB	State Pollution Control Board
SPV	Special Purpose Vehicle
SUMP	Sustainable Urban Mobility Plan
TAZ	Traffic Analysis Zone
TCO	Total Cost of Ownership
TfL	Transport for London
THC	Total Hydrocarbons
TOPIS	Seoul's Transport Operations and Information Service
TSP	Total Suspended Particulate Matter
TUL	The Urban Lab
UKAID	United Kingdom's Aid Program
ULEZ	Ultra Low Emission Zone
UNESCO	United Nations Educational, Scientific and Cultural Organization
VKT	Vehicle km Travelled
WHC	World Heritage Committee
WHO	World Health Organization
YLV	Yellow Lable Vehicle
ZEZ	Zero Emission Zone

Executive Summary

Rapid urbanisation and motorisation in India have resulted in significant environmental degradation and public health challenges, with the transport sector contributing most of the pollution in urban areas. Air quality improvement strategies to be integrated into transport planning are the need of the hour. This project focuses on developing a planning framework for Low Emission Zones (LEZs) that would work for Indian cities.

The planning and implementation of the Low Emission Zone are gaining attention globally as an air quality improvement strategy. A well-planned LEZ has the potential to encourage the transition to low-emission vehicles and facilitate use of active and public transport to combat traffic congestion, promote accessibility, safe movement of all and improve liveability and equity(1). Several cities such as Amsterdam, London, Beijing, Seoul to name a few have successfully implemented LEZs as these cities already had well-established active and public transportation systems that offered good alternatives to road users. However, its widespread adoption has not been observed in Asian cities.

The Planning Framework for Low Emission Zones (LEZ) developed for the walled city of Ahmedabad addresses these challenges by formulating an integrated strategy to reduce air pollution, improve accessibility and mobility and enhance the quality of life. This framework is developed based on international case studies, detailed analysis of local situations and evidence-driven recommendations, making it both actionable and implementable for Ahmedabad and adaptable for other Indian cities.

Context and Challenges

The Walled City of Ahmedabad, a UNESCO World Heritage Site, is characterised by high population density (500 persons per hectare), mixed land use, and a vibrant economic and cultural landscape. A population of 0.32 million (2021) resides in this area, which is 4% of Ahmedabad (municipal area) population of 7.3 million It accommodates 10% of the jobs in Ahmedabad (municipal area) and serves as a hub for cultural heritage, tourism, trade and wholesale markets. However, the walled city faces severe traffic congestion, high vehicular emissions and poor air quality. This impedes the quality of life for the residents and businesses in the walled city. Detailed analysis revealed several key challenges:

Vehicular Composition and Emissions: Two-wheelers dominate the vehicular fleet, contributing 74% of carbon monoxide (CO) emissions, 76% of particulate matter (PM) emissions, and 50% of carbon dioxide (CO2) emissions. Three-wheelers (3Ws), mostly para transit, add 23% of nitrogen oxides (NOx) and 13% of PM emissions and 3W goods vehicles contribute 37% of PM and 36% of CO2. Light commercial vehicles (LCVs) are responsible for over 80% of HC and NOx emissions.

Freight Movement and Traffic Congestion: The walled city's markets, particularly those dealing in textiles, electronics and perishable goods such as fruits and vegetables, generate substantial freight traffic. Three-wheelers handle 60% of incoming trips, while Light Commercial Vehicles (LCVs) account for 28%. Informal and haphazard parking and street encroachments exacerbate the congestion on the roads.

Air Pollution Hotspots: Air quality monitoring indicates frequent PM2.5 levels, above 60 ug/m3 as per National Air Quality Index Standards, on a regular basis. The core area's emission sources are heavily concentrated along major roads such as Relief Road and Gandhi Road. The areas around Kalupur Railway Station and wholesale markets located on the outer ring road of the walled city also contribute.

Socioeconomic Profile and Mobility: Approximately 87% of households own two-wheelers (2Ws), reflecting limited public transport options and the affordability of private vehicles for low-income residents. Internally, 63% of trips are made on foot, but pedestrian infrastructure is inadequate. Four-Wheelers (4Ws) have comparatively less penetration in the walled city due to narrow roads, limited space and congestion.

Mobility and Accessibility: The walled city is served by arterial roads, public transport, and intermediate public transport (IPT), but these systems are strained by high demand. Public and intermediate transport has a substantial mode share, primarily through buses and autorickshaws. Despite high walking dependency, the absence of safe and accessible pedestrian infrastructure limits mobility options.

Scenario Analysis

Based on the existing situation analysis, three sets of measures were outlined to address the air quality concerns – public transport enhancement, improvement in pedestrian infrastructure and clean vehicle technologies. Different scenarios were analysed to evaluate their impacts on emissions and urban mobility. It showed that electrification of vehicles has an impact but could reduce vehicular emissions by

18% over 10 years compared to business-as-usual scenario. Rationalised bus services and expanded coverage and improvement of non-motorised transport could lower emissions by 25%, significantly reducing reliance on private vehicles. Lastly, integrating all three strategies, demonstrated the most substantial benefits and pollutants could be reduced by 40%.

LEZ Framework and Strategic Interventions

The LEZ framework for Ahmedabad thus employs the Avoid-Shift-Improve (ASI) approach, combining demand management, sustainable modal shifts and clean vehicle technologies to address these challenges. The idea here is to develop strategies that could be used in the short, medium and long terms.

The first set of proposed interventions deal with clean vehicle initiatives for reducing emissions. 3W passenger and goods vehicles are significant in numbers as well as in their contribution to air pollution in the walled city area. Transitioning these vehicles to electric would be a win-win scenario as e-vehicles would bring cost savings to existing 3W drivers and operators; additionally, the e-3W are also able to match the operational characteristics to that of conventional fuel vehicles. There is a need for a targeted awareness initiative to enable this transition. The recommendations also include creation of charging infrastructure which will cater to both private as well as commercial vehicles.

For the light commercial vehicle segment, policy impetus for e-LCV market development as well as lowering upfront vehicle ownership costs is required. Alongside electrification, planned phase out of pre-BS IV and BS IV vehicles are recommended.

The next set of measures focus on facilitating mode shifts from private vehicles to sustainable transport options. Two sets of interventions are proposed – public transport enhancement and improvement in accessibility to transit hubs. Key Public Transport (PT) proposals include rationalising bus routes, establishing circular routes and enhancing fleet mix with minibuses.

In terms of mobility management, the proposed interventions are demand management measures including parking management and street redesign. The measures include restricting 4W entry along narrow roads and eliminating 4W parking in congested zones, defining IPT stands, limiting on-street parking and implementing pricing mechanisms. In addition, recommendations for creating pedestrian-only zones in high-traffic areas with restricted vehicular access to enhance walkability are provided.

Actions to be taken Forward

The city authority is instrumental to drive the success of the proposed strategies. To curb the air pollution effectively, the city could share details of highly polluting vehicles retrieved as part of this study with Climate State Level Committee and State Transport Commissioner to take necessary actions. To support the electrification of vehicles, the city could recommend the state government to adopt appropriate policy measures for e-LCV. Further, the city could conduct promotional activities explore the setting up charging stations, including assessing their feasibility, operational models and pricing mechanisms.

As part of ongoing development of a service and business plan for improving bus operations in Ahmedabad, the city could prioritise incorporating electric minibuses into the fleet and establish circular routes to strengthen connectivity within the walled city. Furthermore, the city could recommend the Ahmedabad Urban Development Authority (AUDA) to conduct street development activities and integrate them in development plan and local area plans to improve the street accessibility. Also, the city could develop traffic management plan with Traffic Police to enhance the mobility movement in the walled city.

Scalability to Other Indian Cities

The LEZ framework developed for Ahmedabad provides a robust model that can be adapted for other Indian cities with similar challenges. The approach here is to build on the existing initiatives, develop evidence-based decision-making and prioritise investments in strategic areas. In other words, complicated strategies that require heavy enforcement or investments are avoided.

The methodology and the planning framework's scalability are rooted in:

Data-Driven Analysis: The detailed baseline assessments conducted for Ahmedabad's Walled City — including traffic composition, emission sources, and mobility patterns — can be easily replicated in other urban cores.

Evidence-based Planning Framework: The Avoid-Shift-Improve approach offers flexibility, allowing cities to tailor interventions based on their specific contexts in a phased manner.

Policy Alignment: Integration with national initiatives, such as the National Clean Air Programme (NCAP), ensures institutional support and funding.

Stakeholder Engagement: The Ahmedabad project demonstrated the importance of involving municipal authorities, market associations, autorickshaw associations and residents to build consensus and facilitate implementation.

Phased Implementation: Starting with pilot zones and expansion based on iterative evaluations enables cities to scale interventions effectively.

Conclusion

Successful implementation of LEZ measures requires significant investments and institutional coordination – mobilising private sector participation for Electric Vehicle (EV) charging infrastructure development and public transport improvements, providing targeted subsidies for EV adoption in the walled city area and funding for Non-Motorised Transport (NMT) and public transport infrastructure, establishing comprehensive monitoring systems to track air quality improvements, emission reductions, and mobility outcomes.

The LEZ framework for Ahmedabad addresses critical urban mobility and air quality challenges through a structured, data-driven approach. By combining emissions reduction, and sustainable transport promotion, the framework sets a roadmap for creating cleaner, more liveable urban cores.

The scalability of this methodology to other Indian cities lies in its adaptability and evidence-based planning. With strong institutional backing, robust stakeholder engagement, and phased implementation, LEZs can become transformative tools in India’s transition toward sustainable urban development and low-carbon mobility.

1. About the Project

The High Volume Transport Applied Research Programme project on 'Planning Framework for Low Emission Zone (LEZ) in Core Areas of Indian Cities' conducted by CEPT Research and Development Foundation (CRDF) investigates an area-based approach to facilitate actions towards addressing transportation challenges and GHG emissions. The initiative seeks to resolve mobility issues in the core area of the city, aiming for a better quality of life and improved community well-being. The project explores interventions for the core area with the support of stakeholders, organises capacity building, and formulates a monitoring and evaluation framework to ensure the successful implementation of actions.

1.1 Rationale

Low or Low Middle-Income Countries are faced with rapid urbanisation and higher rates of motorisation leading to an increase in travel demand and thereby congestion. Transportation systems significantly influence the economic development of cities, regions and nations. They also cause adverse externalities like congestion, delays, accidents and fatalities, energy dependence, air and noise pollution and GHG emissions. With the increased demand for travel and reliance on non-renewable energy, transport has emerged as one of the significant contributors to air pollution and GHG emissions. Given the inter-relationship of land use and transport, actions towards improved urban planning and transport systems are essential to address the high transport emission levels in the city. Internationally, LEZs have become the most frequent transport tool adopted by cities to tackle the air quality challenges at the city level.(2)

Low Emission Zone is a defined geographical area with a regulatory measure of access restriction for polluting vehicles, in such area vehicles with higher emissions cannot enter or must pay higher charges for access. The establishment of LEZ intends to reduce air pollutants, such as NOx, PM and ozone, specifically that create the greatest health impacts, however, it subsequently reduces carbon emissions and increases the growth of cleaner or low emission vehicles(3). Europe has over 320 LEZs as of 2022 with significant growth of 40% since 2019 and some of the successful non-European examples are Haifa, Seoul, Beijing and Jakarta(1). This air quality improvement strategy with restriction of vehicles also has the potential to catalyse faster adoption of EVs as well as shift to active and public transportation(1).

London has been proactively addressing transport challenges for decades. To overcome severe congestion due to private vehicles(5), a congestion charge was implemented in 2003 for all vehicles within inner ring road. London's well-functioning public transport system including rail, subway and network of buses offered good alternatives to road users(6). Additional alternatives were provided by introducing new buses, routes and park-and-ride spaces(5). This led to a 30% reduction in traffic congestion and bus passenger numbers rose by 38%(7). Continued investments in metro, bus, bike and pedestrian infrastructure had improved travel(5). Further, to tackle rising air pollution challenges, LEZ was implemented in 2008 across Greater London Area by restricting polluting vehicles with funds reinvested into transportation-related improvements. By 2019, trips by private cars were 14.7% below 2000 levels and the mode share of public transport has increased from 33% in 2000 to 43% in 2019 (8). Subsequently, Ultra Low Emission Zone (ULEZ) was introduced in 2019 targeting the oldest and most polluting vehicles across inner London, which was expanded further to Greater London Area LEZ boundary in 2023. This had led to 44% decrease in NO2(9).

In the case of Seoul, the car registration doubled from one million to two million from 1990 to 1995 causing severe congestion along arterial roads. To manage this, the city introduced mandatory programmes regulated by the law and voluntary programmes that encourage people to get involved. The mandatory programme included Congestion Impact System in 1990, and by the end of decade, the Namsan tunnel congestion charge, charging for parking lots, bus priority lane and expansion of the metro network(10). The expansion of city's subway line surpassed other modes by 1997. The bus service was restructured in 2004 to enhance connectivity to the subway and to form a more integrated network of public transit(11). Further by 2000s, the Weekly No-Driving Day Programme and car-sharing services were introduced(10). These measures increased public transport share from 61% in 2004 to 66% in 2012(10). (18)Despite these efforts, the transportation still accounted for 19.2% of the city's GHG emissions in 2018(12). As a result, LEZ was introduced in 2017 and was fully operational by the end of 2019. Green Transport Zone established in the city centre prohibits the entry of highly polluting vehicles and charges higher fines for those that enter the zone. To support vehicle restrictions within the zone, public bike share and electric car rental services were enhanced, new bus routes were introduced with a 50% reduced fare than regular service, provided a 90% subsidy to attach particulate exhaust filter(13) and

restructured roads for more walking space and less traffic. Consequently, it ensued that the traffic volume decreased by 12.8% by mid-2019(14).

Examining the trajectories of London and Seoul, both cities had already adopted Avoid-Shift-Improve (ASI) planning approach well before the implementation of LEZ. This approach focussed on demand management and to achieve overall sustainable transport systems. Prior to the introduction of LEZ, initiatives were launched to either avoid or reduce the need for travel to overcome the traffic congestion and depicted a significant share of modal shift to public transport, facilitated by the presence of robust transport systems in both the cities had a better foundation for LEZ implementation. Further, the establishment of LEZs to mitigate the air pollutants in the city by restricting vehicles, and existing or upgradation of active and public transport infrastructure offered good alternatives to road users.

India is actively working towards its Nationally Determined Contributions (NDC) aiming for a 45% reduction in the Emission Intensity of its GDP by 2030 and ultimately achieving net-zero emission by 2070. Consequently, the National Clean Air Programme (NCAP) has listed 132 cities in India during 2022 that will be officially designated as non-attainment cities which consistently fail to meet the National Ambient Air Quality Standards (NAAQS)(15). Some of them have adopted measures to reduce transport-related emissions including establishment of rapid transit systems, electrification of public transport, promotion of walking and cycling, transit-oriented development, gender inclusion, etc. However, in most cases, these uncoordinated and piecemeal measures have resulted in insignificant modal shifts to active and public transport, led to limited progress in addressing congestion and pollution. In this scenario, the establishment of LEZs in Indian cities with restrictions on vehicles will not work in isolation and has to be designed to be equitable and link to other strategic components to reduce air pollution and achieve related goals(1). The report on the Opportunity of Low Emission Zones: A Taming Traffic Deep Dive by the Institute for Transportation and Development Policy (ITDP) suggests looking more closely at policies that complement LEZs along with vehicle restrictions including street redesign, public transport service improvements, financial incentives for cleaner vehicles, EV infrastructure, and parking and land use reform to enable access to alternative modes and compliant vehicles(1).

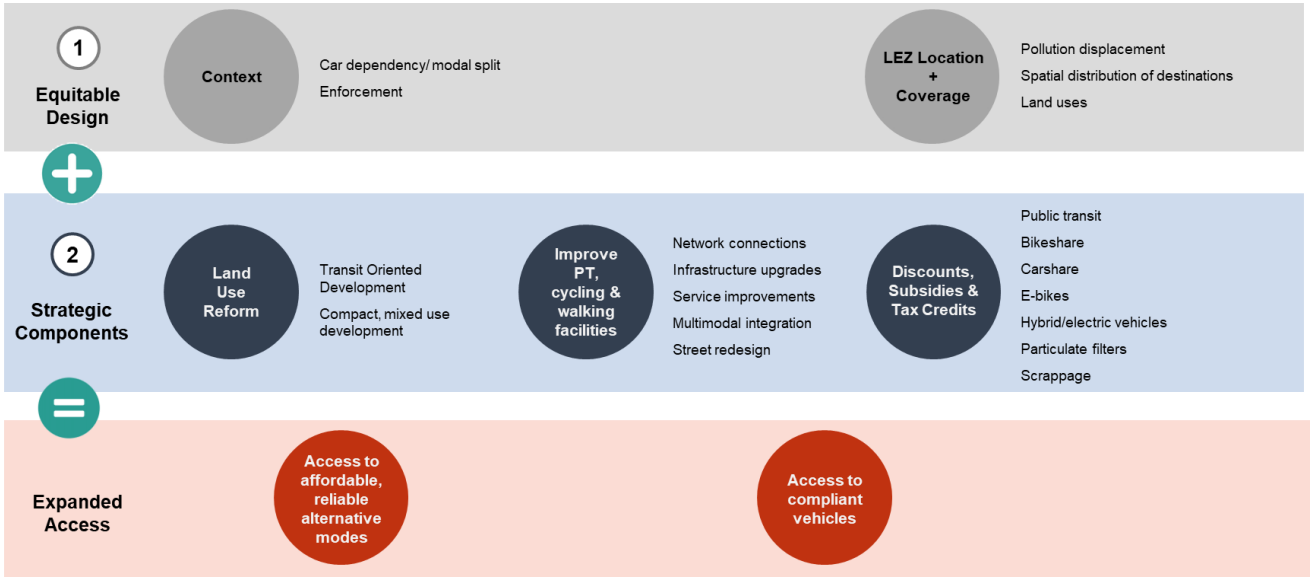


Figure 1-1 Strategic Framework for Successful LEZ

Source: ITDP The Opportunity of Low Emission Zones (1)

The core city area of Indian cities comprises a high concentration of population, jobs, traditional markets, historic monuments, industrial units and major transportation nodes. As a result, these areas have accommodated a high density of people and numerous activities that attract high concentrations of traffic to cause congestion and air pollution. There is a conflict between passenger traffic and freight traffic due to the presence of residences, retail, heritage buildings, industrial manufacturing and processing units, and commodity markets within the core of the city. Some actions towards demand management have been implemented in such areas but these measures gained limited improvements to address the overall challenges. This project, therefore, aims to build on the apparent advantages of low-emission zones in city core areas while proposing a strategic planning framework that can be adopted for Indian cities.

This project holds an operational significance as it is backed by strong political will at the national and state levels for transitioning to low-carbon mobility and promoting EVs. The key agency of the case city,

Ahmedabad Municipal Corporation (AMC) in India, is already keen on supporting this research as core city challenges are impacting the overall city's efficiency as well as contributing to pollution and greenhouse gas emissions. In addition, the partnership of traders/businesses and 3W drivers for this project is an added advantage, ensuring community involvement and more inclusive decision making for the benefit of AMC. The project has the potential to scale beyond the core area of the case city and can be adapted to different cities in India as the city core areas in the country encompass comparable zones and face similar challenges. While the output would be a mid-to-long-term strategy along with defined action areas for implementation, the findings of the project are well positioned to lead the implementation with AMC's support and foster collaboration among stakeholders to achieve a vision of an efficient and green transport system.

1.2 Objective of the Study

The objective of the study is to formulate a framework for planning and designing a LEZ for core city areas in the context of developing countries by taking the case of Ahmedabad, India. The methodology outlined in the project explores to understand the current challenges in the core city and formulate strategies for the implementation of LEZ in the Indian context. The project has the potential to scale beyond the core area of the case city and can be adapted to different cities in India as the core areas in other cities in the country encompass comparable zones and face similar challenges.

1.3 Methodology

The project is structured to comprise seven key tasks to be undertaken over the duration of 11 months (February 2024 to December 2024). First, a review of literature on international experiences was undertaken to gain insights into various aspects of LEZs and explored the policy landscape in India. This study helped to understand the definition of low emission, interventions and implementation process, and its scope that can be leveraged explicitly for the introduction of LEZ interventions. Second, efforts were made to establish stakeholder partnerships by mapping relevant stakeholders that can influence the projects and engaging with them to secure their support. Third, an extensive baseline assessment was conducted to identify mobility and air quality challenges in the core area of Ahmedabad. Fourth, scenarios involving mobility and clean vehicle technology interventions were developed and an assessment on improvement in air quality was formulated to identify a feasible strategy mix. Fifth, a LEZ strategy was outlined in detail taking into consideration the perspectives of different stakeholders and the implementation feasibility. Along with these, stakeholder consultations and capacity building workshops were conducted during the planning phase of the project. Finally, a strategic plan LEZ was developed with the experiences of the case city which can be referred to and adapted for other cities.

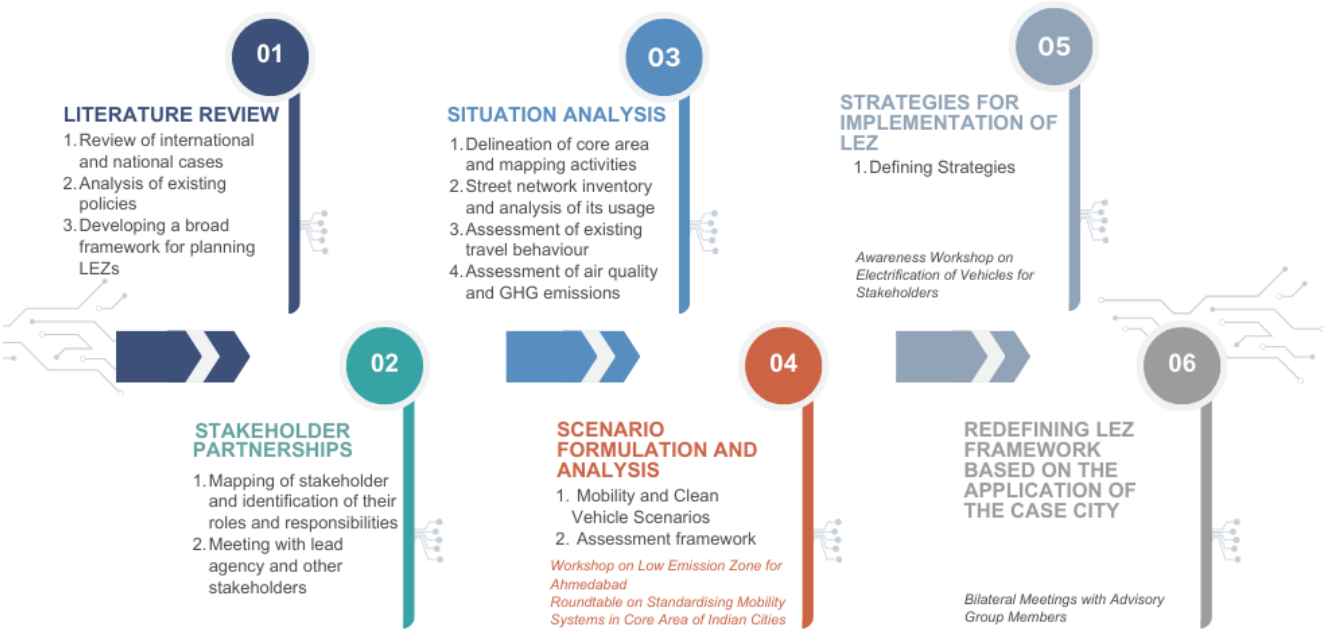


Figure 1-2 Methodology of the Project

Source: CoE-UT, CRDF

1.3.1 Literature Review

This task involved a comprehensive review of literature essential to understand LEZ both globally and within the Indian context that helped to identify the challenges associated with various planning interventions, effectiveness overtime the timeline as well as existing policy and regulatory landscape helped to identify opportunities and obstacles for integration of LEZ interventions.

1.3.1.1 Review of International and National Cases

Information on existing low-emission zones was retrieved from relevant articles, research papers, and reports from global and national sources to gain insights into various aspects of LEZs, such as the effectiveness and limitations of various planning measures, and a comparison of the studies was undertaken. The literature review has adopted a topic-based approach to explore the diverse research landscape surrounding LEZs. It has undertaken systematic searches using specialised online academic databases, emphasising on published literature, along with a broader search on Google.

Online academic search engines such as Science Direct, Scopus and Web of Science were used to search for published academic literature. The search terms LEZ and LOW+EMISSION+ZONES provided over 4,00,000 references in these search engines, however, this number got significantly reduced when applying a filter to include only publications for the last five years. Beyond academic publications, various reports were reviewed to gain insights into the implementation and impact of LEZs across different regions globally. Particular attention was given to the planning framework of LEZs in core city areas, their implementation phases, impact, and monitoring. All of this supported the development of a methodological framework for planning LEZs in core areas of Indian cities.

1.3.1.2 Analysis of Existing Policies

A detailed review of existing policy frameworks in India regarding the city's economic development, spatial development, and transportation system was conducted to identify the existing framework and institutions for the implementation of LEZs interventions in Indian cities. This task helped recognise key enablers within the existing policies that could be leveraged for the introduction of LEZ interventions and policy/regulatory challenges.

1.3.1.3 Developing a Broad Framework for Planning LEZs

An understanding of international cases along with study of the Indian planning and policy regime helped to outline a broad framework for the planning of LEZs with key intervention measures for introducing low-emission zones, including strategies for implementation, engagement with stakeholders to secure their buy-in and programmes for awareness creation and evaluating the implementation of the initiatives.

1.3.2 Stakeholder Partnerships

This section delved into the pivotal aspect of stakeholder partnerships in the context of implementing LEZs within Indian cities. Recognising the importance of collaboration and engagement with diverse stakeholders, it outlined a structured approach towards fostering effective partnerships to drive LEZ initiatives forward.

1.3.2.1 Mapping of Stakeholder and Identification of their Roles and Responsibilities

Identification of the stakeholders involved in the planning of core city areas was carried out. Along with the urban and transport planning agencies at the local level, heritage agencies and representatives from associations of autorickshaw drivers, traders and residents were included. The detailed mapping and role clarifications helped to formulate effective stakeholder engagement and facilitate seamless collaboration and coordination to ensure support from the planning to implementation stages. The relevant organisations involved are shown in Table 1-1**Error! Reference source not found.**. The role of the stakeholders and details of engagement are provided in Appendix A. An advisory group/ working group with representatives from the relevant organisations was formed with the support of the lead agency, Ahmedabad Municipal Corporation.

Table 1-1 Network of Stakeholders involved in the Project

Category	Organisation
Government Organisation	Ahmedabad Municipal Corporation (AMC)
	Ahmedabad Urban Development Authority (AUDA)
	City Planning Department, AMC
	Regional Transport Office (RTO)
	City Traffic Police
Transport Service Providers	Gujarat Metro Rail Corporation Limited (GMRCL)
	Ahmedabad Janmarg Limited (AJL)
	Ahmedabad Municipal Transport Service (AMTS)
Heritage Organisation	Heritage Department, AMC
Associations	Traders Association
	Autorickshaw Drivers Association
	Residents Association

Source: CoE-UT, CRDF

1.3.2.2 Meeting with the Lead Agency and other Stakeholders

With a broad understanding of the case city and core area, meetings with the key stakeholders, the Municipal Commissioner of AMC, and other official agencies were conducted to initiate the project. In this initial meeting, the unique challenges in the core city area and the need for planning and implementation of LEZs were presented. This meeting helped to convey the purpose and potential impact of the planning framework and serve as a foundation for building collaborative partnerships. This meeting provided an opportunity for suggestions or recommendations from AMC officials in the project design.

1.3.3 Situation Analysis

This task undertook a comprehensive study for understanding the current situation of core city of Ahmedabad that can lay a foundation for the planning and implementation of LEZ. By dissecting various aspects of urban mobility and environment, it threw light upon the current scenario and identified key factors that could influence the development of LEZ.

1.3.3.1 Delineation of Core Area and Mapping Activities

The core area of the case city lies under the central zone of the AMC boundary, which spreads up to 18 sq. km and the walled city is 4.5 sq. km(16). This area comprises various historical monuments and mixed-use buildings used for residential and commercial purposes, with small-scale shops or clustered as specific commodity markets. It also has processing and distribution centres that contribute to the movement of goods. The details of the markets, their role, commodity handled, and their movement were explored through interview with Traders' association and establishments generating freight trips (including retail shops, garage, godowns/ warehouse and small scale industry). The walled city of Ahmedabad houses several historical monuments and buildings, the details of heritage-related activities were explored through secondary sources.

1.3.3.2 Street Network Inventory and Analysis of its Usage

Understanding the current utilisation pattern of street networks involved a detailed examination of how streets were currently used. The transport research centre, the Center of Excellence in Urban Transport (CoE-UT), CRDF has undertaken several planning and transportation studies for the case city and

possesses a substantial volume of data. The Sustainable Urban Mobility Plan for Greater Ahmedabad Region (SUMP) 2041 (17), conducted in 2023, was referred to explore the road and public transport network. Along with it, some of the data from recently concluded research studies have also been used. In alignment with it, activity mapping, pedestrian activity, infrastructure placement, parking locations and encroachments were recorded during on-site observation. In the heritage context, visitation statistics of tourists were retrieved from the Heritage Department. The major tourist trails and infrastructure facilities were also identified during field visit. Further, the existing traffic management measures and regulations in the locality were identified in consultation with the City Traffic Police. This assessment provided insights into the spatial and functional aspects of streets and supports the identification of areas for improvement and integration of sustainable intervention without significantly disrupting the existing activities.

1.3.3.3 Assessment of Existing Travel Behaviour

For the assessment of existing travel behaviour, the following primary and secondary data are being utilised. Refer to Appendix B for the list of data explored and collected.

- The Household Survey conducted by CoE-UT, CRDF in 2022 as part of SUMP was explored to understand the passenger travel characteristics of people in Ahmedabad, focussing on those in the core city. Details such as mode share, trip pattern, purpose, and vehicle type were identified with respect to the temporal distribution of the trip, internal and external movement, origins, and destinations. In addition, disaggregated data on transportation patterns were explored to identify vulnerable groups. Moreover, socio-economic characteristics such as household income and vehicle ownership details were looked at. In addition to quantitative data exploration, six focus group discussions (FGDs) with 68 residents were conducted to understand their mobility challenges and perception on transition to sustainable modes.
- The project named UK PACT Strategy for Electrification of Public Transport and Intermediate Public Transport in Ahmedabad (18) carried out by CoE-UT, CRDF during 2021-2023 explored to study public transport and intermediate public transport networks. Public transport networks were analysed to understand their configuration and quality of services. An assessment of operations of 3W drivers/operators was conducted as part of this project by conducting 3W Driver Survey with 20 drivers located at four key locations of their operations within walled city. This was conducted to understand the operation of 3Ws across the walled city. Surveys with autorickshaw drivers included their socio-economic characteristics and their perception about EVs. However, the assessment highlighted similar concerns with the IPT Driver Survey conducted in 2022 as part of UK PACT project. In addition, interview with autorickshaw drivers' association was conducted to explore the service routes, stand locations and operational challenges/concerns.
- An Activity Survey or Non-Residential Property survey was conducted with the establishment generating freight trips in and around the walled city. The details such as loading and unloading locations, duration, identify the overall operational routes and internal and external movement of goods, and commodity handling were explored from this data. The core area comprises several other commodity markets and commercial units, previous research including Feasibility Study on Electrification of Urban Freight Vehicles: A Case of Ahmedabad (19), Electrification of Urban Logistics: A case of Ahmedabad City, Ahmedabad(20) and Managing urban freight transport in an expanding city — Case study of Ahmedabad(21) were referred to understand the operation of all establishments and plan freight-related interventions. In addition, the freight operations data collected as part of HVT project Freight Emission Index for the Heritage City of Ahmedabad (22) were also look at. Surveys with drivers/ operators were carried out to assess their awareness of EV technology and its variants.

The information gathered from various sources provided valuable insight for the design interventions by identification of potential vehicle category for restriction or electrification to encourage shift to sustainable modes of transportation.

1.3.3.4 Assessment of Air Quality and GHG Emissions

Quantifying energy consumption for transport is important for estimating carbon emissions and air quality indicators. The composition of vehicles, fuel, and age details of private vehicles and buses were available from the Household Survey 2022 data, in addition, details on 3Ws and freight vehicles are being retrieved from the activity survey and driver/operator survey. These were utilised to estimate the level of emissions and assess the air quality. Further, the data on air quality were retrieved from formally established air

quality monitoring stations across the city. This information was instrumental in formulating measures that aim to reduce air pollution caused by transport in the core area of the city.

1.3.4 Scenario Formulation and Analysis

This task focussed on the formulation and analysis of scenarios crucial for shaping the trajectory of LEZ implementation in Ahmedabad. Through strategic planning and rigorous assessment frameworks, this task aimed to devise inclusive and sustainable strategies tailored to address the multifaceted challenges of urban mobility and environmental degradation.

1.3.4.1 Mobility and Clean Vehicle Scenarios

The presence of several activities in the core city area such as residential, retail businesses, freight movement and heritage buildings has led to a high volume of traffic movement including both passengers and goods and causes severe problems affecting the quality of life of people in the core area. The project intends to develop a strategic plan for a LEZ in the core area of Ahmedabad with a focus on a mix of strategies to address the mobility and environmental challenges such as mobility and clean vehicle technology interventions. The project on Sustainable Urban Mobility System (SUMP) for Greater Ahmedabad Region (17) which was developed for a horizon of 20 years with a focus on reducing GHG emissions and an integrated transport system was referred for building scenarios. A 10-year plan was outlined for LEZ in the core area with consideration of intermediate year of SUMP. Various scenarios on mobility and clean vehicle technology were formulated considering share of captive users that can shift to sustainable modes and the national target on electrification of vehicles.

1.3.4.2 Assessment Framework

To evaluate the combination scenarios including electrification of vehicles, enhancing public transport and improving NMT, an assessment framework on improvement in air quality was used. This was conducted using the GHG Emissions Estimation Tool(23) of City Electric Mobility Strategy (CEMS), which would analyse the effect of proposed mode share and electrification scenarios. The scenarios were assessed based on reduction in air pollutants to determine the optimal combination to achieve significant benefits. This was discussed with city officials and mobility experts to understand their perspectives and concerns, if any.

1.3.5 Strategies for Implementation of LEZ

The defined strategies include a mix of actions such as management of mobility and parking, encouraging pedestrians by improved street accessibility, enhancing accessibility to transit hubs, improving bus service, phasing out highly polluting vehicles, facilitating adoption of EVs to limit usage of conventional vehicles, and most importantly, communicating the measures to relevant stakeholders for awareness creation and secure their buy-in. A LEZ strategy was outlined taking into consideration the perspectives of different stakeholders and implementation feasibility.

1.3.5.1 Defining Strategies

Detailed studies were conducted for each strategy to identify the specific challenges and outline recommendations for improving traffic and environmental conditions in the walled city. As part of clean vehicle technology, the comparison study on pollution by vehicles in terms of its fuel type and technology were conducted to identify highly polluting vehicles. For electrification of vehicles, operational and financial feasibility studies of target segment (including LCVs and 3Ws) were conducted to understand the viability of shift to its electric counterparts. To support the electrification of vehicles, development of charging infrastructure is crucial to overcome the range anxiety issue and create confidence in the people. Hence, existing charging facilities were studied, and recommendations were outlined based on the operations of predominant modes. In the case of mobility management, classified volume count (CVC) and site observations on parking, pedestrian movement and activities along major corridors were conducted to drive recommendations on street accessibility improvement, parking management and pedestrianisation of streets.

1.3.6 Knowledge Exchange

For seeking inputs, fostering collaboration and sharing knowledge, four Knowledge Exchange programmes with different segments of stakeholders were conducted.

1.3.6.1 Workshop on Low Emission Zone for Ahmedabad

A workshop was organised for Ahmedabad city officials on the LEZ on September 9, 2024 at Ahmedabad Municipal Corporation, West Zone Office, Usmanpura, Ahmedabad. The workshop brought experts involved in the planning and implementation of LEZ in international and national cities to share their learnings and facilitate discussion among the key stakeholders to identify feasible strategies for the walled city of Ahmedabad.

1.3.6.2 Awareness Workshop on Electrification of Vehicles for Stakeholders

An awareness workshop on electric variants of 3Ws was conducted on October 13, 2024 to bring together stakeholders including AMC, RTO, bank representatives, vehicle manufacturers and 3W operators/ drivers to deliberate on electrification possibilities and action areas. Exhibition of electric 3Ws along with information on their technology, financial incentives, bank loan details and opportunity to test drive encouraged drivers to opt for electric variants, was held.

1.3.6.3 Roundtable on Standardising Mobility Systems in Core Area of Indian Cities

As part of the 17th Urban Mobility India Conference cum Exhibition 2024, CRDF in collaboration with the Urban Catalysts organised a roundtable on Standardising Mobility Systems in the Core Areas of Indian Cities on October 27, 2024. The roundtable discussion aimed to share evidence and knowledge based on the project and facilitate a discussion for standardisation of interventions to overcome air quality challenges in the context of core areas of Indian cities. The roundtable identified opportunities for policy development, stakeholder collaboration, air quality enhancement and integration of public transport, intermediate PT and NMT specific to core area of Indian cities.

1.3.6.4 Meetings with Advisory Group Members

The advisory group formed comprises of representatives from urban and transport agencies, heritage department and traffic police. For discussing the key project outputs, meetings with advisory group members were conducted to seek their comments and secure their buy-in for implementation of initiatives in the city. Stakeholders playing an important role in decision-making shared their views or recommendations in the adoption of strategies. These meetings provided an opportunity to refine the LEZ strategic plan and gain their support to advance the plan toward the next steps.

Table 1-2 List of Advisory Group Members

S. No.	Department	Representatives
1	Ahmedabad Municipal Corporation (AMC)	Deputy Municipal Commissioner
2	Ahmedabad Janmarg Limited (AJL)	General Manager
3	Gujarat Metro Rail Corporation (GMRC) Limited	Deputy General Manager -Environment Assistant Manager – Multimodal Integration
4	Ahmedabad Municipal Corporation (AMC)	Deputy Manager Urban Planner
5	Regional Transport Office	Assistant Regional Transport Officer
6	Ahmedabad World Heritage City Trust (AWHCT)	Director Assistant Architect

Source: CoE-UT, CRDF

1.3.7 Redefining LEZ Framework based on the Application of the Case City

The draft framework developed was refined based on the methodology of the project carried out for Ahmedabad including stakeholders' engagement, base situation assessment, formulation of scenarios and its analysis, strategic plan with the illustration of case city experiences which can be referred to and adapted for other cities.

1.4 Structure of Report

The report is structured into four chapters. The first chapter introduces the project with the rationale, objective and detailed methodology of the study. The second chapter presents the comprehensive review of LEZ experience both globally and within the Indian context that helped to identify the challenges associated with various planning interventions including existing policy and regulatory landscape and measures adopted. The third chapter details the current situation of the walled city of Ahmedabad by outlining various aspects of urban mobility and environment. Finally, the fourth chapter outlines the approach, formulation of scenarios and their assessment, followed by the strategic plan of LEZ for the walled city of Ahmedabad.

2. LEZ Case Studies and Regulatory Instruments

This chapter presents comprehensive review of international experiences of LEZ and existing policy landscape in India including legal pathways, policy framework, the efforts and its implementation.

2.1 International Cases

In recent years, the area-based approach has gained traction among cities worldwide as a means of mitigating air pollution. Many cities have adopted LEZs as a strategy to address air pollution, congestion, and carbon emissions within the city limits. An article by Martin Guttridge-Hewitt showed that around 320 European cities had adopted LEZs as part of their strategy to improve urban air quality till 2022(24).

To gain deeper insight into the implementation of LEZs, this section of the report outlines the measures adopted by different cities globally related to LEZs. Furthermore, it discusses the characteristics of these measures, strategies for implementation, complementary actions, stakeholder engagement, monitoring protocols, and the resultant impacts. The Table 2-1 informs about the various aspects considered in the case study analysis and their respective objectives (1).

Table 2-1 Analytical Framework for Case Studies

Aspect	Purpose
Contextual Information	Provide an overview of the city, demographics, area, economy, and air quality challenges.
Policy and Governance	Describe the governance structure, roles, and responsibilities of government agencies and stakeholders. Analyse policy formulation, objectives, criteria, vehicle access, and complementary policies or schemes.
Interventions	Explore the range of strategies adopted within the zone and the implementation of various measures and regulations to complement the interventions.
Technology & Infrastructure	Examine the technology used for enforcement, location of monitoring stations, evaluation, and data collection.
Stakeholder Management & Public Awareness	Evaluate stakeholder engagement processes, including consultation mechanisms, involvement of residents, businesses, transportation providers, environmental organisations, and community groups. Analyse public awareness campaigns, educational initiatives, and outreach efforts.
Monitoring and Evaluation	Assess monitoring and evaluation mechanisms, impacts and improvements, and emission reductions.

Source: CoE-UT, CRDF

The case studies of the following cities were conducted to better understand the procedural framework followed for the implementation of LEZs.

- Amsterdam, The Netherlands
- London, United Kingdom
- Beijing, China
- Seoul, South Korea

These cities were selected as case studies for their extensive experience in planning and implementing LEZs. Their track record includes expertise in managing the technical aspects, establishing regulation criteria, implementing complementary measures to support LEZ initiatives, developing robust monitoring frameworks, and evaluating the impacts of such zones. Furthermore, the availability of substantial literature accessed through comprehensive search engines provided valuable insights into the frameworks for planning and implementing LEZs in these cities, making it considerably extensive for detailed analysis and comparison in the study of urban environmental policies and practices.

The detailed description of each city is provided in Appendix C. The following table depicts the summary of the international case studies with respect to the analytical framework.

Table 2-2 Summary of International Case Studies

City	Amsterdam	London	Beijing	Seoul
City Area (sq km)	219.3	1,572	4,567	605.2
Population (2024)	1.2 million	9.7 million	22.18 million	9.9 million
LEZ Extent	• Within A10 Ring Road for all diesel vehicles. • For Mopeds and two-wheelers, neighbouring residential areas are also included	• Congestion Charing: Within London City • LEZ: London (All Boroughs Included) • ULEZ: London (All Boroughs Included)	• Entire Beijing area for YLVs • 6th ring road - city pass requirement for non-local vehicles • Trucks allowed inside the city from 12 am to 6 am only	• Green Transport Zones area: 16.7 sq. km. within the walled city in the Seoul downtown

Policy and Governance	• Preparation of Clean Air Action Plan.
	• Main measures used for achieving the goals:
	  ○ Communication
	  ○ Stimulation
	  ○ Facilitation
	  ○ Regulation
		• Political commitment Clarity in the objectives Effective strategic project governance.
		• Robust and consistent stakeholder and public consultations.
		• Research and monitoring Effective supplier and contractor management.
		• Targeted public campaigns and media relations.
			• Devising periodic 5-year air pollution control programmes.
			• Phase-wise implementation and expansion of LEZ.
			• Clear objectives on building new vehicle standards, fuel quality standards, alternative fuels, control of vehicle population and in-use vehicle emission control.
				• Identification of target area
				• Discussion of overarching strategies to be implemented in designated area
				• Engagement with experts, residents, businesses, and other stakeholders.

Operational Time	24 hours, throughout the year	24 hours, throughout the year		6am to 9pm, throughout the

				year
Restriction	Ban on entry of polluting vehicles	Daily entry charge on polluting vehicles to enter the zone	Ban on entry of polluting vehicles	Ban on entry of polluting vehicles
Complementary Measures	• Expansion of charging network • Promoting public transport, cycling and walking	• Healthy streets • Scrappage scheme • Strategies for taxis • EV charging infrastructure • Go Ultra Low City Scheme	• Maintaining and inspection for managing vehicle emissions • Scrappage policies • Retrofitting • Promotion of alternative fuels	• Promotion of active transportation modes • Subsidy for attachment of exhaust filter • Enhancing public transport network and shared transportation
Infrastructure & Enforcement	• Automated enforcement system: Advanced RADAR Technology. • Around 53 cameras positioned across the zone.	• Automatic Number Plate Recognition (ANPR) cameras. • About 1,500 cameras fixed and operational for CC, LEZ and ULEZ.	• Manual enforcement by police officers as well as license plate recording.	• Seoul's Transport Operations and Information Service (TOPIS) oversees conducts real-time monitoring. • 45 gateways leading in and out of zone installed with surveillance cameras.
Monitoring	• Amsterdam Air Quality Monitoring Network consists of 14 stations. • RIVM compiles data from these stations & local government measurements to generate annual reports assessing impact of air quality measures.	• To assess impact of LEZ, air quality data from roadside monitoring stations was analysed over four 12-month periods—two years before & two years after implementation of Phase 1. • About 100 stations managed by respective	• Consistent expansion of air quality monitoring network. • About 35 stations covering entire Beijing city 1000 PM2.5 sensor stations across the city.	• Consistent investment in expanding the air pollution measurement stations. • Increase from 4 in 1973 to 45 stations in 2023.

		boroughs		

Impacts of Low Emission Zones	• Heavy-only environmental zone reduced PM10 and NOx by 5.8% & 4.9% respectively
	• Reduction of 12.8% of elemental carbons (EC) due to LEZ implementation
		• 2008 to 2013: Reduction in PM10 emissions: 20% Reduction in PM2.5 emissions: 27% Reduction in NOx emissions: 25%
		• Reductions in NO2 concentrations:
		  ○ Central London: 6% decrease
		  ○ Inner London: 47% decrease
		• PM Concentrations: 41% reduction in both Central and Inner London
			• Total CO, THC, NOx and PM2.5 vehicle emissions were reduced by 76%, 72%, 40% and 70% respectively from 1998 to 2003.
			• Decline in NO2 by 30% from 74 µg/m3 in 1998 to 56 µg/m3 in 2013.
			• A 58% reduction of average annual CO concentration in Beijing from 1998 to 2013.
				• 23-46% reduction in Grade 5 vehicles.
				• 16.7% reduction in PM10
				16% reduction in PM2.5
				• A 13% reduction in traffic flows.

Source: Various secondary sources, Refer Appendix C

Based on the case studies outlined above, LEZs can be defined as the spatially defined areas for either banning or restricting the entry of polluting vehicles to reduce air pollution. These zones adhere to specific vehicle emission standards determined by factors such as engine type and the release of pollutants like NOx, CO, PM2.5, and PM10. Vehicle access within the zone is contingent upon compliance with these emission standards.

Implementation of LEZs primarily focusses on the following technical aspects:

- Spatial extent within the city with air quality issues (usually CBD)
- Mode type (Bus, Trucks, Cars, Mopeds, etc.)
- Vehicle type (Diesel, Petrol, CNG, etc.)
- Emission Standard (Euro 1, 2, 3, 4, etc.).

However, the cities have not only focussed on these technical aspects, the implementation of LEZs required much more than these which included comprehensive policy and governance, robust enforcement, complementary measures to support the low emission zones, continuous monitoring and release of the results, stakeholder consultations during the planning and implementation stage and conduct constant communication with the public.

- Comprehensive Policy and Governance: Effective implementation requires strong political commitment, clear objectives, strategic governance, and consistent stakeholder engagement.
- Robust Enforcement: Use of advanced technology and automated systems for effective monitoring and enforcement.
- Complementary Measures: Implementation of mode-focussed complementary measures such as retrofitting incentives, scrappage and retrofitting policies, healthy streets, development of EV charging infrastructure plan to support the LEZs and promote more sustainable choices of transport modes.
- Continuous Monitoring and Reporting: Consistent evaluation of air quality through monitoring networks and annual reports is essential for assessing the impact of implemented measures and for adjusting strategies as needed. Additionally, continuous development and expansion of the monitoring network are crucial for improving its coverage and effectiveness.
- Public Communication: Public awareness campaigns and stakeholder consultations are essential for gaining support and ensuring compliance. Actively involving stakeholders in the planning and implementation process. Prioritising public communication and awareness campaigns to educate residents about the significance of air quality and regularly reporting on its status.

2.2 LEZ Approach in India

India has made significant efforts at the national, state and local level by implementation of several policies and projects to overcome pollution and protect the environment. This section outlines regulations and policy aspects that support the implementation of LEZ. Furthermore, it looks into the legal pathways to explore the opportunities and efforts made so far for setting up a zone.

2.2.1 Potential Provisions

The legal provisions for LEZ include national and state laws. State-level acts for Gujarat are considered here to explore the areas that support the implementation of LEZs. Some of the regulatory measures that can be leveraged for creating explicit LEZ include:

Table 2-3 List of Regulations for LEZ in India

Level	Acts	Description
National	Air (Prevention and Control of Pollution) Act, 1981	authorises the State Pollution Control Board (SPCB) to set the air quality standards, carry out inspections, declare control areas, etc. with consultation with the Central Pollution Control Board (CPCB) for the prevention, control, and abatement of air pollution.

	Environment Protection Act, 1986	protects and improves the human environment and the prevention of hazards to human beings, other living creatures, plants and property have sufficient provisions to abate vehicular pollution in India.
	The Central Motor Vehicle Act, 1988	regulates the road transport and traffic management system, ensuring safety, efficiency, and environmental protection with provisions on licensing, registration, rules and regulations, vehicle standards, insurance, penalties and offences.
State	Bombay Provincial Municipal Corporations Act, 1949	outlines the framework for local self-governance with provisions for the administration of urban areas, focussing on public health, sanitation, safety and regulation, urban planning, infrastructure development, and financial management. The state can direct any municipal corporation to make any rules or amend any rules it has made.
	Gujarat Police Act, 1951	provides the legal framework for the functioning of the police force in the state with an outline of the powers, duties, and responsibilities of police officers, aiming to maintain public order, prevent and detect crime, and ensure the safety and security of citizens. Police have the authority to restrict vehicles to avoid danger, obstruction, or inconvenience to the public.
	Gujarat Town Planning and Urban Development Act, 1976	regulates urban development and town planning in the state with provisions for the preparation and implementation of development plans, control of land use, zoning regulations, and the establishment of urban development authorities.

Source: Various Secondary Sources

Policies and programmes related to vehicular emission control and area-wise development have been adopted in India to address congestion and transport-related emissions in cities or specific areas, and at a local level, such policies and plans can support the implementation of LEZs.

Table 2-4 List of Policies and Plans for Urban Transport Development in India

Policies and Plans	Description
National Auto Fuel Policy, 2003	addresses vehicular emission norms, fuel quality, and standards of CNG/ LPG kits, as well as measures to reduce emissions from in-use vehicles, vehicle technology, air quality, and research and development.
National Urban Transport Policy, 2006	focusses on the mobility of people and goods through sustainable modes along with multimodal solutions and integrated land use and transport planning.
National Action Plan on Climate Change, 2008	focusses on transport sector emission reduction through a modal shift to public transport for mitigation of GHG emissions through the introduction of compressed natural gas (CNG) in cities, retiring old and polluting vehicles, and strengthening mass transport.
National Electric Mobility Mission Plan, 2013	indents to achieve national fuel security by promoting hybrid and EVs in the country and presented road map and electric mobility strategies for the early adoption of EVs.
FAME Scheme	boosts the adoption of EVs by providing financial support for the purchase of EVs and the establishment of charging infrastructure.
State Electric Vehicle Policies	have defined a range of supporting incentives for EV demand creation,

	manufacturing and infrastructure development, research and campaign. Currently, 28 state EV policies are notified in the country. To facilitate this transition in the transport sector, Gujarat has implemented the EV Policy in 2021 to create a favourable ecosystem for people to adopt EVs.
India's Intended Nationally Determined Contribution, 2015	has pledged to achieve the following targets by 2030: reduction in the emissions intensity of its GDP by 33% to 35% from 2005 levels with the promotion of renewable energy, cooling action plan and the electrification of vehicles.
Green Urban Mobility Scheme, 2017	has made significant importance for the development of BRTS, and promotion of NMT by establishing pedestrian walkways and cycling tracks and promoting bike sharing to serve last-mile connectivity.
National Policy on Transit-Oriented Development, 2017	to create the opportunity within a 400 sq. m. area radius around transit nodes to improve accessibility along the transit network, impose parking restraints, have density prescription, and improve road design and station area design to reduce personal vehicle usage.

Source: Various Secondary Sources

2.2.2 Legal Pathways

To improve air quality in cities through transport-focussed low and zero emission zones, the International Council on Clean Transport (ICCT) has explored legal pathways and opportunities for implementing emission zones in India. The pathways referred from the research are(25):

2.2.2.1 Pathway 1: The central government notifies LEZs and ZEZs through the Ministry of Environment, Forest and Climate Change (MoEFCC) and empowers state governments to implement them.

Under Environmental Protection Act 1986 (EP Act) and Air Act 1981 (Air Act), the central government has the power to publish the list of cities and declare them as low emission zones (LEZs) and zero emission zones (ZEZs) with guidelines like an overall framework for planning and implementing zones, its rules, planning process, monitoring framework and phase out targets for various vehicle types. To manage the implementation of an emission zone, the central government can set up and delegate its powers to special authorities. This agency directs state governments for implementation and ensures compliance and facilitates coordination and management between various organisations. The establishment of special authority is not a requirement; instead, the central government can direct the Pollution Control Board at the central and state level to oversee the planning and implementation. At the local level, the state government can be given the power to work with the city government to implement the zones. The creation of an eco-sensitive area in Matheran, Maharashtra in 2003 by the central government serves as a case of having a regulatory authority over a designated area. A case of special authority is the Taj Trapezium Zone Pollution Authority established by the central government to protect the Taj Mahal from air pollution generated through all sectors. The Commission for Air Quality Management in the National Capital Region and Adjoining Areas (CAQM) is another agency that provides directives and guidance to manage air quality in the Delhi NCR region. In Ahmedabad, Air Quality Management Cell (AQMC) coordinates between the agencies and implements the action plan to improve the city's air quality.

2.2.2.2 Pathway 2: The central government launches a national LEZ and ZEZ programme through MoEFCC and empowers state governments to implement the zones.

A national programme on LEZ or ZEZ should be launched by the central government through MoEFCC and direct Pollution Control Board at the central and state level to work with state and city governments to plan and implement the programme. As part of it, MoEFCC can publish a guidance document that comprises the criteria for eligibility of the cities and targets with the timeline to be achieved. An example of a national programme launched by the central government is the National Clean Air Programme (NCAP), which is a long-term, time-bound, national-level strategy to tackle the air pollution problem across the country in a comprehensive manner(15).

2.2.2.3 Pathway 3: States declare air pollution control areas

The entire city or part of the cities should be declared as LEZs or ZEZs by the state government in consultation with the State Pollution Control Board (SPCB). The regulations regarding vehicle type allowed, fuel specifications, operation schedules and selected day are determined by the state. An example of such a pathway is the Delhi Pollution Control Committee, which prohibits entry of non-BS VI diesel light motor vehicles and all medium and heavy-duty vehicles (except those running on CNG, electric and carrying essential goods).

2.2.2.4 Pathway 4: States use the Central Motor Vehicle Act

According to the Central Motor Vehicle Act 1988 (CMV Act), the state government can provide powers to any authority to prohibit vehicle access restrictions on polluting vehicles across specific areas. In such cases, the state government can provide powers to the city government to manage vehicular movement across city limits or areas within the city. The odd-even scheme in Delhi for rationing road space use is using the CMV Act. Further, access restrictions for heavy-duty vehicles in Pune, Ahmedabad and Mumbai during certain times of the day also rely on provisions under the purview of the same act.

2.2.2.5 Pathway 5: The state government and city municipal corporations use Bombay Provincial Municipal Corporations Act, 1949

Using the provisions in the Bombay Provincial Municipal Corporations Act (BPMC Act), the municipal corporations can empower municipal commissioners to impose schemes on the prohibition of the use of public streets for certain kinds of traffic and acquire premises for the improvement of public streets. The state government can frame such rules or direct municipal corporations to frame and implement them. The municipal commissioner should plan and implement the LEZ and ZEZ in the city. Implementation of a LEZ in Ahmedabad would involve environmental regulations and planning laws such as the BPMC Act, Gujarat Pollution Control Board (GPCB) Regulations, Gujarat Town Planning and Urban Development Act 1976 (GTPUDA), and Gujarat Motor Vehicles Act 1989.

Various pathways exist for introducing air pollution control areas in the country. The first and second pathways generate a national-level impact, where the central government designates various cities as LEZ or establishes a programme at the national level that mandates the state to work with cities. The third and fourth pathways create a state-level impact, where state governments declare various cities as control areas or empower cities to impose vehicle restrictions. The fifth pathway is confined to the city level, where the municipal corporation plans and implements control areas without any state or national mandates. Hence, the existing legal framework in India permits the implementation of LEZ.

Along with the implementation through such pathways, some acts and regulations support enforcement and ensure the effectiveness of emission zones. The Ministry of Road Transport and Highways (MoRTH) publish standard registration marks for vehicles and issues stickers to distinguish between petrol, diesel, CNG and identify BS VI vehicles(26). In the case of implementation of LEZ, MoRTH can publish registration marks to identify vehicles based on emission standards, strengthen in-vehicle inspection, organise maintenance programmes and draft rules for acceptable levels of emissions. National Highways Authority of India is empowered to make regulations to restrict vehicles in any part of the national highway. Gujarat Police Act 1951 has powers to restrict traffic to prevent danger, obstruction, and inconvenience to the public. Moreover, the CMV Act contains numerous provisions for penalising noncompliance and violation of regulations with fines or imprisonment for up to six months or both.

2.2.3 Greening of Zones in Urban India

The country is working towards its Nationally Determined Contributions (NDC) aiming for a 45% reduction in the Emission Intensity of its GDP by 2030 and ultimately achieving net-zero emission by 2070. The National Clean Air Programme (NCAP) has listed 132 cities in India during 2022 that will be officially designated as non-attainment cities as they consistently fail to meet the National Ambient Air Quality Standards (NAAQS)(15). These include major cities like Delhi, Mumbai, Bengaluru, Ahmedabad, Hyderabad, Pune and Kolkata. As a result, these cities have adopted measures to reduce transport-related emissions including electrification of public transport, promotion of active transportation, transit-oriented development, gender inclusion, etc.

With deteriorating Delhi's AQI levels, the city has adopted initiatives including a mandate for public transport and local commercial vehicles to run on CNG and other clean fuels, imposition of Environment

Compensation Charge on all heavy-duty trucks with ban on 10-year-old trucks, time-based restriction on daily truck entry, 1% cess on diesel SUVs/cars with 2000cc engines and above, Air Ambience Cess imposed on each litre of diesel sold, and parking management with rules and variable pricing(27).

A complete ban on ICE vehicles has been implemented in historical or tourist areas such as the Taj Mahal, Agra and Statue of Unity, Kevadia, and prohibits entry of all motor vehicles in Ecologically Sensitive Hill Station, Matheran. The movement of vehicles has been restricted across a defined area within urban limits and in some cases, over a specific period. Chennai restricts entry of heavy vehicles from 6 am to 10 am and from 4 pm to 10 pm, similarly, Kolkata has time-based restrictions on heavy commercial vehicles and Mumbai has a designated no-entry zone for trucks during peak hours(27).

Cities such as Delhi, Bangalore, Pondicherry, Hyderabad, etc. have also partially or fully pedestrianised the stretches of streets. A busy market in Delhi, named Chandni Chowk, has restricted entry of motor vehicles from 9 am to 9 pm with an exemption for special vehicles, and as a result, the street could support active and sustainable modes of transportation and depicted a significant increase in footfall of visitors. Other approaches include parking area management plans by applying a parking pricing system to manage demand and control the vehicle usage. This initiative was mandated by the Supreme Court in Delhi for the National Capital Region (NCR) in 2019.

2.2.4 Summary

India has implemented actions to tackle congestion and vehicular emissions such as pedestrianising small stretches of road and regulating the movement of vehicles in small-scale areas or stretches of road. However, these initiatives are fragmented, restricted in scope and are not conducive to attaining scale. There is a funding push for electric mobility by the government of India, but despite this, the actual uptake of EVs by cities has been slow. The absence of a cohesive strategy at the local level means that it limits both the ‘scaling up’ of these efforts and their impact on GHG emissions.

The establishment of LEZ at the national level through centralised programmes can yield impact across the country and facilitate the scalability of initiatives to maximise the benefits. Moreover, empowering state or city governments to create a specific area-based approach is essential. This approach should include traffic management regulations, prioritisation of cleaner modes and exploring green mobility solutions and strengthening city-based efforts by incorporating LEZ to attain social, economic and environmental benefits.

3. About the Case City – Ahmedabad

This chapter presents a comprehensive detailed case city aimed at understanding the current situation in the walled city of Ahmedabad. By dissecting various aspects of urban mobility and the environment, it sheds light on the present scenario and identifies key factors that can influence the development of an LEZ.

3.1 Context

The city of Ahmedabad is located in western India and is the largest city in the state of Gujarat. Ahmedabad is the seventh-largest metropolis in the country. It is the state's commercial capital and has good air, road, and rail links with Mumbai and Delhi, as well as an international airport. The city of Ahmedabad was founded in 1411 AD. The World Heritage Committee (WHC) of UNESCO declared Ahmedabad city as India's first World Heritage City in July 2017. It houses a rich cultural heritage and has emerged as an important economic and industrial hub in the country. The city has developed around river Sabarmati which cuts the city into two parts: the eastern part which includes the walled city, and the western part comprising the newly developed areas of the city. The urban fabric of the walled city is characterised by a neighbourhood setting with tightly packed houses along narrow lanes protected by gates and supported by amenities. Along with residential complexes, historical, cultural and commercial buildings make the area vibrant but also congested.

3.2 Key Characteristics of the Walled City

This section lays a foundation on the understanding the characteristics of walled city in terms of its land use, demography, socio-economic, connectivity and air quality.

3.2.1 Study Area

The study area for this project is the core area of the city known as the Walled City of Ahmedabad and this area is also listed as a Historic City of Ahmedabad under the UNESCO World Heritage Convention. The boundary wall, also known as the fortress wall which imparts the name 'Walled City', of this area was established by Sultan Ahmad Shah in 1411 AD across a length of 10 km with 12 entry gates (darwajas). This area extends up to 4.5 sq. km. (16) which is only 1% of Ahmedabad Municipal Corporation (AMC)'s jurisdiction area of 486 sq. km.

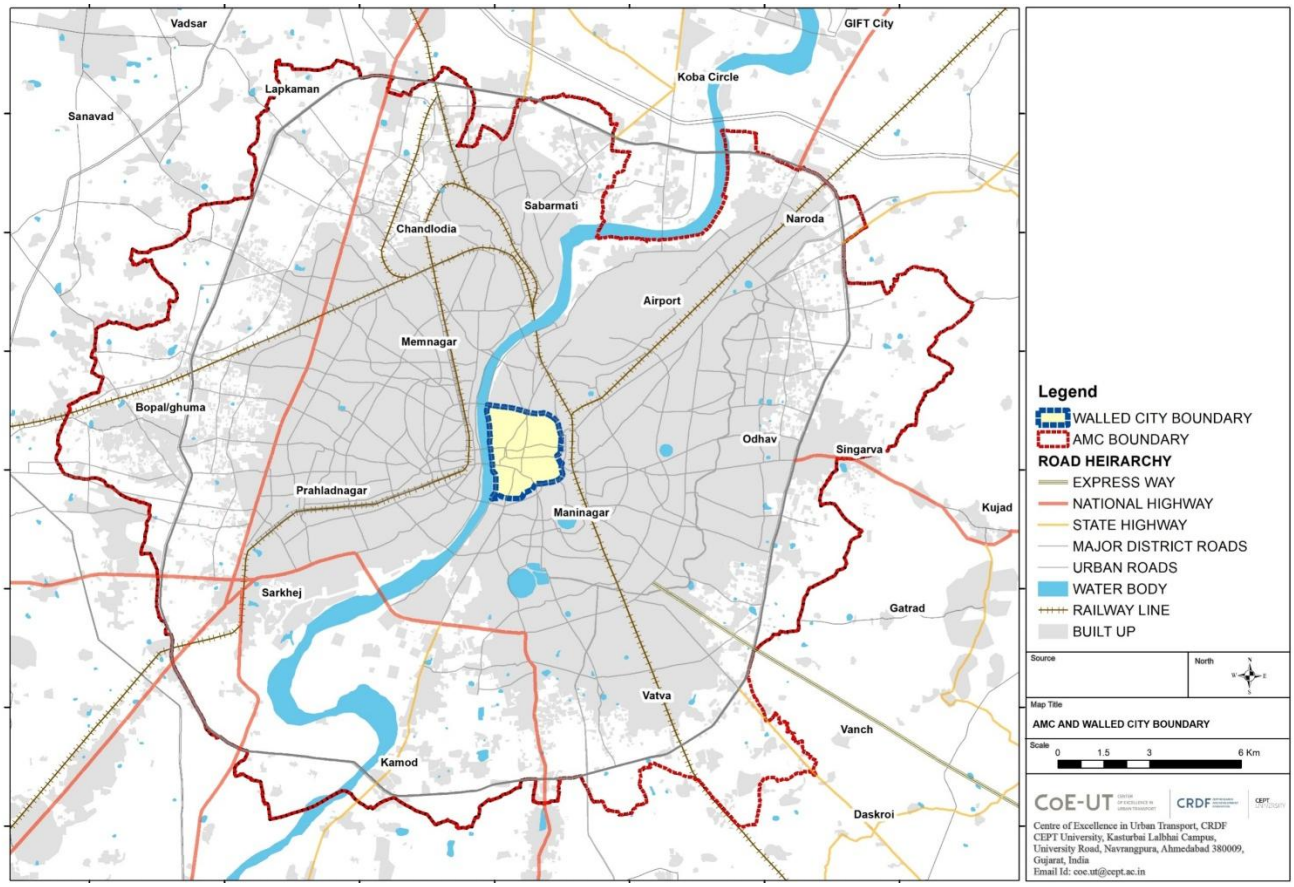


Figure 3-1 Location of the Walled City within AMC

Source: CoE-UT, CRDF

3.2.2 Land Use

The land use composition inside and around the walled city is a heterogeneous mix with residential areas comprising a large portion - 42% of the total land area. Commercial establishments are primarily located along major roads such as Relief Road, Gandhi Road, Swami Vivekananda Road and Gheekanta Road. Moving away from these main roads, the land use gets transitioned into mixed-use or residential areas. Additionally, various specialised wholesale markets including textile, perishables, electronics, electrical, plywood, etc. are concentrated in different parts of the walled city, primarily in the central areas and along the periphery, contributing to the commercial and mixed-use nature of the region. The industrial activities are concentrated in the GIDCs in the periphery of Ahmedabad in Naroda, Odhav, Vatva, Narol, Piplaaj, and Isanpur.

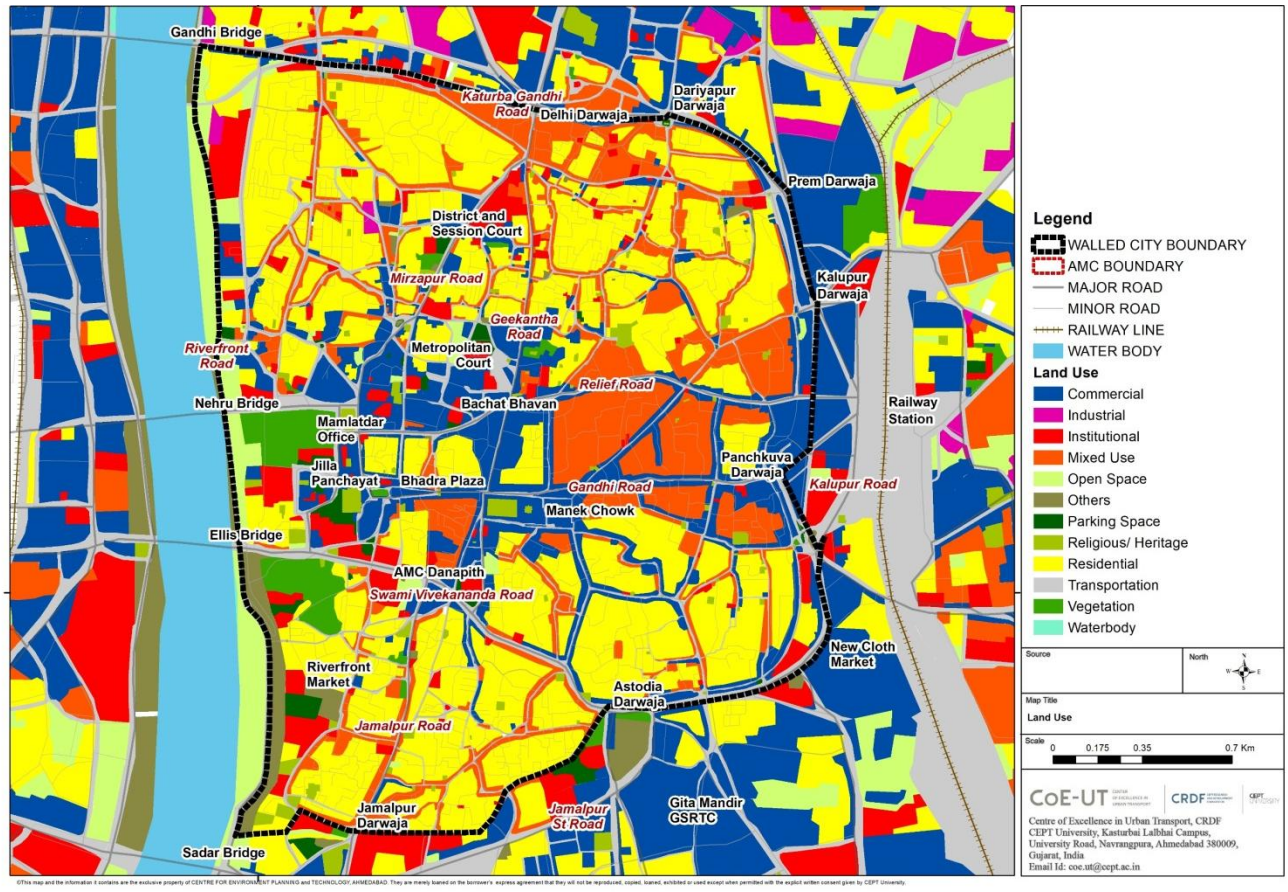


Figure 3-2 Land Use Distribution across the Walled City

Source: Primary Survey

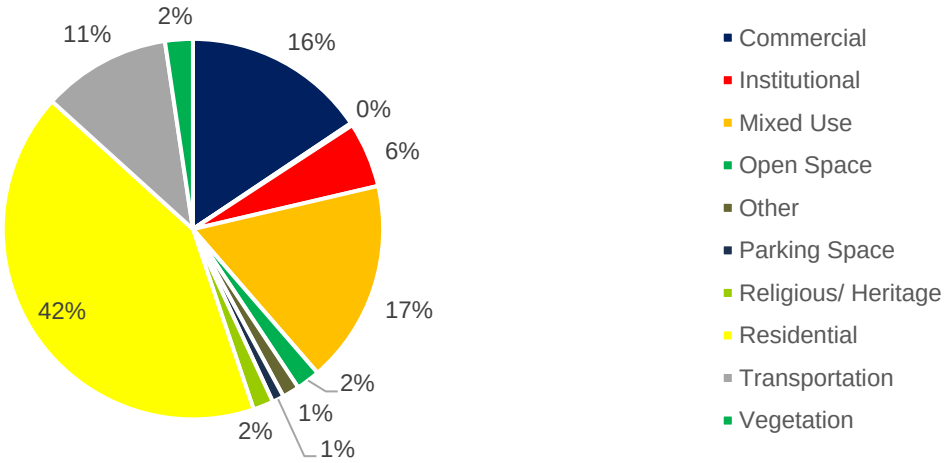


Figure 3-3 Land Use Composition within the Walled City Boundary

Source: Primary Survey

Residential zones are most prominent near the Dariyapur, Jamalpur, and Astodia Darwaja. Within the walled city, residents live in settlements known as Pols, which have gradually evolved into mixed-use areas with numerous commercial establishments emerging, especially near the central parts (along Relief and Gandhi Road) of the walled city. This diverse land use distribution within the walled city significantly increases both passenger traffic and freight demand in Ahmedabad.

3.2.3 Heritage Context of the Walled City

The city dates to the 15th century when Ahmad Shah, one of the early rulers of Gujarat Sultanate shifted his capital from Anahilwad-Patan to the eastern bank of the Sabarmati River. The city formed as a small area around the citadel of Bhadra as already existing trade routes had flourished under the Sultanate rule. In the late 16th century, the city was captured by the Mughal Empire, who expanded the city beyond the walls and developed the northern side of the city. Mughals were succeeded by the Gaekwads and Peshwas in the mid-18th century. The British East India Company took over Ahmedabad in the 19th century further promoting trade and commerce in the city. The economy of the city entered into a new phase with the opening of textile mills and the city transformed into the national centre for the textile industry. Post-independence, a new identity for the city was created with the addition of modernist buildings within the dense fabric of the city.(28) By 1980s, the collapse of the textile manufacturing business and the shifting of industrial activities to the eastern periphery of the city had affected the walled city's economy.(29)

The walled city of Ahmedabad is the first Indian city to be inscribed as a World Heritage City. According to UNESCO the Outstanding universal value of the city lies in its monumental architecture of the Sultanate period which exhibits an important interchange of human values.(28). In the city of Ahmedabad, there are 32 monuments protected by the Archaeological Survey of India (ASI), whereas, within the walled city, there are 28 ASI monuments, one historic building protected by the State Department of Archaeology (SDA) and 2,696 important buildings listed and notified by the Heritage Department of the Ahmedabad Municipal Corporation (AMC). Refer Appendix D for locations of heritage buildings. The significant heritage assets of the World Heritage City of Ahmedabad include:

Monumental Architecture

The Sultanate period monuments include Bhadra Citadel, Ahmad Shah's Mosque, Teen Darwaja, Jama Masjid, Gaekwad Haveli, Fort Wall, Gateways (Darwajas) and several other mosques and tombs, as well as important Hindu and Jain temples of later periods.

Residential Neighbourhoods

The settlement pattern of the city follows a hierarchical system with the largest division being the gated traditional streets (puras) which are neighbourhoods. Each neighbourhood is divided in different gated communities (pol) which are accessed through a gate (khadki). A pol includes between 50 and 100 closely packed houses that share side walls. The public spaces of the pol are characterised by vibrant street life, community wells, bird feeders (chabutaro), and public and religious buildings. The traditional courtyard houses are built using composite construction techniques with timber and brick-lime, with its elaborately decorated wooden facades, reflects symbols and myths connected with the inhabitants. (30)

Markets

With the strong roots of rich traditions of trade and commerce from the Sultanate period, the walled city has several trade centres that have evolved today as commodity-specific wholesale and retail markets. (Refer Section 3.3.1.4 for further details)

Institutional and Public Buildings

The walled city is famous for its many institutions, textile industries and public infrastructure. Prema Bhai Hall, Calico Dome and Fernandes Bridge are some of the important landmarks in this area.

3.2.4 Demography Characteristics

The study area is divided into various areas known as Traffic Analysis Zones (TAZs) which are adopted from the Sustainable Urban Mobility Plan (SUMP) for Greater Ahmedabad Region 2023. In total 399 TAZs had been defined for AMC in the SUMP study and 33 TAZs lie within the walled city boundary.

3.2.4.1 Population

Ahmedabad Municipal Corporation houses a population of 7.3 million people in 2021, and it has increased from 5.6 million in 2011 with an annual growth rate of 2.6%. The average density of the AMC population is 151 PPH in 2021 and the central zone is highly densified as it contains the walled city area.

Table 3-1 Population of AMC

Year	Walled City		Other Areas in AMC		Total Population in AMC
	Population	CAGR	Population	CAGR	
1991	382,735		3,063,616		3,446,351
2001	342,198	-1.1%	4,209,864	3.2%	4,552,062
2011	337,965	-0.1%	5,335,718	2.4%	5,673,683
2021	328,626	-0.3%	7,008,100	2.8%	7,336,726

Source: CoE-UT, CRDF

The core city of Ahmedabad has a population of 0.32 million. However, this area is densely populated with around 500 persons per hectare. In recent decades, it has been observed that the population of the core area has been declining as the city is expanding towards newly developed areas in the west of Ahmedabad. The share of the AMC population residing within the walled city was 11% in 1991 and has reduced to 4% in 2021. This is due to the significant emergence of several non-residential activities within the walled city, and residents are moving out of the core area to newer parts of the city for better infrastructure and quality of life. Refer Appendix D for spatial distribution of population density in the walled city.

3.2.4.2 Employment

Ahmedabad has a large concentration of economic activities in terms of employment generation that contributes to state's GDP growth. The city is the trade and industrial capital of Gujarat and has employment of 3 million in 2021 within the AMC boundary.

Table 3-2 Employment of AMC

Year	Walled City	Other Areas in AMC	Total Employment in AMC
2011	229,204	1,863,409	**2,092,613**
2021	292,117	2,800,781	**3,092,898**
CAGR	**2.5%**	**4.2%**	**4.0%**

Source: CoE-UT, CRDF

The Walled City marks up the highest density of 450 persons employed per hectare. Nearly 10% of the city's employment is within this area. Employment has increased from 0.22 million in 2011 to 0.29 million in 2021 with a growth rate of 2.5%. The retail businesses and traditional markets are the major employment centres in the walled city and therefore attract significant passenger movements from various parts of the city. Refer Appendix D for spatial distribution of employment density in the walled city.

3.2.5 Socio-Economic Characteristics

3.2.5.1 Household Income

The average monthly income of a household in AMC area is INR 38,448 according to the CoE-UT Household Survey 2022. There is a clear distinction between monthly household income across the east and west of Ahmedabad. Nearly 60% of the households residing in the east of Ahmedabad earn less than INR 20,000 per month, whereas there is a more diverse distribution across income brackets showcasing a significant presence of households in various income categories exist in the west.

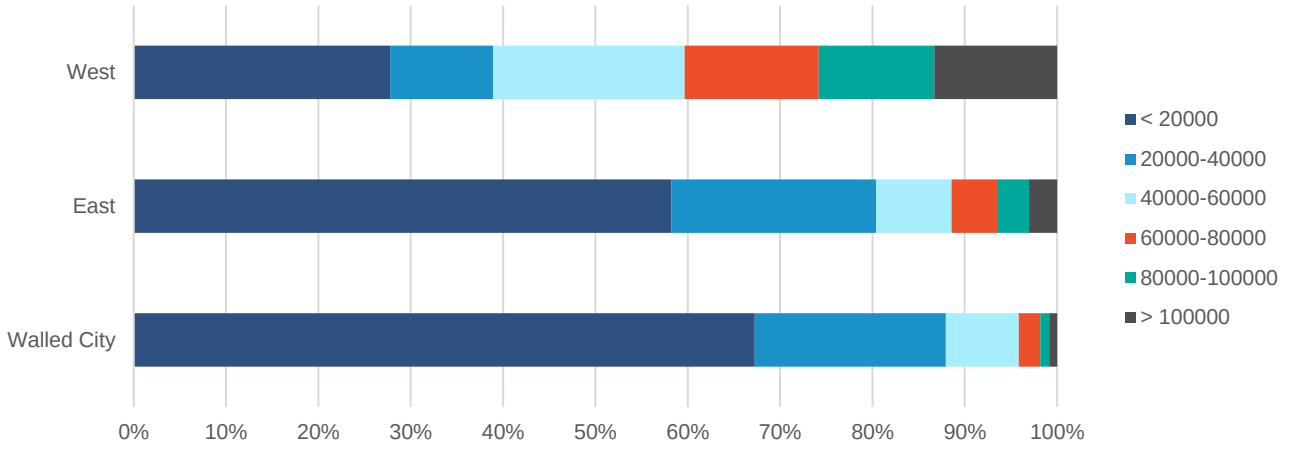


Figure 3-4 Monthly Household Income Distribution across AMC (2022)

Source: Household Survey Data 2022, CoE-UT, CRDF

Focussing on the walled city of Ahmedabad, the area is largely lived in by low-income households. The average monthly household income in this area is INR 23,783. Around 67% of the households in the walled city have a monthly income of less than INR 20,000 and 21% of households earn between INR 20,000 and 40,000. Other income categories have a minimal presence here.

3.2.5.2 Vehicle Ownership

The income levels of the household can influence vehicle ownership and mode choice for transportation. About 76% of the households own motorised vehicles in walled city, whereas that is 84% across AMC. Across the city, the ownership of car is 53 per 1000 people and two-wheeler is 263 per 1000 people. Similar to the distinction in household income between the eastern and western parts of Ahmedabad, there is also a difference in private vehicle ownership which includes 2Ws and 4Ws. In the west of Ahmedabad, 442 per 1000 people own private vehicles and it is 227 per 1000 people in the east. Disaggregating the analysis for the AMC zones conveys that the west of Ahmedabad has higher private vehicle ownership than that of its east. However, the ownership of cycles across the city is contrasting as the east of Ahmedabad has 27 cycles per 1000 people, whereas it is only 13 per 1000 people in the west. Refer Appendix D for vehicle ownership in walled city and AMC.

In the walled city, private vehicle ownership is 227 per 1000 people among which two-wheeler ownership is 222 per 1000 people, 3W is 17, cycle is 10 and cars is only 5. Due to poor socio-economic characteristics the ownership of cars is very low in the walled city, whereas across the city it is 53 per 1000 people. In terms of the composition of vehicle type among households, 87% own a 2W, 7% own 3W, 4% own cycle and only 2% own 4W. The ownership of 2Ws is significant among all income categories, cycles are owned by the lowest income group and 4Ws are owned by the higher income group.

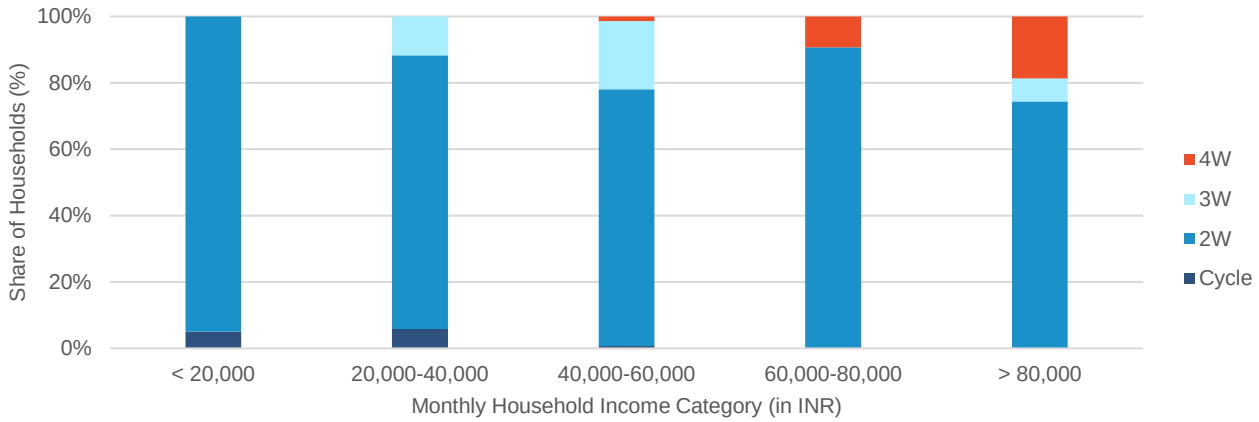


Figure 3-5 Distribution of Vehicle Ownership by Monthly Household Income Levels[1] in the Walled City (2022)

Source: Household Survey Data 2022, CoE-UT, CRDF

3.2.5.3 Private Vehicle Fuel and Technology

In terms of fuel category of vehicles owned in walled city, all the 2Ws run on petrol. Among 4Ws, 39% use diesel, 41% use petrol and 20% use CNG. For 3Ws, 95% operate on CNG while only 5% use petrol. Bharat Stage (BS) Emission Standards are auto emission norms adopted by the Government of India to check the air pollutants released from internal combustion engines and they are based on European emission norms. Looking at the composition of vehicle distribution based on technology, the share of BS-IV vehicles is significant by 81% notably comprised 2W and 3Ws. There is no ownership of EVs in the walled city as of 2022. However, FGDs with residents conducted as part of this project indicates that few households in the walled city own EVs.

Table 3-3 Composition of Private Vehicle Ownership in the Walled City (2022)

Vehicle Category	Vehicle Distribution based on technology			Total Vehicles	Fuel Distribution (%)	Vehicle based technology distribution %		
	BS III	BS IV	BS VI			BS III	BS IV	BS VI
2W Petrol	2,494	61,239	11,893	75,626	100%	3%	81%	16%
4W Diesel	0	484	149	633	39%	0%	76%	24%
4W Petrol	0	540	130	670	41%	0%	81%	19%
4W CNG	0	149	172	321	20%	0%	46%	54%
3W Diesel	0	0	0	0	0%	0%	0%	0%
3W Petrol	99	187	0	286	5%	35%	65%	0%
3W CNG	468	4,300	780	5,548	95%	8%	78%	14%
Total	3,061	66,899	13,125	83,084	100%	4%	81%	16%

Source: Household Survey Data 2022, CoE-UT, CRDF

[1] 1 INR = 0.0092 Pound sterling (as of December 2024)

Table 3-4 Composition of Conventional Private Vehicle Ownership in AMC (excluding the Walled City) (2022)

Vehicle Category	Vehicle Distribution based on technology			Total Vehicles	Fuel Distribution (%)	Vehicle based technology distribution %		
	BS III	BS IV	BS VI			BS III	BS IV	BS VI
2W Petrol	79,864	1,522,007	261,964	1,863,835	100%	4%	82%	14%
4W Diesel	2,432	80,713	21,318	104,463	27%	2%	77%	20%
4W Petrol	9,478	1,90,878	47,493	247,849	63%	4%	77%	19%
4W CNG	1,408	32,263	5,191	38,862	10%	4%	83%	13%
3W Diesel	0	5,273	1,288	6,561	7%	0%	80%	20%
3W Petrol	453	10,132	1,334	11,919	13%	4%	85%	11%
3W CNG	3,705	57,225	9,779	70,709	79%	5%	81%	14%
Total	97,340	1,898,491	348,367	2,344,198	100%	4%	81%	15%

Source: Household Survey Data 2022, CoE-UT, CRDF

3.2.6 Connectivity

The transportation network in Ahmedabad largely depends on the roadway systems. The concentration of economic activities in the walled city, the city bus terminals and regional transport nodes in and around it attracts a large volume of traffic from all over the city.(29) Hence, there is a conflict between various streams of traffic.

3.2.6.1 Road Network

The walled city is situated between the Sabarmati River on its west and the railway line on its east. The core area connects west and east Ahmedabad by four bridges, namely, Gandhi Bridge, Nehru Bridge, Ellis Bridge, and Sardar Bridge, in sequence from north to south. The major roads that form the backbone of the urban road network run along the periphery of the walled city and one of them traverses through this area. This road functions predominantly as an arterial road connecting Kalupur railway station, the state transport bus terminal at Gita Mandir and industrial areas in the east of Ahmedabad. The major inner roads that cut across the walled city predominantly connect the gateways in the east, north and south and these roads traverse through commercial activity areas.

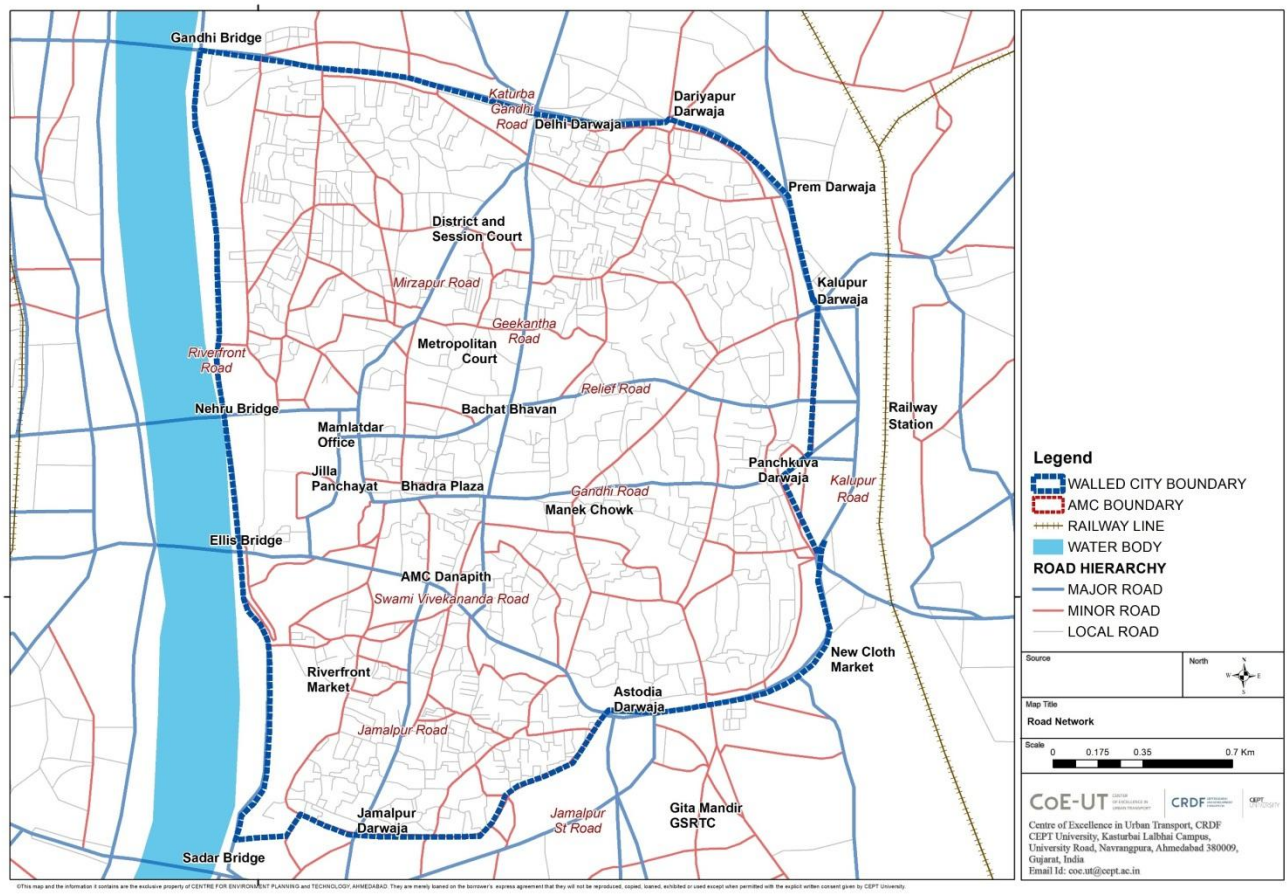


Figure 3-6 Road Network across the Walled City of Ahmedabad

Source: CoE-UT, CRDF

The details of the road across the walled city are detailed in the following and refer to Appendix E for the cross-sectional view of the inner major roads:

- Kasturba Gandhi Road, Kalupur Road and Jamalpur St Road: This stretch of 7 km forms a ring road with right of way (RoW) varying from 24 m to 30 m. It runs along the boundary of the walled city to connect Gandhi Bridge to Sardar Bridge via Delhi Darwaja, Prem Darwaja, Kalupur, Sarangpur Darwaja, Astodia Darwaja and Jamalpur Darwaja. The northern and southern parts of this ring road feature mixed-use activities, while commercial activities predominantly lie along Kalupur Road in the east. The road functioning as an arterial road carries the traffic entering eastern Ahmedabad through Gandhi Bridge and Sardar Bridge travels along this road, connecting major transport nodes such as the railway station, state transport bus terminal, Narol in the north, Odhav in the east, and Naroda in the south. Kasturba Gandhi Road has a dedicated Bus Rapid Transit System (BRTS) corridor along the median.
- Swami Vivekananda Road: An arterial road that traverses through the walled city with a length of 3.7 km has a Right of Way (RoW) of 30 m. This stretch connects Ellis Bridge to Sarangpur Darwaja via Astodia Darwaja. This road majorly carries traffic from western Ahmedabad to its east, as well as connects the railway station and state transport bus terminal. Similar to the ring road, mixed use of activities is present along this road, and it also has a BRTS corridor.

(a) Kasturba Gandhi Road

(b) Swami Vivekananda Road

Figure 3-7 Major Arterial Roads across the Walled City

Credits: CoE-UT, CRDF

- Riverfront Road: This road is present along either side of the Sabarmati River, which flows through the city. This stretch of 3.1 km has a width of 15 m along the western periphery of the walled city connecting Gandhi Bridge and Sardar Bridge. At present, the Riverfront Road has transformed into a bypass that caters to a significant amount of urban traffic connecting different parts of the city. However, to prevent pollution levels along the Sabarmati River and to contain vehicle movement, entry of heavy vehicles, 3W goods and passenger 3Ws are restricted along this road.(31) Residential use is predominant along with a few educational institutions and hotels.
- Relief Road: This road cut across the walled city in the east-west direction connecting Lal Darwaja and Kalupur Railway Station. The stretch of 1.8 km has a width ranging from 12 m to 18 m. The traffic entering the walled city through the Nehru Bridge to reach the railway station passes through Relief Road. The activity along this road is predominantly commercial as it is present along wholesale and retail centres for textiles, electronics and power tool machineries.
- Gandhi Road: A one-way road which is parallel and nearly 0.25 km apart from the Relief Road connects Bhadra Fort to Pachkuva Darwaja. This road of 1.6 km in length has a width of different 9 m to 12 m. in maximum region, there are various commercial establishments located along this road which sell textiles, electricals, cycles, plastic sheets and so on. The effective RoW of this road has been reduced due to parking and encroachment by street vendors and shops for displaying their wares. The stretch of 0.25 km of road from Bhadra Fort to Teen Darwaja has permitted entry only for 2Ws and 3Ws.

(a) Relief Road

(b) Gandhi Road

Figure 3-8 Major Economic Corridors within the Walled City

Credits: CoE-UT, CRDF

- Mirzapur Road: This road connects Lal Darwaja and the heritage monument Sidi Saiyyed Mosque to Delhi Darwaja situated along Kasturba Gandhi Road. The traffic along the Nehru Bridge from west of Ahmedabad generally opts for Mirzapur Road to access the Ring Road. This road of 1.3 km length ranges RoW between 9 m to 18 m, mostly has offices, government institutions and commercial establishments.
- Gheekanta Road: A one-way road that diverts from Mirzapur Road at 175 m from Delhi Darwaja and brings in traffic to the Gheekanta Cross Road at Relief Road. The road of 9 m RoW extends for 1 km and has Gheekanta metro station, textile markets, and several other commercial and mixed-use buildings along it.

(a) Mirzapur Road (b) Gheekanta Road

Figure 3-9 Major Roads within the Walled City

Credits: CoE-UT, CRDF

- Jamalpur Road: This road connects Khamasa Cross Road along Swami Vivekananda Road to Jamalpur Darwaja in the south. The stretch of 1 km with 9m-12m RoW has mixed use of commercial and residential activities along it.
- Local Roads: The densely built area of the walled city is further connected by local roads to specific commodity markets, commercial establishments and residences. These roads are very narrow with widths ranging from 3 m to 9 m.

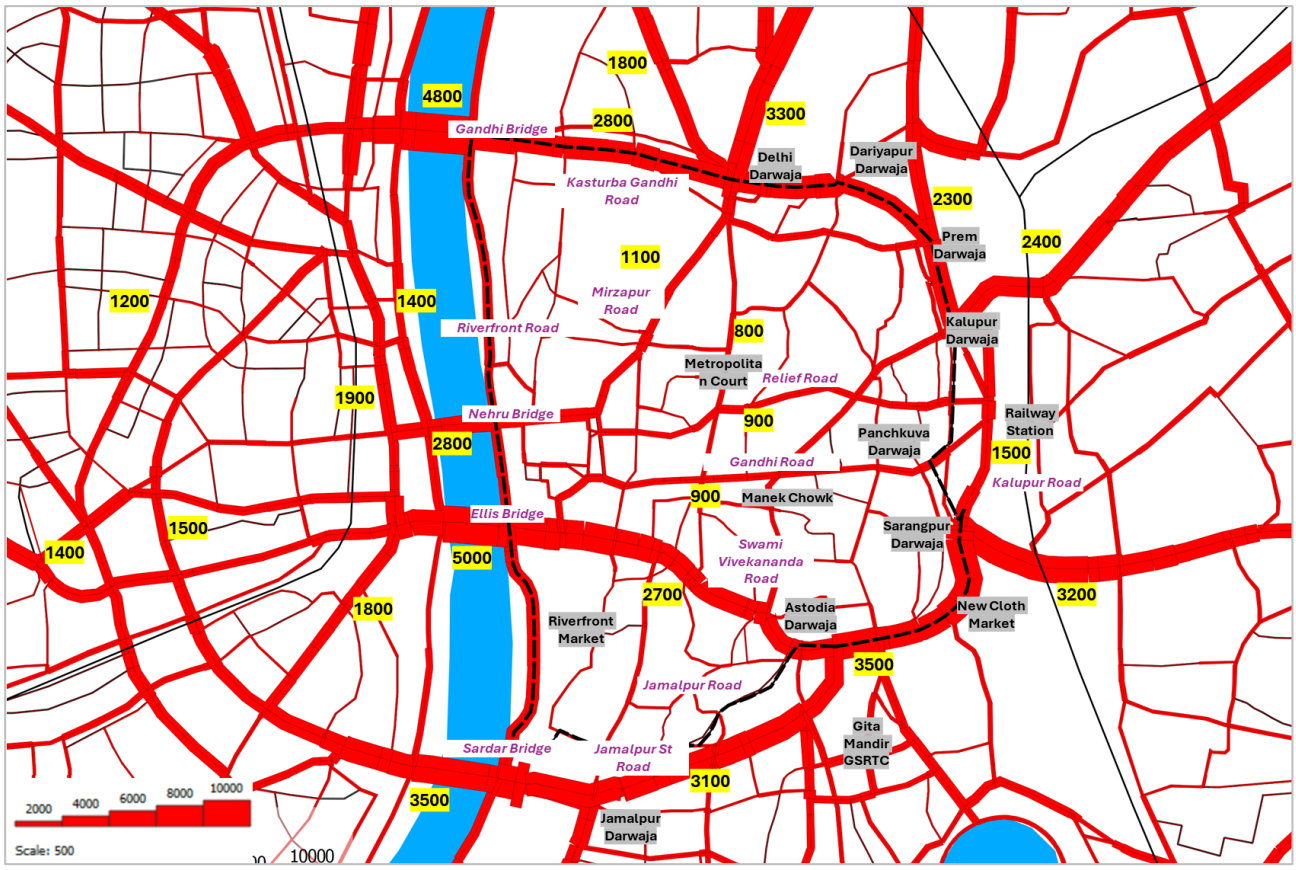


Figure 3-10 Peak Hour Traffic Flow across the Walled City

Source: Adapted from Sustainable Urban Mobility Plan for Greater Ahmedabad Region, CoE-UT, CRDF (2023)

As part of the Service Level Benchmark (SLB) in Urban Transport for Indian Cities, a Travel speed analysis conducted along the arterial roads was conducted by CoE-UT. While observing the major roads across the walled city carrying various types of vehicle types indicates that the speed of buses is less than 15 kmph in the stretches of Swami Vivekananda Road, Kasturba Gandhi Road and Kalupur Road. Private vehicles comprising 4Ws and 2Ws ply at less than 25 kmph and reduce to less than 15 kmph along Kalupur Road, Jamalpur Road towards Astodia Darwaja from Ellis Bridge and towards Delhi Darwaja from Gandhi Bridge.

The road network in the walled city featuring arterial roads plays a crucial role in connecting the transport nodes and industrial areas to various parts of the city. Major roads like Kasturba Gandhi Road, Kalupur Road, Swami Vivekananda Road and Jamalpur St Road form a ring road that connects important city points and supports mixed-use activities. Commercially vibrant roads like Relief Road and Gandhi Road are crucial economic corridors within the walled city but face congestion and encroachment challenges. Efficient traffic management strategies are essential to balance urban mobility and commercial viability in this dense area.

3.2.6.2 Public Transport System

The existing public transport services in Ahmedabad consist of city buses, Bus Rapid Transit System (BRTS) and metro system, and these services are also present within the walled city boundary. The city bus services are provided by Ahmedabad Municipal Transport Service (AMTS) while BRTS services are operated by Ahmedabad Janmarg Limited (AJL), a special purpose vehicle (SPV) formulated by Ahmedabad Municipal Corporation (AMC) to govern the BRTS operations in the city. The service which began in 2009 was the first BRTS project in India which aimed at creating a city-wide network rather than delineating the service corridor by corridor (32). In addition, BRTS has won several national and international awards for design, implementation and operation. The metro system, named Ahmedabad Metro is operated by the Gujarat Metro Rail Corporation Limited (GMRCL). These three public transport services are present across the walled city. The bus service extends to 11 km of road within the walled city boundary, and this marks Service Coverage of Public Transport in the study area as Level of Service (LOS) 1 as per SLB 2019.

Table 3-5 Characteristics of Ahmedabad Public Transport System (2022)

PT System	AMTS	BRTS	Metro
Network Length (km)	676	130	35 (Phase-1) 27 (Phase-2)
Fleet Size	687	350	96 coaches
Stops	2603	178	32
Depot	11	6	2
Routes	149	18	2 lines
Daily Ridership	428,672	208,709	66,868*

*For the year 2023

Across the city, the coverage of bus network service is 93%. However, the supply for bus in the city has not improved w.r.t. the growth in the city. The buses per 1000 population have declined significantly over the last decade, which falls from LOS from 3 in year 2001 to 4 in 2021 which is much lower than desirable standard of 0.5-0.6 as per SLB (18).

Bus Rapid Transit System

The Ahmedabad BRTS operates nine routes along a designated median corridor across the walled city boundary and traversing the area along Swami Vivekananda Road, where the Kalupur Road near the Railway Station lacks segregation. There are 13 BRT stations are present in this area, and they are spaced at approximately 500 m apart on average. These routes connect the walled city to major urban centres across the city, namely, Airport, Gota, Iskcon, Maninagar, Naroda, Narol, Navrangpura, Odhav, Sola and Vasna.

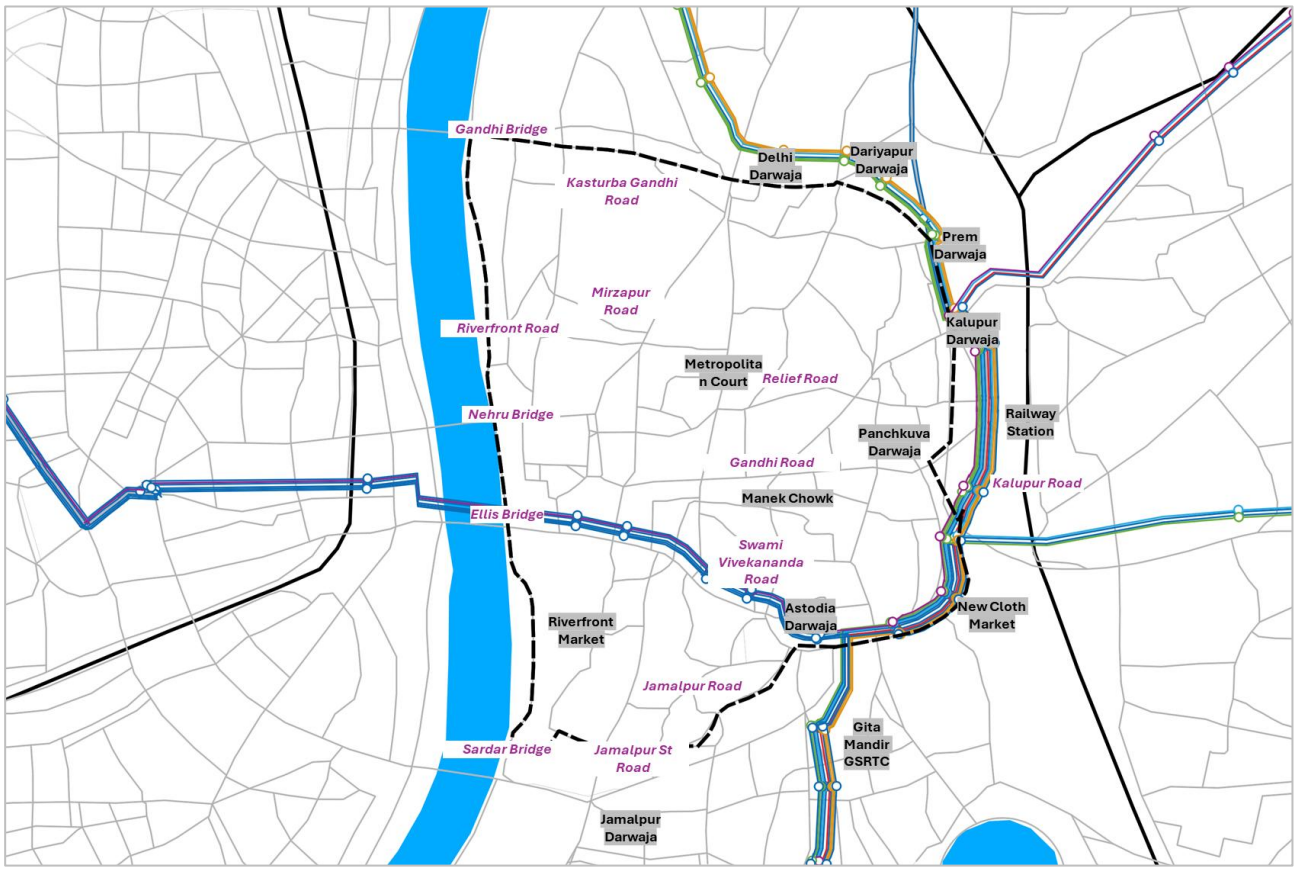


Figure 3-11 Bus Rapid Transport System service across the Walled City

Source: Adapted from Sustainable Urban Mobility Plan for Greater Ahmedabad Region, CoE-UT, CRDF (2023)

Ahmedabad Municipal Transport Service

Across the walled city, the city bus service known as Ahmedabad Municipal Transport Service (AMTS) provides services along major arterials as well as major inner roads such as Relief Road, Mirzapur Road and Jamalpur Road. There are three AMTS terminals located in this area, namely Lal Darwaja, Kalupur and Sarangpur. Out of 149 AMTS routes, nearly 117 routes operate across the walled city. The bus stops are spaced at 200 m to 500 m. Among these routes, across the river, 42% of the routes are passing by Nehru Bridge, 35% across Gandhi Bridge and 19% along Sardar Bridge. The details of bus operations are provided as:

- Lal Darwaja: The terminal serves as one of the central facilities for the whole city and specifically for the walled city. Fifty-one routes operate at this terminal, which makes it 44% of routes operating across the walled city. This facility serves more than 2,647 bus trips. These routes connect to all parts of the cities.
- Sarangpur: The terminal is located near Sarangpur Darwaja and close to the Kalupur Railway Station. Nearly 30 routes operate at this terminal mainly which generates 1,389 bus trips per day.
- Kalupur: The terminal serves the commuters from Kalupur Railway Station and nearby commercial areas. This facility operates 17 routes and nearly 556 bus trips per day are generated at this terminal.
- Through trips: Apart from the trips through terminals located at the walled city, 19 bus routes pass through the walled city which generate over 1,178 bus trips per day.

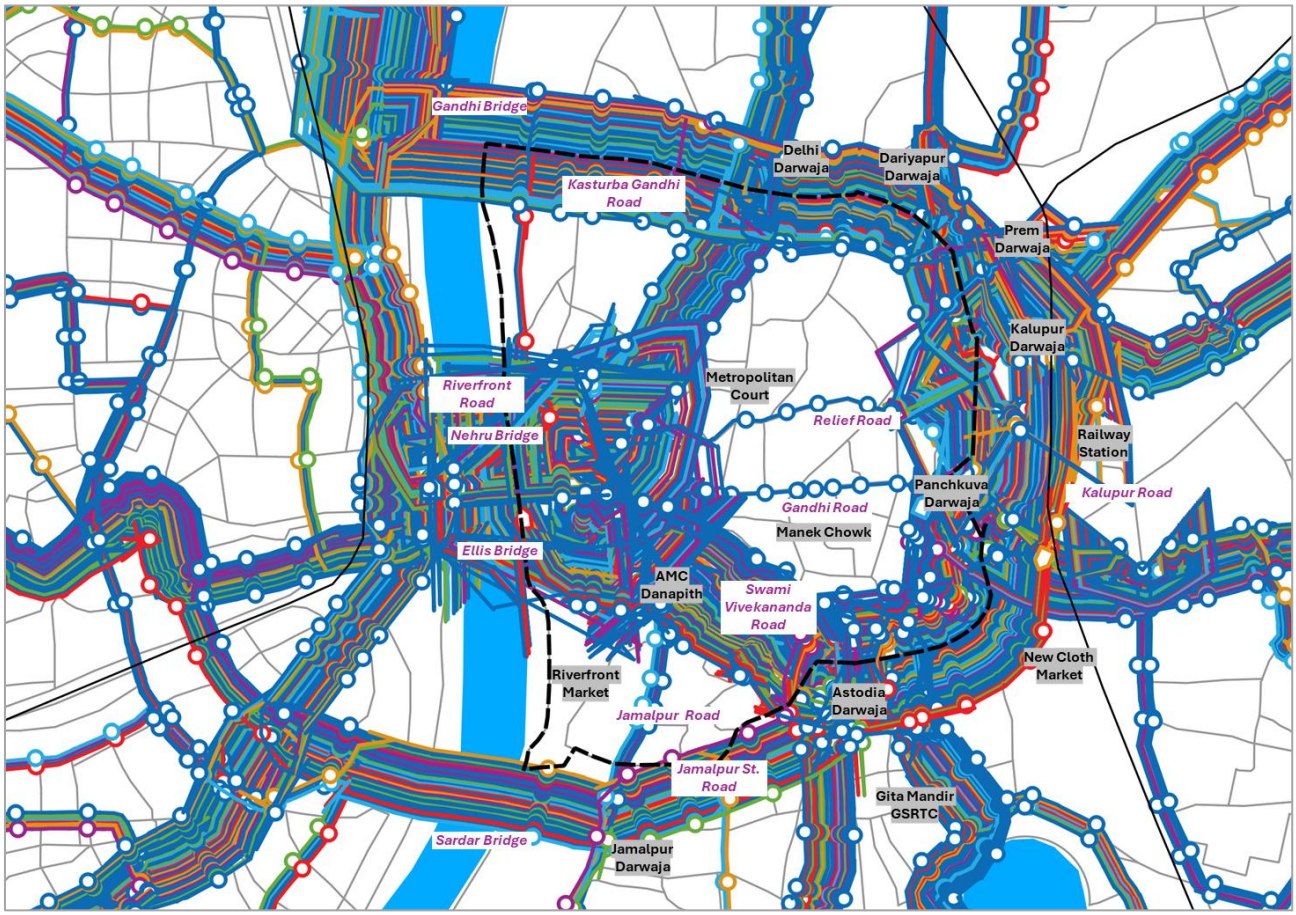


Figure 3-12 City Bus Service across the Walled City

Source: Adapted from Sustainable Urban Mobility Plan for Greater Ahmedabad Region, CoE-UT, CRDF (2023)

Ahmedabad Metro

A 3.5 km east-west line of Ahmedabad metro connecting Vastral Gam and Thaltej passes through the walled city providing underground service and connectivity with three stations at Shahpur, Gheekanta and Kalupur Railway Station. On an average, these stations together handle 15% of the daily average ridership of the Ahmedabad metro.

Regional Transport Nodes

The Kalupur Railway Station serves as a crucial regional transportation hub in this area, linking with various other public transport services within the city and facilitating substantial movements of both goods and passengers. Moreover, the Gujarat State Road Transport Corporation (GSRTC) depot and terminal located at Gita Mandir towards the south of the walled city has about 1900 departures (17).

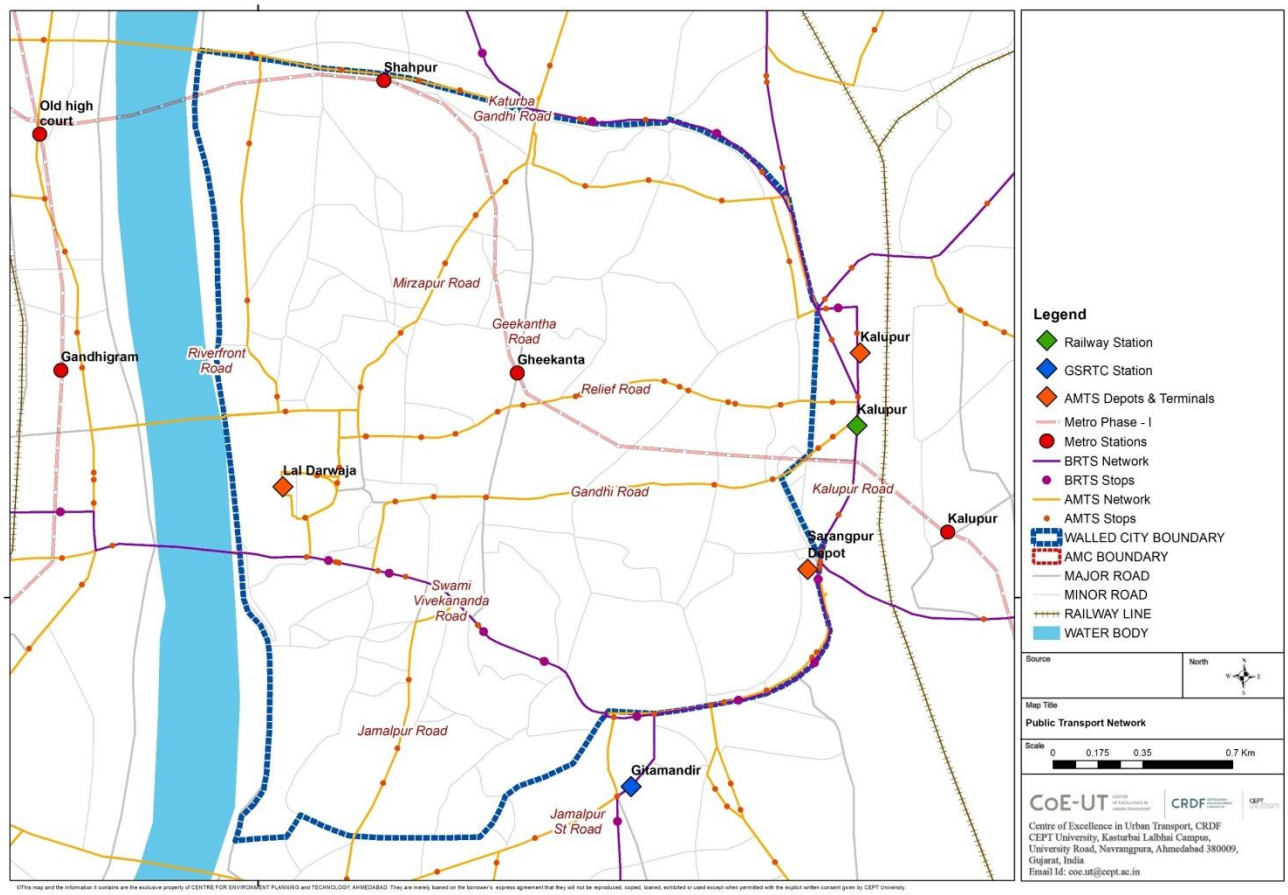


Figure 3-13 Public Transport Network across the Walled City

Source: Adapted from Sustainable Urban Mobility Plan for Greater Ahmedabad Region, CoE-UT, CRDF (2023)

3.2.6.3 Intermediate Public Transport

Intermediate Public Transport (IPT) corresponds to all modes of transport which fulfil the need that neither public transport nor personal vehicles can fulfil. IPT services in Ahmedabad comprise 3Ws, also known as autorickshaws, and 2W and 4W taxis.

Types of Service

Among IPT services, 3Ws are the predominant mode of intermediate public transport in the city as well as in the walled city which are majorly compressed natural gas (CNG) fuelled vehicles. There are four types of 3W service in the city:

- Hail and Hire: The service is hired by a commuter; it operates as a personalised mode of transport. Typically, this operates on a point-to-point service depending on the passenger's requirements. The fare structure is defined and regulated by the government.
- Shared Service: Vehicles ply as shuttle services along major corridors of the city. The commuters share their 3W vehicle ride with others travelling on that corridor. With declining bus services in Ahmedabad, shared 3W operations have been high in demand, particularly from low-income commuters. Fare levels are managed by the IPT operators. Fare levels are lower than 'hail and ride services but higher than city bus services. The average occupancy of shared vehicles is around 5-6 passengers.

- School Rickshaw: Some of the autorickshaws are also associated with schools in the city and ferry children from home to school and back. This is an approved service for which a school autorickshaw permit has to be issued by RTO every year. As per this permit, a maximum of seven school students can be carried at a time. Though they are associated with different schools as is the case of school buses, these drivers directly work with parents to transport their children.
- Feeder electric 3W: AJL launched a pilot project consisting of e-Rickshaws called Savaar-E to ensure first and last-mile connectivity on fixed routes from and to high ridership BRT stations, for a flat fare of INR 10. As of February 2022, 60 e-rickshaws were plying on 10 routes, entirely situated in the west of the city.(17)

The permit for IPT service falls under two categories – contract carriage and stage carriage:

- Contract carriage allows hiring of a vehicle for the exclusive use of the passenger, from the point of origin to destination, subject to the condition that the vehicle cannot stop to pick up other passengers not included in the 'contract' anywhere during the journey. Ride-hailing and individual autorickshaws and taxis operated in this model.
- Stage carriage allows the motor vehicle for hire or just reward at separate fares paid by or for individual passengers, either for the whole journey or for stages of the journey. This is only allowed for vehicles which can carry more than six passengers excluding the driver. Buses operate on stage carriage permits. Shared autorickshaws are given contract carriage, but they operate as stage carriage, informally without any permit.

Three-wheeler Route Characteristics

A total of 66 routes have been identified across the city for shared service with an average route length of 8.6 km (33) that carries 1.1 million passengers daily (17).

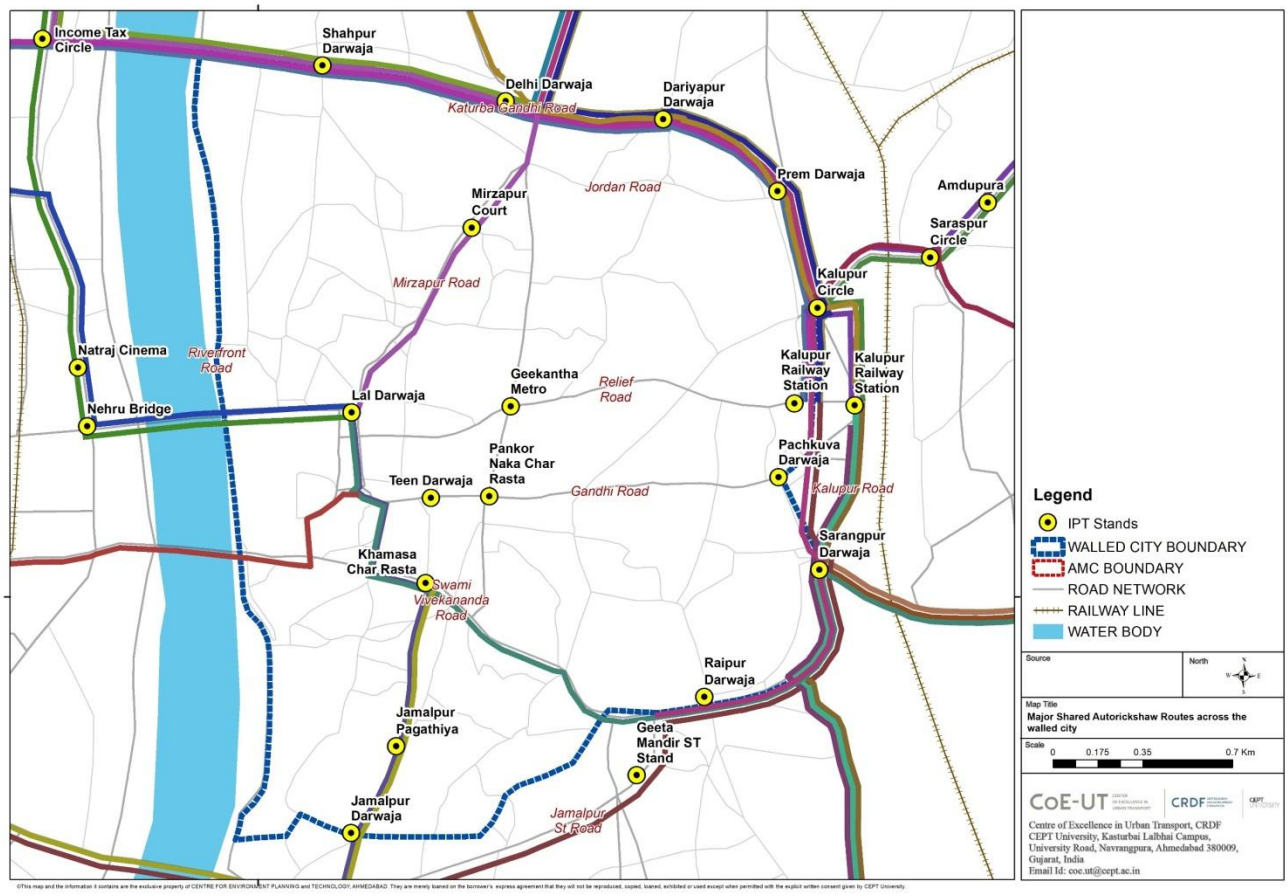


Figure 3-14 Shared Autorickshaw Routes across the Walled City

Source: Adopted from UK PACT IPT Driver Survey 2022 and Primary Survey

Nearly 28 shared autorickshaw routes operate across the walled city(33) carry 59,000 passengers daily. Kalupur and Lal Darwaja are major pick-up and drop-off points of shared autorickshaw routes. Within the walled city, only eight shared autorickshaw routes are operating which connect to Iskcon, Narol, Narol, Odhav, Sarkhej, Thaltej and Vadaj. During a meeting with the IPT association, several autorickshaw stands are present across the walled city namely Kalupur Railway station, Gita Mandir stand, Lal Darwaja, Delhi Darwaja, Pachkuva Darwaja, Khamasa Char Rasta and Teen Darwaja. On an average, roughly 200 to 300 vehicles are parked at these stands in a day.

Figure 3-15 Three-wheeler Stands at Kalupur and Lal Darwaja

Credits: CoE-UT, CRDF

3.2.7 Air Quality Monitoring Locations

Ahmedabad launched an air pollution monitoring and risk communication project, the Air Information and Response (AIR) Plan in 2017 as well as an Air Quality Index (AQI), the centrepiece of the plan, to protect local communities from rising air pollution levels.

The Ambient Air Quality Monitoring (AAQM) programme launched by the Central Pollution Control Board (CPCB) monitors and assesses major pollutants as part of AQI. To understand and assess the ambient air quality, the Gujarat Pollution Control Board (GPCB) monitors air quality at 62 locations within the state of Gujarat (34). This monitoring is conducted under two key programmes focussing on Ahmedabad's air quality:

- National Air Quality Monitoring Programme (NAMP): This programme monitors ambient air quality at 38 stations across Gujarat, including eight stations in Ahmedabad. The programme is executed by the state with financial assistance from the Central Pollution Control Board (CPCB), Delhi.
- State Air Quality Monitoring Programme (SAMP): This programme consists of 24 monitoring stations in Gujarat, with five located in Ahmedabad.

Both programmes measure the same air quality parameters, which include SO2 (sulphur dioxide), NOx (nitrogen oxides), O3 (ozone), NH3 (ammonia), CO (carbon monoxide), PM10 (particulate matter up to 10 micrometres), PM2.5 (particulate matter up to 2.5 micrometres), lead, arsenic, nickel, benzene, and benzo[a]pyrene. Under these programmes, the Gujarat Pollution Control Board (GPCB) monitors the ambient air quality in Ahmedabad.

In addition to the National and State Air Quality Monitoring Programmes, Ahmedabad's Air Quality Index (AQI) is further monitored by the technical expertise of the Indian Institute of Tropical Meteorology, Pune (IITM), and the Indian Meteorological Department's System of Air Quality and Weather Forecasting and Research (SAFAR) programme. The SAFAR programme operates a network of eight monitoring stations across Ahmedabad, providing comprehensive air quality data and forecasts(35). Continuous air monitoring stations record real-time information on air quality. This data is used to increase awareness among residents on air pollution, to share information, avoid harmful exposure, coordinate responses to reduce the health impacts of air pollution on vulnerable populations and adopt long-term policy strategies to achieve cleaner air.

Therefore, there are a total of 23 stations (nine stations under NAMP, six stations under SAMP and eight stations under SAFAR) located within Ahmedabad Municipal Corporation for the real-time monitoring of

ambient air quality (34)(35). Within the walled city, three monitoring stations are located at Raikhad (SAFAR), Nehru Bridge (SAMP) and Mirzapur (NAMP). According to Guidelines for Ambient Air Quality Monitoring (36) for the population of the walled city, CPCB suggests five monitoring stations for Suspended Particulate Matter (SPM), four for SO2, five for NO2 and one for CO. The existing monitoring stations are located near public parks and government institutions. Hence, there is a need for monitoring stations at transit hubs, industrial areas and concentration of high traffic volume.

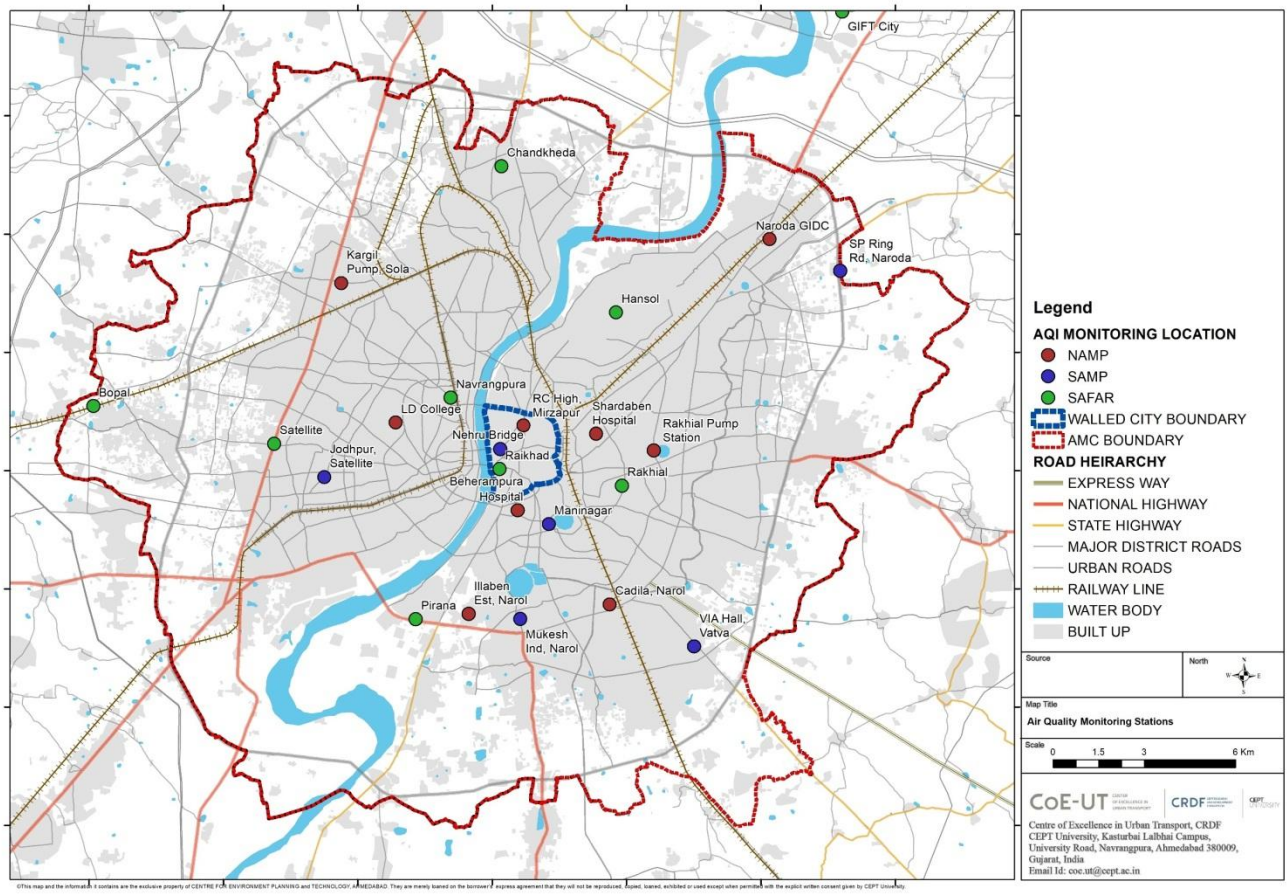


Figure 3-16 Location of Air Monitoring Stations in Ahmedabad (37)

Source: Gujarat Pollution Control Board, Indian Meteorological Department, Pune

3.3 Generators of Traffic

The walled city of Ahmedabad comprises historic monuments, bustling commercial markets, industrial units, religious sites and several other cultural landmarks. These areas serve as a focal point of economic, social and cultural activity attracting residents, jobs and tourists. Evolved of several activities, the core city is a dynamic environment conducive to interaction and engagement (74)

3.3.1 Industrial and Commercial Centres

Ahmedabad is the commercial capital and a major industrial centre of Gujarat and it has been designated as a mega city. Today, Ahmedabad remains a prominent hub for multiple commodities namely, textiles, food grains, construction materials, industrial and oil-based products and has significant interactions with many cities across Gujarat and India. These freight-generating zones are spread across Ahmedabad, both within and on the periphery of the AMC boundary. These zones can be broadly categorised into four types based on their location and activities: factories and industries, warehouses, transporter hubs, and trade centres. This section will elaborate on the various freight-generating zones located across the city and their significance in facilitating the movement of freight both within and outside the city. Refer Appendix D for locations of these zones.

3.3.1.1 Factories and Industries

Ahmedabad, being a prominent industrial hub, factories and industries make up a significant number of properties within the city. According to Property Tax Data 2021, there were around 135,025 industrial units identified within the city. These industries are spread across the city and mainly concentrated in the six clusters (depicted in Figure 6-7) established and managed by the Gujarat Industrial Development Corporation (GIDC). Of these clusters, Vatva, Odhav and Naroda contribute to the greatest number of units, collectively totalling 8,700 units.

3.3.1.2 Warehouses

Warehouses are located mainly in three places within the city of Ahmedabad, namely, Narol, Aslali and Sarkhej. In 2021, around 39,000 properties were occupied by transporters and warehouses, most of them being clustered in the periphery of the city. The Sarkhej and Aslali warehouse destinations were established by the private sector outside the city limits due to octroi taxes and time restrictions on heavy trucks entering the city.

3.3.1.3 Freight Transporters

A surfeit of transporters are situated on the periphery of the walled city, near Shahibaug, Madhupura, Raipur Darwaja, Sarangpur, Kankaria, Kalupur and Astodia (refer to Figure 3-17). These transporters aggregate the commodities from different parts of Ahmedabad and distribute them to various cities across India.

3.3.1.4 Trade Centres

In the walled city, a multitude of markets are primarily located on the eastern side, including Gheekanta Market, Madhupura Wholesale Market, Revadi Bazar, Chokha Bazar, Lati Bazar, Panchkuva Bazar, Relief Road, Gandhi Road, and others. These markets serve as distribution hubs for a wide range of commodities such as vegetables, clothing, food grains, oil, ghee, dry fruits, coconut, plywood, and more. Each market generates significant freight vehicle traffic for receiving and distributing goods both within Ahmedabad and beyond. To gain a comprehensive understanding, previous research projects were referred and discussions with the traders' associations were undertaken.

Table 3-6 Details of Wholesale Markets within and around the Walled City

Market Name	Area	Number of Shops	Commodity Traded
Agricultural Produce Market Committee	Jamalpur	165	Perishables
Chokha Bazar	Kalupur	200 - 250	Grains, Spices, and Dry Fruits
Gheekanta Market	Gheekanta	1000	Readymade Garments
Lati Bazar	Gita Mandir	500 – 600	Plywood
Madhupura Market	Madhupura	500 - 600	Perishables
New Cloth Market	Sarangpur	1500 - 2000	Fabric Cloth
Sindhi Market/ Revadi Bazar	Panchkuva Gate, Kalupur	300 - 500	Fabric Cloth, Readymade Garments

Source: Primary Survey and Previous Research

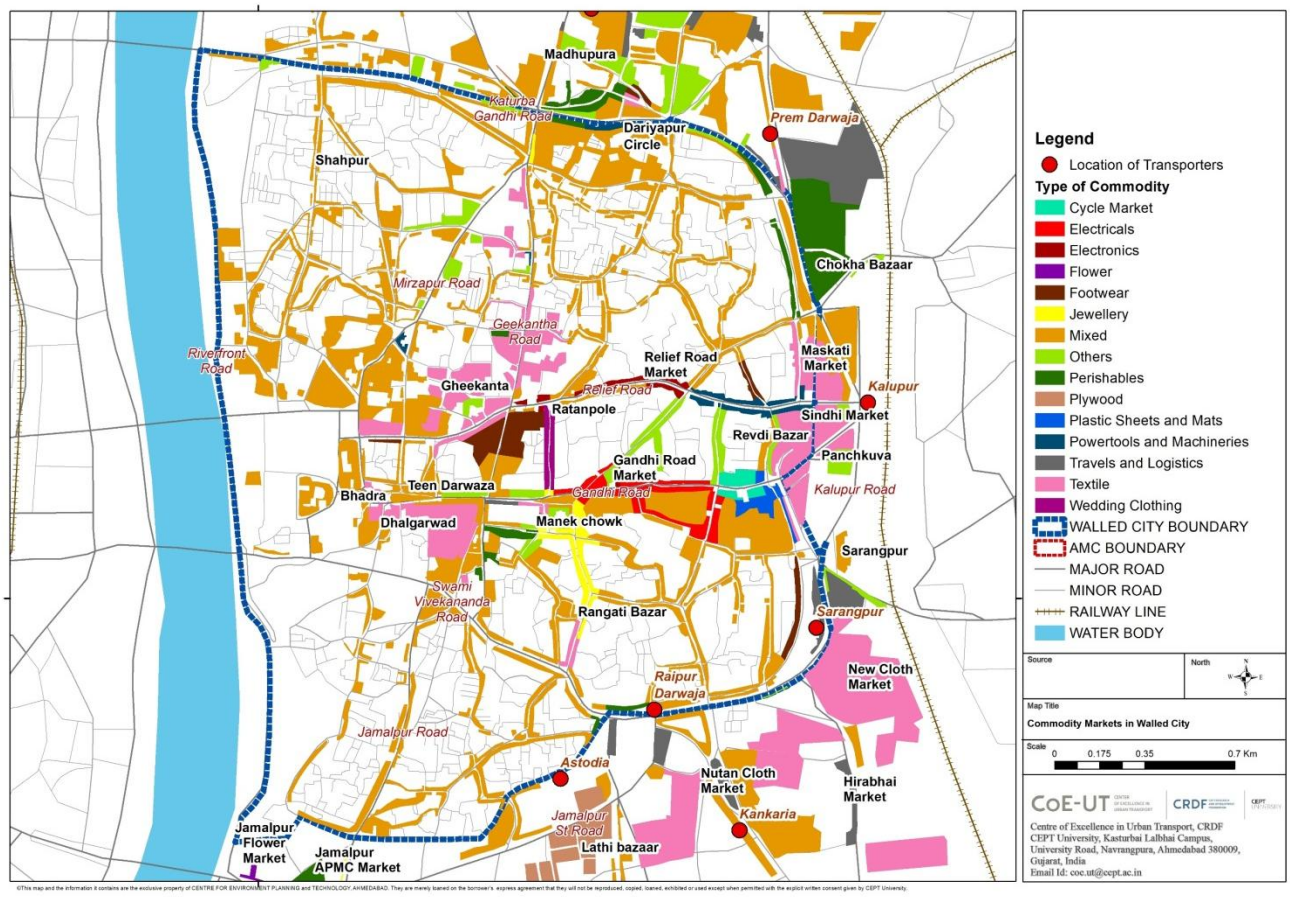


Figure 3-17 Commercial Markets located within and around the Walled City

Source: Primary Survey

Each market has distinct supply chains and often sources goods from across India or abroad, with storage and processing happening in nearby industrial areas like Narol and Vatva. The products like raw teak and timber wood for the plywood market are shipped from Latin America and Eastern Africa through waterways to Mundra port. The goods from various parts of India outside Gujarat like grains, pulses, dry fruits, cloth for textile market, finished plywood is imported via road and rail. The markets rely heavily on LCVs and 3W goods for handling commodities from industries and storages in the city and also for distribution in the city. Retail markets like Manek Chowk and Ratanpol further add to the commercial activity, supported by a hub-and-spoke model for efficient freight distribution. For a detailed overview of the supply chains of major markets, including specific modes of transportation involved in commodity handling, refer to Appendix F.

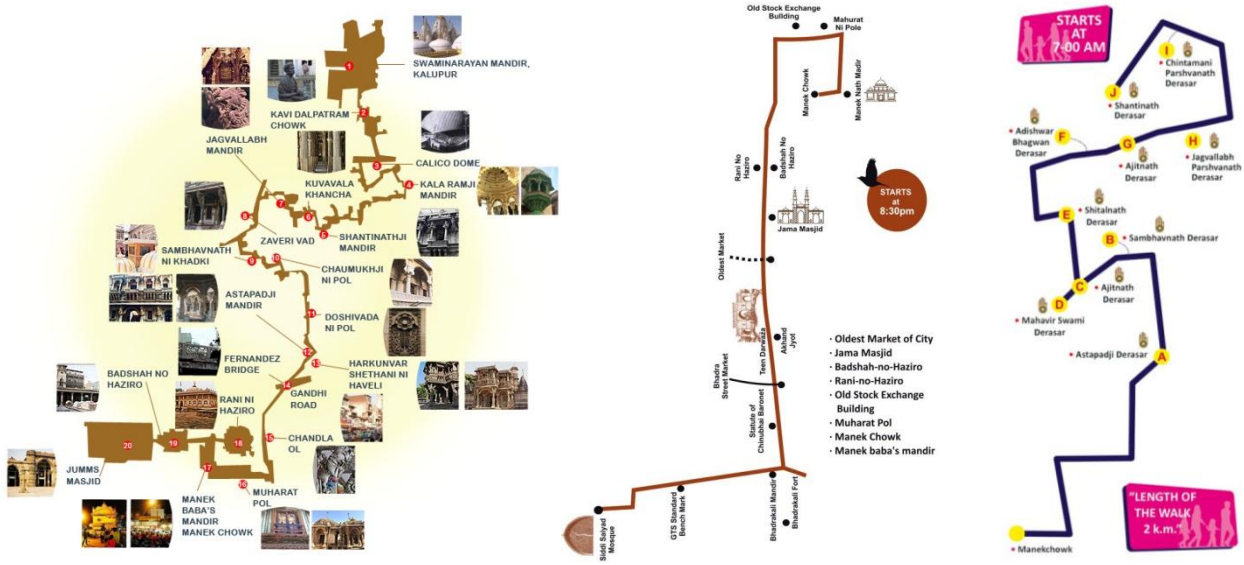
3.3.2 Heritage Area

The urban fabric is made up of densely packed traditional houses (pols) in gated traditional streets (puras) with characteristic features such as bird feeders, public wells and religious institutions. The historic residential timber architecture, with its elaborately decorated wooden facades, reflects symbols and myths connected with their inhabitants. Apart from the residential heritage area, the walled city comprises the Bhadra Plaza, the fort wall and gateways of the historic city and numerous mosques and tombs as well as important Hindu and Jain temples of later periods. Ahmedabad as a historical and religious destination has been a top choice for foreign tourists, of the 1.54 million foreign tourists who visited Gujarat in the first eight months of 2023, 0.35 million have visited Ahmedabad.(38)

Figure 3-18 Jama Masjid and Swaminarayan Temple in the Walled City

Credits: Gujarat Tourism Department (39)

AMC has arranged Heritage Walk of Ahmedabad since 1997 which is a guided tour of 2 km that takes visitors through historical and cultural landmarks in the walled city. This heritage walk is organised in three options known as Morning Walk from 7:30 am, Evening Walk from 8:30 pm and Jain Walk from 7 am for nearly two hours each. This walk covers 10 to 20 locations, including Swaminarayan Temple at Kalupur, numerous pols and chowks with very popular and famous 15th century Jama Masjid. The Ahmedabad Heritage Walk is also known as the journey of 'Mandir (temple) to Masjid (mosque)'.



Morning Route | Night Route | Jain Route

Figure 3-19 Routes of Heritage Walk in the Walled City

Credits: Ahmedabad Heritage Walk, AMC (40)

The majority of the residential area in the walled city has low-rise high-density development comprising traditional houses and gated streets. The traditional residences, known as pols, present in this area have been identified by UNESCO and bear enormous historical value, however, due to deteriorating living conditions, people have moved out from such structures and as a result, some of these are collapsing from neglect. (41)

Figure 3-20 Residential Structures in the Walled City

Credits: Times of India (2017), Creative Yatra (2016) (42,43)

3.4 Travel Characteristics

The current scenario of the travel behaviour of people of Ahmedabad, focussing on those across the walled city, is explored in the following section in terms of passenger and freight traffic.

3.4.1 Passenger Traffic

The data from the CoE-UT Household Survey 2022[2] was explored to understand the travel characteristics of passengers in Ahmedabad, including those in the walled city. This survey was conducted as part of SUMP project (17) to analyse the socio-economic and travel characteristics of city residents in each of the Traffic Analysis Zones (TAZs). Within AMC, household surveys of 12,025 samples were carried out. This data helped to identify various aspects of trips across the walled city: mode share, trip patterns, purposes, and vehicle types in relation to the temporal distribution of trips, as well as the internal and external movement of passenger traffic and their demand patterns.

3.4.1.1 Trip Interaction

The walled city accounts for 861,866 trips, i.e. 8% of the trips taking place across Ahmedabad of 10,213,071 trips. Among these, 28% of the trips originating from the walled city end within it and the remaining are originating from or destined to the walled city from other parts of the city. The external trip interactions majorly take place in all parts of the city, south zone (16%), west zone (14%), central zone (12%) and new west zone (11%).

Table 3-7 Trip Interaction with the Walled City (2022)

Trips	Internal - Internal	Internal – External and External - Internal
	244,433 (28%)	617,433 (72%)

Source: Household Survey Data 2022, CoE-UT, CRDF

[2] The household survey was carried out during February to August 2022, during which the city's economic activities had fully resumed driven by industrial and trading activities and returned to normal from COVID-19. However, educational trips were limited because lower grade classes were conducted online, while senior school students attended school in person.

3.4.1.2 Trip Rate

The trip rate depicts the total number of trips made per capita per day. The trip rate is high across the walled city as it marks 2.48 trips compared to that of 1.39 trips across Ahmedabad. The motorised trip rate of the walled city is twice as high as the city. The presence of a wide variety of economic activities in the core area could be the reason for the higher trip rate.

Table 3-8 Trip Rate of the Walled City and AMC (2022)

Trips	Walled City	AMC
Non-Motorised	0.75	0.57
Motorised	1.73	0.82
Overall	2.48	1.39

Source: Household Survey Data 2022, CoE-UT, CRDF

3.4.1.3 Mode Share

One-tenth of motorised trips of AMC occur across the walled city. However, motorised mode of transportation is high in the walled city by 70% of trips while comparing it with the average of 60% across the city. Two-wheeler is the predominant mode of transportation for the people of the walled city which accounts for 42% of the trips, followed by 28% of walk and 14% of 3W trips. When examining the motorised modes used in the walled city in comparison to the AMC, it is evident that 2Ws, 3Ws and city buses (AMTS) are more commonly utilised for the trips across the walled city.

Table 3-9 Mode Share and Trip Length of all trips across the Walled City and AMC (2022)

Trips	Walled City		AMC	
Mode	Number of Trips	Mode Share (%)	Number of Trips	Mode Share (%)
Walk	245,154	28%	3,864,759	38%
Cycle	16,236	2%	336,735	3%
2W	360,670	42%	3,717,959	36%
3W	65,019	8%	547,678	5%
Shared 3W	59,444	7%	559,731	5%
4W	34,855	4%	580,339	6%
Staff Bus	3,706	0.4%	131,098	1%
AMTS	57,459	7%	299,374	3%
BRTS	19,324	2%	175,398	2%
All NMT	261,390	30%	4,201,494	41%
All Motorised	600,476	70%	6,011,577	59%
Overall	**861,866**	**100%**	**10,213,071**	**100%**

Source: Household Survey Data 2022, CoE-UT, CRDF

While observing the mode share of trips interactions, it is evident that motorised trips are higher by 83% for internal-external and external-internal interactions, whereas walk is the predominant mode of transportations by 63% for travelling within the walled city. The predominant motorised modes for external trips are two-wheelers, 3Ws as well as city buses.

Table 3-10 Mode Share of Internal and External Interactions across the Walled City (2022)

Trips	I-I		I-E & E-I		Total Trip Interactions in/with Walled City	
Mode	No. of Trips	Share (%)	No. of Trips	Share (%)	No. of Trips	Share (%)
Walk	153,350	63%	91,804	15%	245,154	28%
Cycle	2,498	1%	13,738	2%	16,236	2%
2W	62,430	26%	298,240	48%	360,670	42%
3W	15,605	6%	49,413	8%	65,019	8%
Shared 3W	5,375	2%	54,069	9%	59,444	7%
4W	2,392	1%	32,463	5%	34,855	4%
Staff Bus	1,075	0.4%	2,630	0.4%	3,706	0.4%
AMTS	1,112	0.5%	56,348	9.1%	57,459	7%
BRTS	595	0.2%	18,728	3%	19,324	2%
All NMT	155,848	64%	105,542	17%	261,390	30%
All Motorised	88,585	36%	511,892	83%	600,476	70%
Overall	**244,433**	**100%**	**617,433**	**100%**	**861,866**	**100%**

Source: Household Survey Data 2022, CoE-UT, CRDF

3.4.1.4 Trip Purpose

The share of work trips is highest in the walled city while looking at the overall trips taking place across Ahmedabad. The core area accounts for 10% employment of AMC. The significant share of 56% of work trips to this area is due the extensive the retail businesses, traditional markets, industrial processing units. The walled city is home to numerous schools and colleges with 6% of the trips originating within this area and 14% are from external locations. Notably, the presence of various commodity markets in the core area attracts 10% of trips beyond the walled city and sees 7% of its residents commuting within its confines for shopping or visiting markets.

Table 3-11 Trip Purpose of the Walled City and AMC (2022)

Trips	Walled City	AMC
Work	56%	44%
Education	20%	27%
Others	24%	29%

Source: Household Survey Data 2022, CoE-UT, CRDF

3.4.1.5 Trip Length

The average trip length for trips across the walled city is 4.56 km and for the predominant mode, 2W-, it is 5.40 km.

Table 3-12 Mode-wise Average Trip Length (2022)

Mode	Walled City Avg. Trip Length (km)	AMC Avg. Trip Length (km)
Walk	1.88	1.94
Cycle	4.23	3.29
2W	5.40	5.52
3W	4.55	4.42
Shared 3W	5.51	4.57
4W	6.37	5.88
Staff Bus	4.32	5.57
AMTS	7.83	8.71
BRTS	7.32	8.22
All NMT	2.03	2.05
All Motorised	5.67	5.61
Overall	**4.56**	**4.14**

Source: Household Survey Data 2022, CoE-UT, CRDF

Mode-wise distribution of trip based on length reveal that on an average 20% of the trips take place within 2 km. In terms of each private mode, 50% of the trips by 2Ws cover distance up to 5 km and 50% of 3W trips are within 3 km.

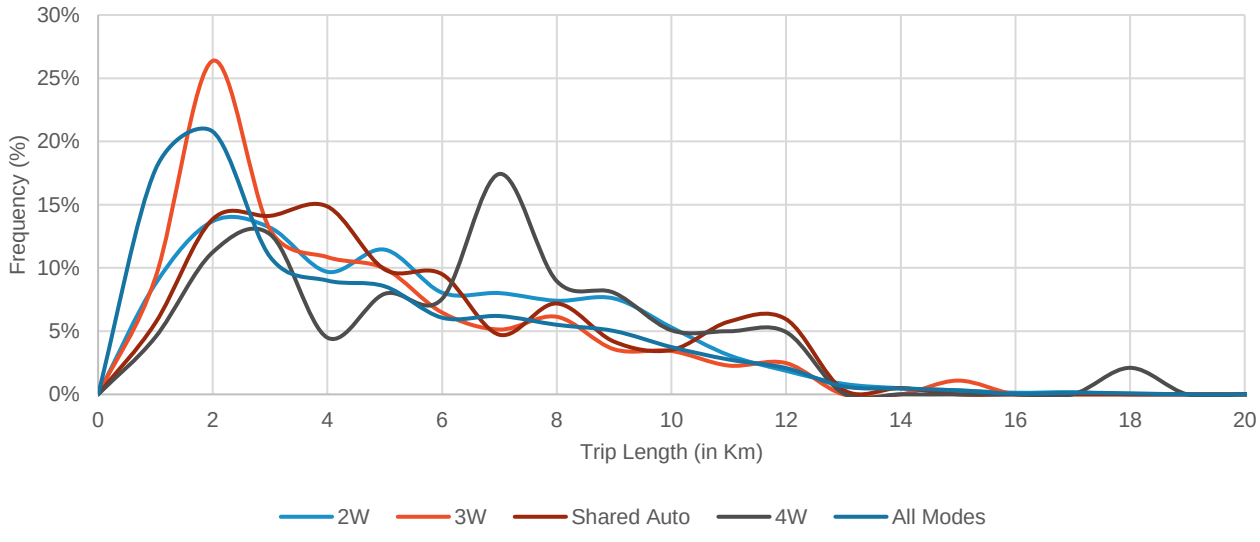


Figure 3-21 Mode-wise Trip Length Frequency Distribution of Trips across the Walled City (2022)

Source: Household Survey Data 2022, CoE-UT, CRDF

3.4.1.6 Temporal Distribution of Passenger Trips

It is observed that there are two peak periods in a day in the walled city. The morning peak hour is from 9 am to 11 am and the evening peak is from 6 pm to 8 pm. Both the peak hours are dominated by 2W trips and there are very insignificant share of 3Ws and 4Ws during this peak period.

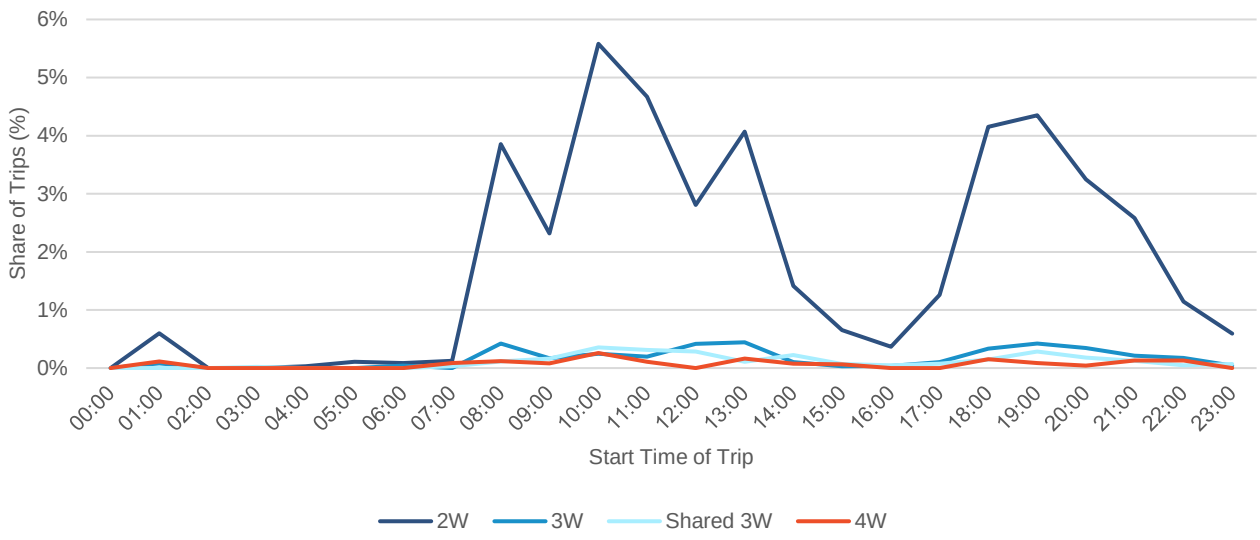


Figure 3-22 Temporal Distribution of Private Vehicle Trips across the Walled City (2022)

Source: Household Survey Data 2022, CoE-UT, CRDF

3.4.2 Freight Traffic

To understand the trip characteristics of freight vehicles within the walled city, an Activity Survey or Non-Residential Property survey is being carried out. Based on the Property Tax data 2022, there are approximately 69,638 non-residential properties within this area, including garages, godowns/warehouses, small to large-scale polluting and non-polluting industries and retail shops. Nearly 18% of establishment generating freight activities are present inside the walled city. This survey covered 750 samples to capture the details of the establishment in terms of type, commodity handled, number of employees, operation hours, the incoming and outgoing movement of visitors and goods to/ from the establishment. Activity Survey form is presented in Appendix G. This analysis focusses on incoming freight traffic due to its high share compared to the outgoing trips.

3.4.2.1 Incoming Freight Traffic

The commercial and industrial centres within the walled city attract a large share of heavy and light goods vehicles daily. It was observed that a total of 145,612 freight vehicles enter the walled city daily, with the majority of the vehicles being 3W goods by 60% and LCV by 28%. Two-wheelers are also used for commodity movement by 9%. The share of heavy and medium commercial vehicles (HCV and MCV) including trucks is low at around 1.5%, as there are restrictions posed for the entry of these vehicles into the walled city during the day time. Retail shops contribute to nearly 80% of the incoming freight trips.

Table 3-13 Traffic Count (24-Hour) of Different Freight Vehicles Coming into the Walled City (2024)

Mode	Number of Trips	Share (%)
2W (used for cargo movement)	13,490	9%
3W Cargo	87,852	60%
Auto (used for cargo movement)	218	0.2%
Pedal rickshaw/ Handcart	488	0.3%
LCV	41,229	28%
Truck	2,335	1.6%
Total	**145,612**	**100%**

Source: Activity Survey Data 2024, CoE-UT, CRDF

3.4.2.2 Predominant Commodity Transported

The analysis reveal that major commodities transported are textiles, electronics, vehicles/auto parts or food grains and oil. Of these commodities, around 40% of the trips were carried out for handling textile, followed by, 12% of electronics, 8% of vehicle/auto parts and 8% of food grains. Moreover, 88% of the trips are conducted by 3Ws and LCVs trips indicating a significant reliance on these modes for the transport of commodities in the walled city.

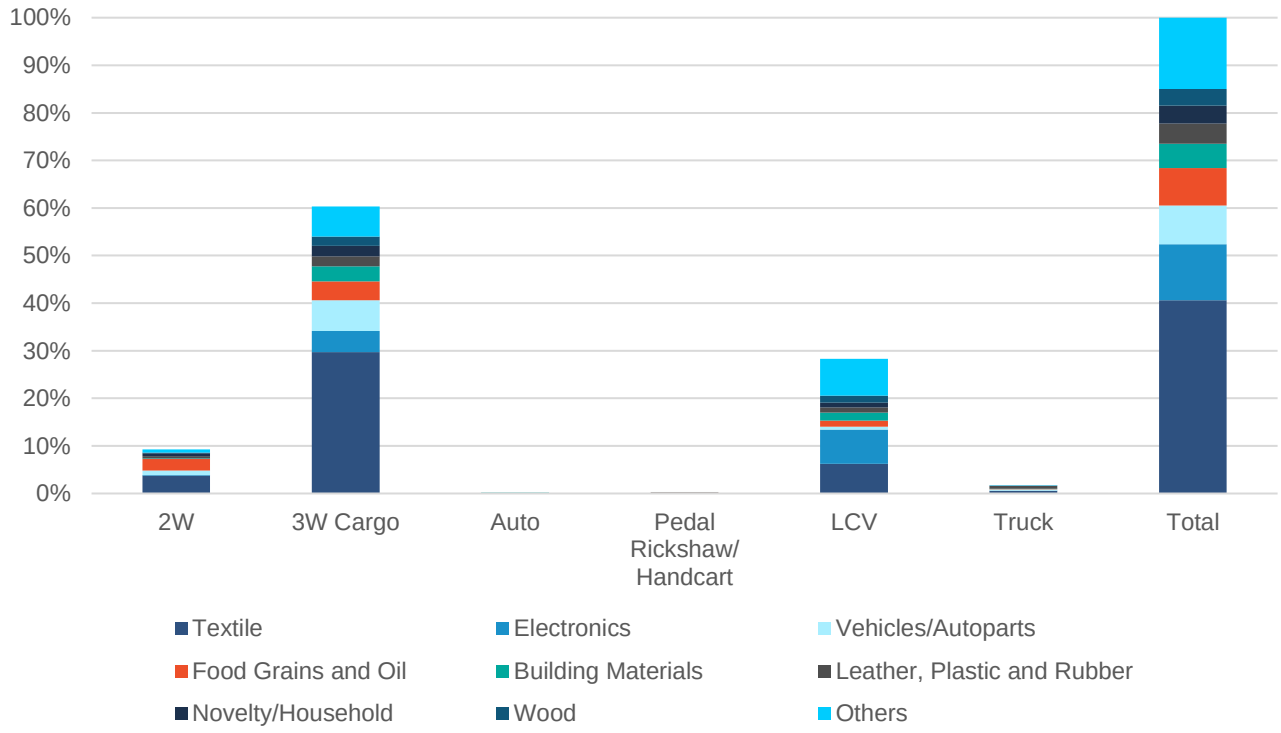


Figure 3-23 Composition of Freight trips by Vehicle Type and Commodities

Source: Activity Survey Data 2024, CoE-UT, CRDF

3.4.2.3 Temporal Distribution of Incoming Freight Vehicles

An analysis of the temporal distribution of different freight vehicles entering the walled city reveals that 3Ws and LCVs are the primary mode for transporting commodities throughout the day. The traffic of 2Ws is also significant. Furthermore, the truck counts are insignificant throughout the day as there are restrictions posed for the entry of heavy vehicles into the walled city during the day time.

The temporal distribution of 3Ws goods shows notable variations than that of the other freight vehicles. The number of 3Ws entering the walled city is lowest between 6 pm and 10 am, averaging 350 vehicles per hour. However, traffic surges after 10 am, peaking at approximately 15,300 vehicles per hour around 12 pm and again at 4 pm with about 14,000 vehicles per hour. This variation in the 3W traffic could be attributed to their widespread use in all the markets within the walled city boundary and the differing supply chain operations of these various markets. Around 93% of the incoming trips are operating between 11 am and 5 pm.

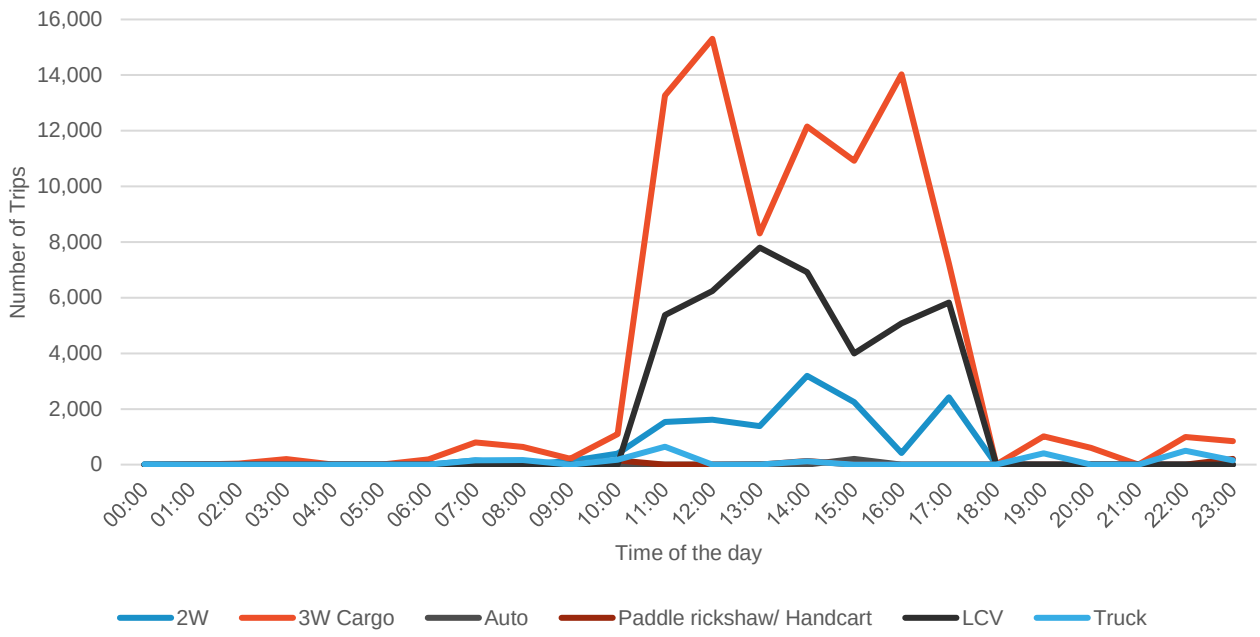


Figure 3-24 Temporal Distribution of Incoming Freight for Various Vehicle Types (2024)

Source: Activity Survey Data 2024, CoE-UT, CRDF

3.4.2.4 Average Trip Length and Tonnage

The average trip length of 3W goods is 5.5 km and LCV is 7.4 km. Two-wheeler are involved in short distance trips to travel an average distance of 3.4 km. However, within the walled city, the average trip length of all the freight vehicles is only 1.6 km. This shows that the lighter vehicles are used for the distribution of commodities within and around the walled city market, while the heavier vehicles are preferred for longer trips.

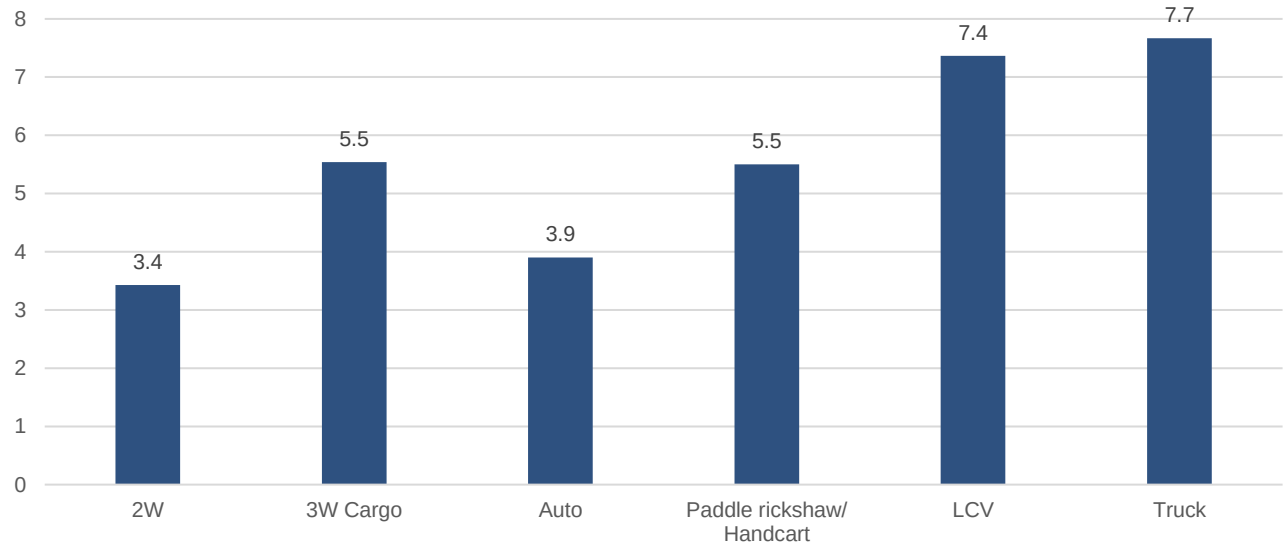


Figure 3-25 Average Trip Length of Freight Vehicles

Source: Activity Survey Data 2024, CoE-UT, CRDF

The selection of mode also depends on the weight carried and the type of commodity transported to the walled city. The 3W and LCVs dominate the transportation of commodity in terms of weight handled as nearly 45% of the goods weight is handled by 3W cargo and 50% by LCVs.

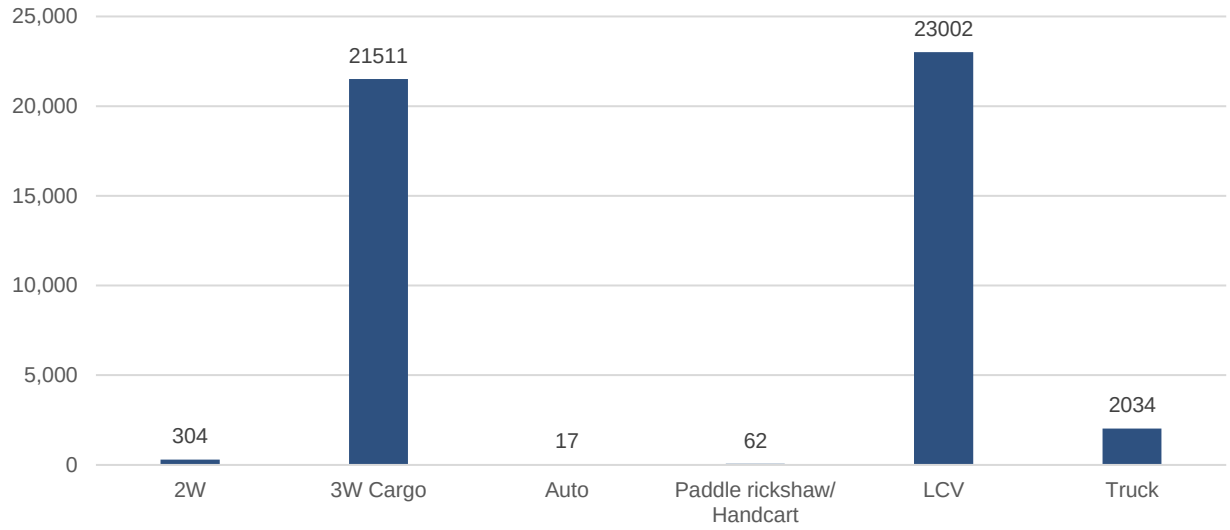


Figure 3-26 Cumulative/ Total Weight carried into the Walled City by Different Vehicles

Source: Activity Survey Data 2024, CoE-UT, CRDF

3.4.2.5 Interaction

Though 60% of the freight trips are handled by 3W goods and their operations are dominant during 11 am to 5 pm, the predominant location of their arrival was identified. Along Relief Road, Gandhi Road, Sarangpur, Dhalgarwad and Gheekanta largely handle 3W goods movement. Nearly 43,000 3W trips are involved in textile handling. Textile market areas like Dhalgarwad, Ratanpol and Pankore Naka deal with more than 40% of textile related 3W trips.

Figure 3-27 Freight activities in the Walled City

Credits: CoE-UT, CRDF

3.5 Operations of IPT and Goods Vehicles

The operations of 3Ws in the walled city are predominant for passenger as well as goods movement. It is crucial to understand the operations of 3Ws in the walled city from its drivers or operators' perspective.

3.5.1 Passenger Three-wheeler

To understand operator/drivers' economics and perception of EVs, a 3W Driver Survey was conducted across the walled city. In consultation with the IPT association in the walled city, major IPT pick-up and drop-off points were identified and the locations were selected within the walled city to understand the characteristics of drivers operating in the area. Three locations were considered to conduct the survey of 20 drivers. The surveys were conducted along Relief Road, Gandhi Road, Lal Darwaja and Gheekanta Road. This survey was conducted in continuation of IPT Driver Survey 2022 of 60 samples conducted by the team as part of UK PACT project (33). Passenger 3W Driver Survey form is presented in Appendix H.

Socio-economic Characteristics

It was observed that the nearly half of the drivers operating across the walled city belong to poor households and they earn less than INR 30,000 monthly. The primary reason for 3Ws is the challenge of

finding suitable formal employment due to low education levels. The ease of entry into 3W operations and it has the potential for better income compared to daily wage work make this an appealing livelihood choice. All the drivers operate CNG fuel 3W. Nearly three-fourth of the drivers owns their vehicles of which almost two-third of drivers bought new vehicles and more than one-third of them purchased used vehicles.

Operation Characteristics

Three-wheelers operate predominantly in peak hours from 8:30 am to 11:30 am and 5 pm to 8 pm, and for the rest of the day drivers operate hail and hire services. About one-fifth of the drivers operate on rent for daily operations, paying an average of INR 200 to INR 300 day. The average age of a first-hand autorickshaw is four years, while the average age of used vehicles is six years. Apart from providing passenger service, less than one-fifth of the drivers are involved in delivery of goods like vegetables, groceries, etc. to secure an additional earning of INR 200 per day. The table below presents the operating and financial details of passenger 3W service in the city.

Table 3-14 Operating and Financial Details of Passenger Three-Wheeler (2024)

Parameters	Unit	Details
Daily Vehicle km	km	80-100*
Average no. of passengers/ day	Number	55*
Average age of vehicles	Years	6
Average purchase cost of a vehicle	INR	290,000
% of respondents who took a loan	%	85%
% of the loan amount of the purchase price	%	73%
Average EMI Amount	INR	6,800
Average Monthly Maintenance	INR	1,800
Fuel (CNG) cost per day (Range)	INR	250 - 350
Gross Monthly Income	INR	22,500
Net Monthly Income	INR	13,900

*Details in case of passenger trips

Source: Passenger Three-wheeler Driver Survey (2024)

Perception about Electric Vehicles

The drivers' awareness and perception about electric passenger 3Ws was captured through the survey. Nearly three-fourth of the drivers operating in the walled city was aware about EVs however, majority do not have an understanding on its technology and financial gains of electric variant. However, most of the drivers were not aware about the financial incentives provided by the state and national governments which have made them suspect that the EVs are unaffordable. Moreover, concerns in terms of range, capability to navigate along the gradients, management of vehicle during summer and monsoons. They compare the vehicle with capability of lead-acid battery vehicles. Though the EV with lithium-ion batteries promises better operations, the awareness about the vehicle is low.

3.5.2 Goods Vehicles

A survey with freight operators or drivers was conducted in the walled city to understand the operations of freight vehicles, assess its economics and operator/drivers' perception of the electric variant of freight vehicles. The Freight Operator/ Driver Survey took place at four locations, Kasturba Gandhi Road, Kalupur Road, Swami Vivekananda Road, Relief Road and Gandhi Road to capture 50 surveys. Freight

Operator/Driver Survey form is presented in Appendix I. Across the sample, nearly 40 drivers were operating goods 3W, five were driving autorickshaws, while the remaining were LCV operators.

Socio-Economic Characteristics

Nearly 65% of the drivers belong to lower income group, i.e. less than INR 30,000 per month. These drivers operate their vehicles consistently throughout the week, regardless of weekdays or weekends, with 75% of them engaged in full-time operations without breaks. Around, 98% of the drivers have purchased vehicles with the support of loan.

Operation Characteristics

It was noted among sampled 50 drivers, the mode share of 3W goods is 80%, followed by 11% of autorickshaw. Among the recorded 258 trips per day, only 12% of trips take place within walled city with an average trip length of 4 km. To the external locations, vehicles travel up to 12 km on an average. However, it is important to note that nearly 36% of the total trips were empty runs and 61% of them were across walled city. Nearly 164 trips were conducted for goods movement, where 49% of the trips are made for transporting textiles, followed by 16% for electronics.

On an average, goods vehicles conduct five to six trips per day. Three-wheelers cover nearly 45 km per day, whereas LCV travels cover 70 km. The weight of commodities transported varies by vehicle type, with autorickshaws typically handling up to 500 kg, 3W goods vehicles managing around 800 kg, and LCVs accommodating up to 1000 kg. However, on an average, 3W carry nearly 330 kg of goods and whereas LCVs carry average of 570 kg. In terms of utilisation of its capacity, almost 50% of trips use less than 60% of the vehicle's capacity, while 13% of trips exceed the vehicle's capacity.

Loading and unloading activities typically take around 15 minutes, with 81% of trips requiring vehicles to park along the roadside during these operations. However, parking facilities for freight vehicles are notably inadequate, as 83% of trips result in vehicles remaining parked roadside for rest periods averaging 60 minutes.

On an average 3W goods operator earn monthly income of INR 23,000 and they spend nearly 40% of income on capital, fuel and maintenance expenses. The table below presents the operating and financial details of goods vehicles.

Table 3-15 Operating and Financial Details of Goods Three-Wheeler

Parameters	Unit	3W Auto	3W Goods	LCVs
Daily Vehicle km	km	45	45	70
Average Trips	No.	6	5	5
Average Weight Carried	kg	330 (max. 500)	350 (max. 800)	570 (max. 1000)
Average purchase cost of a vehicle	INR	290,000	319,000	418,000
% of respondents who took a loan	%	100%	100%	100%
% of the loan amount of the purchase price	%	83%	43%	65%
Average EMI Amount	INR	8,300	7,500	7,800
Average Monthly Maintenance	INR	2,200	2,200	2,900
Fuel cost per day (Range)	INR	150 - 200	150 - 200	300 - 400
Gross Monthly Income	INR	26,400	23,000	21,600
Net Monthly Income	INR	15,900	13,300	10,900

Source: Freight Operator/ Driver Survey (2024)

Perception about Electric Vehicles

Awareness of EVs was assessed through the survey, which revealed that nearly 90% of the drivers are familiar with EVs. Most of them have known EV by seeing it on road, hearing from media or peers and few even had opportunity to test-drive it. However, a significant gap in knowledge persists, as 72% of the drivers are unaware of the financial incentives provided by state and central governments to support EV adoption. Despite this, 68% of drivers expressed a lack of interest in purchasing an EV. The primary reasons include the high upfront cost of the vehicles, limited personal financial resources, concerns about higher maintenance expenses and the perceived poor quality of EV bodies. These barriers highlight the need for enhanced awareness campaigns on technology and incentives to address drivers' financial constraints and build confidence in the long-term benefits of electric mobility.

3.6 Street Usage in the Walled City

The passenger travel characteristics indicate that the people of the walled city majorly preferred to walk for commuting within the core area. However, the walkability in this area is significantly compromised due to the poor availability of footpaths due to path discontinuity, and encroachment by vehicles as well as commercial establishments. This encroachment not only affects the pedestrian movement but also the overall traffic flow.

Figure 3-28 On-Street Activities along Inner Roads across the Walled City

Credits: CoE-UT, CRDF

3.6.1 On-Street Activities

The streets within the walled city of Ahmedabad face significant challenges due to encroachments and unregulated on-street activities. The effective right of way (RoW) has significantly reduced, leading to congestion, compromising safety of pedestrians and inefficient traffic management. Encroachments by shops, informal vendors and unregulated on-street parking have substantially decreased the functional width of both major and local roads. Overall, across the streets of the walled city, approximately 20% of the length is encroached upon by unregulated parking. These include both short-term parking for visitors and long-term parking by shopkeepers. However, parking encroachments are particularly severe along major roads. Relief Road, a critical 2.6 km corridor connecting Nehru Bridge to the railway station, has approximately 80% of its length occupied by parking on both the sides. The encroachment starts from Krishna Cinema Bus Stop and continues towards Ratanpol Market and the electronic market areas. These sections serve as a key economic and cultural hub with various commodity markets and religious landmarks. Swaminarayan Mandir, one of the major religious institutions in the walled city, experience high vehicular movement, specifically by 4Ws. Similarly, Swami Vivekananda Road faces significant encroachments with a mix of 3Ws and 4Ws, particularly near AMC Danapith. Inner roads are equally affected by parking and encroachment. Gheekanta Road, a 2.04 km stretch, is predominantly occupied by 2Ws and 3Ws, with parking encroaching up to approximately 90% of its length due to the presence of retail establishments. Gandhi Road, connecting Teen Darwaja Market to the Railway Station, is encroached by nearly 86% of its length with scattered parking. This road intersects Bhadra Plaza, where designated pedestrian spaces have been converted into informal parking zones. Dhalgarwad Market, a high-footfall shopping destination, further intensifies congestion with pedestrian activity and informal

vendor encroachments. The challenges are similar in Ratanpol Market. The residents in the locality park their vehicles in their courtyard, but it is found to be spilling onto the streets. An additional 2-3% of street space is occupied by loading and unloading, and other activities, particularly during peak business hours, causing frequent disruptions in traffic flow. Informal street vendors further reduce accessibility for pedestrians and vehicles by occupying the road space.

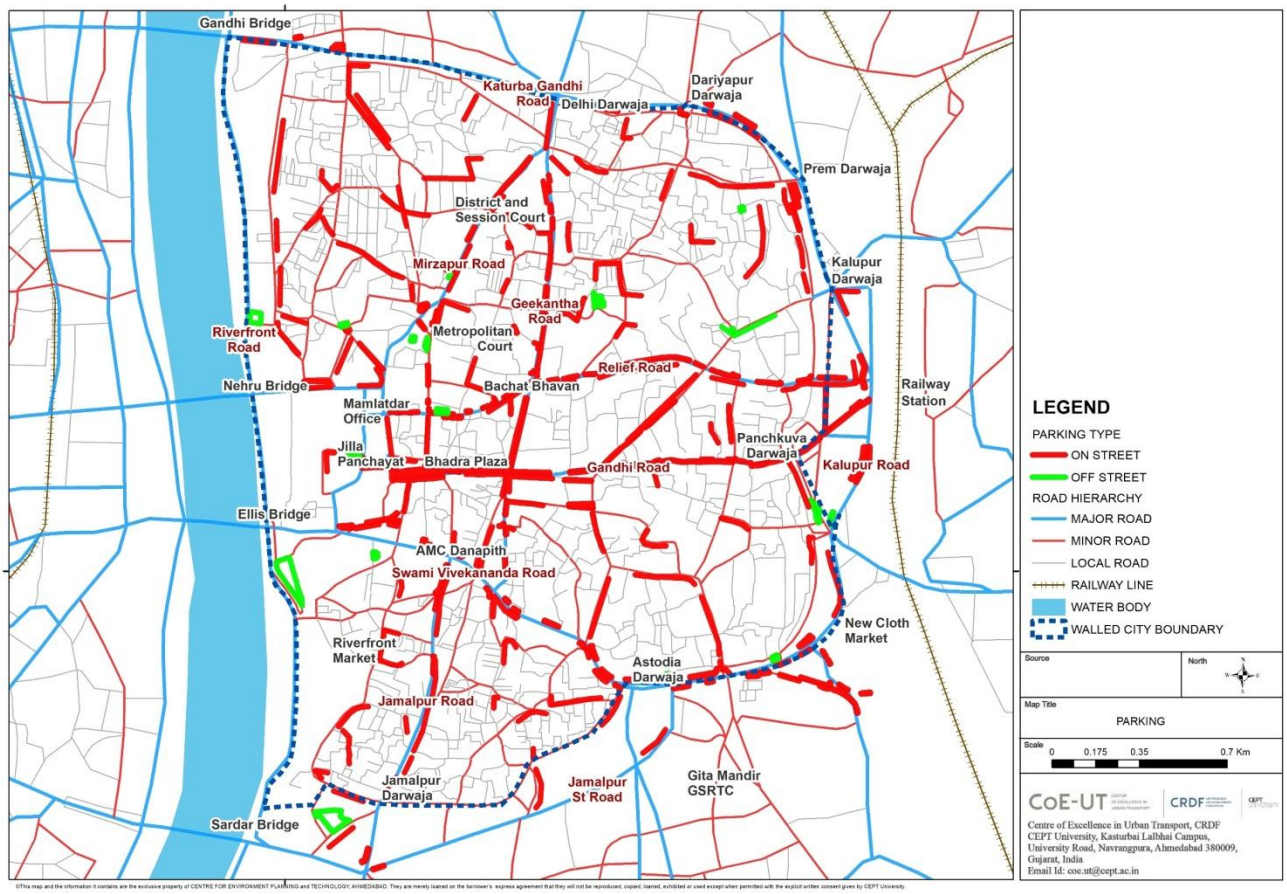


Figure 3-29 Parking and Encroachment along Major Roads in the Walled City

Source: Primary Survey

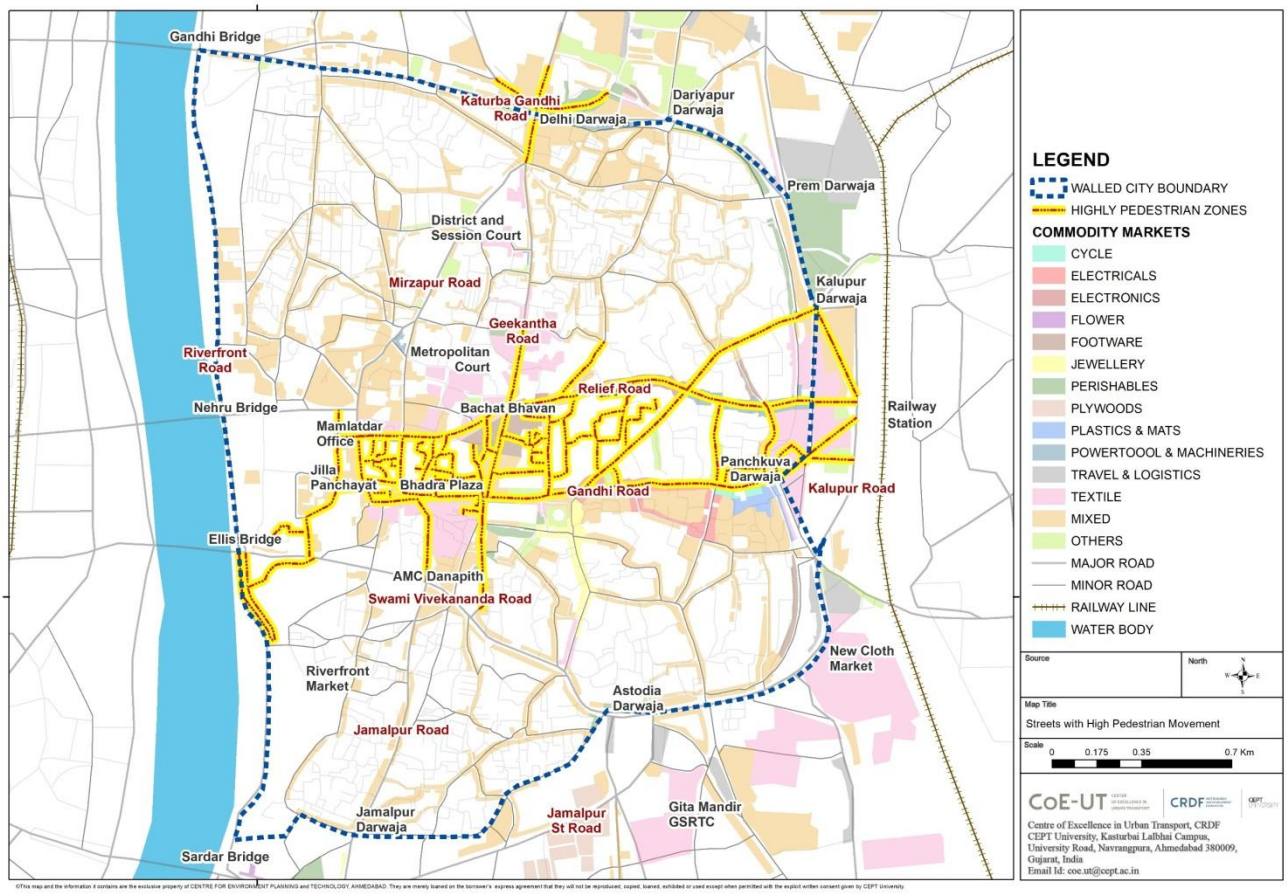


Figure 3-30 Streets with High Pedestrian Movements

Source: Primary Survey

3.6.2 Traffic and Parking Management

To manage the traffic flow, the Traffic Department has adopted one-way traffic systems across ten roads in the walled city. Out of these, the major corridors are Gandhi Road, Gheekanta Road, Lal Darwaja and Kalupur. But some of these one-ways pass through fruit and grain markets which have a high volume of pedestrian movement and as a result, the traffic speed is low, and these roads become unsafe for pedestrians.(29) Along the major roads, 21 junctions has traffic light. However, to manage the movement of the high amount of mixed vehicle traffic and enforcement of rules, police are stationed at the major junctions as well as at inner roads such as Relief Road, Gheekanta Road and Mirzapur Road. Traffic violations are monitored and recorded on the road by traffic police and through camera surveillance facilitated by Ahmedabad Smart City (Mission).

A vehicle parking system (free) was established along the Relief Road and Gandhi Road to park on one side of the road on a specific day. On Mondays, Wednesdays and Fridays, vehicles have to be parked on the left side, while on Tuesdays, Thursdays, Saturdays, and Sundays, vehicles have to be parked on the right side. Electrical, electronics and power tools machinery markets are present along the Relief Road, due to which 65% of the road length from Gheekanta Road to Khiskola's Pol is utilised for parking and Khiskola's Pol to Revadi Bazar Post Office by 50%. Gandhi Road is heavily encroached upon by street vendors and shops displaying their goods, as well as by parking. As a result, most of these roads are extensively occupied by on-street activities. AMC has provided designated off-street parking spaces at Gheekanta, Lal Darwaja, Riverfront and Sarangpur. However, there is a significant demand for parking and lack of enforcement has led to unauthorised parking in the core area.

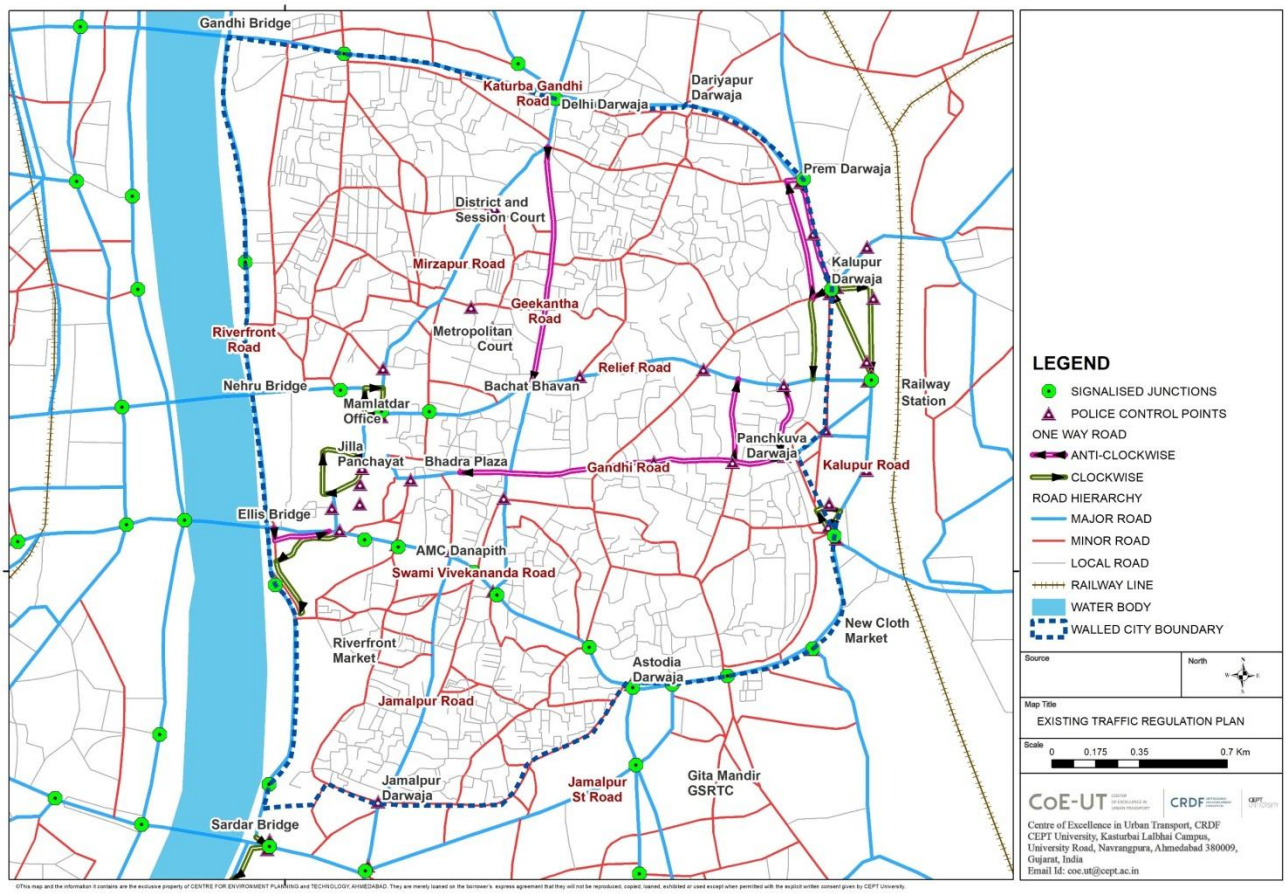


Figure 3-31 Signalised Junctions and Police Check Points in the Walled City

Source: Ahmedabad Traffic Police (2024)

The movement of heavy goods vehicles (HCVs) is regulated within the city between 8 am and 11 pm, whereas HCVs carrying daily essentials are allowed between 1 pm to 4 pm. However, it is the goods vehicles in the walled city of Ahmedabad have become a significant concern, according to site observation and discussions with residents. Despite regulations on entry restriction on HCVs, violations have been frequently observed during the day. These unauthorised movements disrupt the flow of regular traffic and public transport, especially in critical areas like Jamalpur, which houses the APMC market. The Jamalpur Darwaja and Sardar Bridge serve as major access points, while the Swami Vivekananda Road remains open to freight vehicles, causing congestion and traffic conflicts. These issues are compounded by the parking of freight vehicles on narrow streets, often due to the absence of designated parking facilities, which creates bottlenecks and impedes both vehicular and pedestrian movement.

The presence of freight vehicles during restricted hours also adversely affects public transport efficiency by encroaching on essential road space, leading to delays and reduced movement for buses and other modes. Furthermore, the movement and idling of these vehicles generate significant emissions, worsening air quality in the highly populated and densely developed area of the walled city.

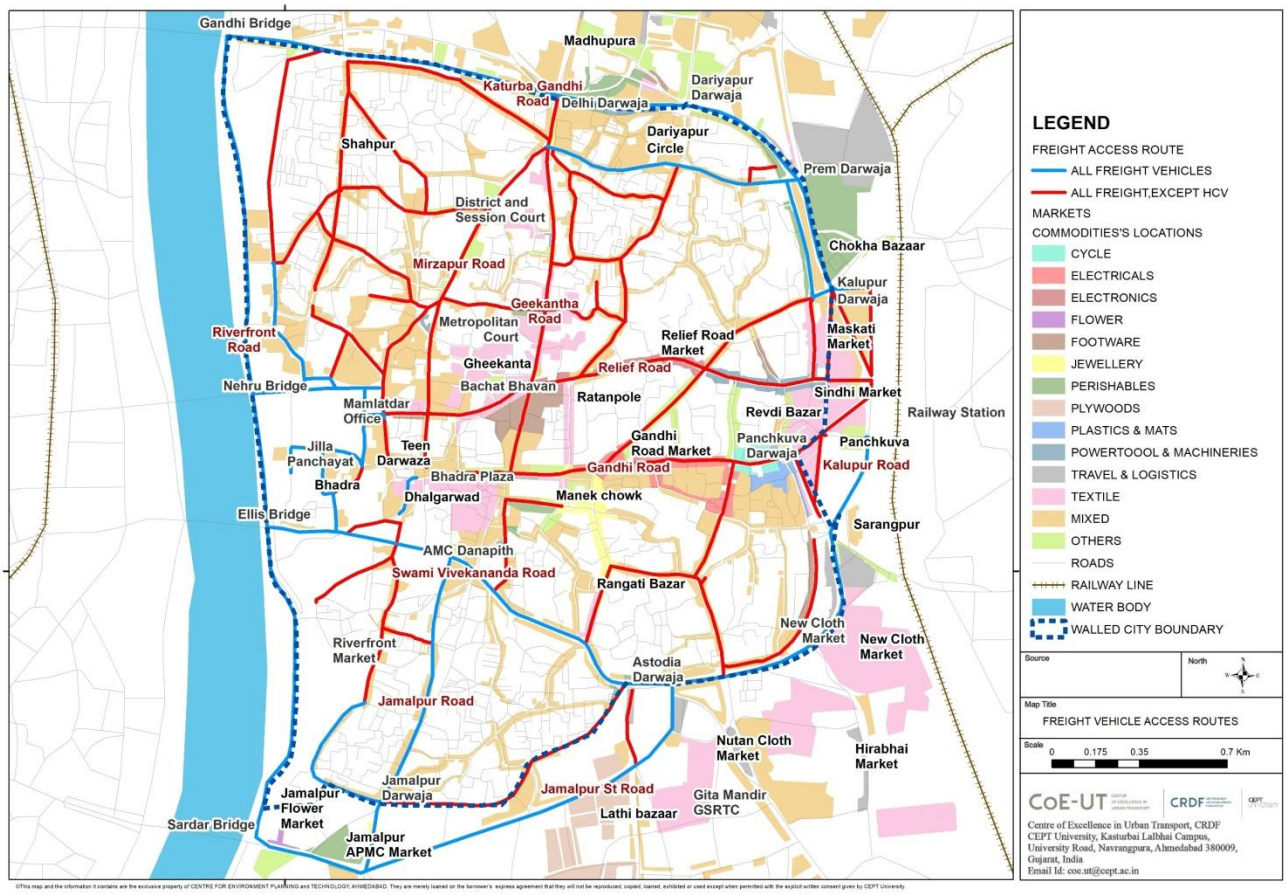


Figure 3-32 Freight Access Routes

Source: Ahmedabad Traffic Police (2024)

3.6.3 Accidents

When comparing the accident rates, 2% of the accidents in AMC happen within the walled city, while the fatality rate stands at 5% in 2020. However, the incident rate is 4.3 per vehicle km travelled within the walled city compared to that of across the entire city is 4.6. Among these, fatal incident rate is 2.13 in the walled city, while it is 1.2 across the city.

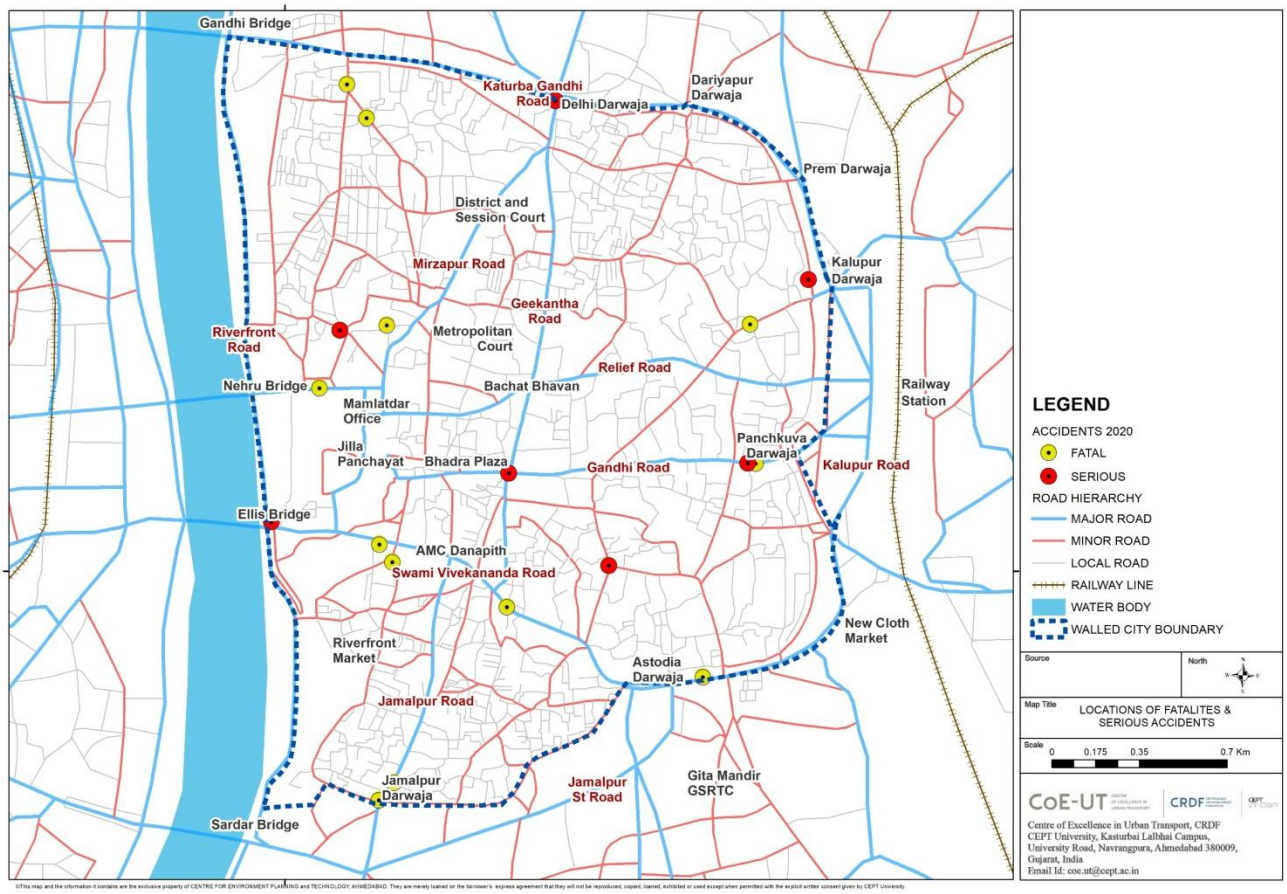


Figure 3-33 Locations of Serious and Fatal Incidents

Source: CoE-UT, CRDF

The fatalities in walled city area have increased in 2020 compared to 2009. In 2020, 15 accidents and 15 fatalities were reported within the walled city. During 2009, 2W users were responsible for a majority of the incidents and pedestrians were mostly affected in terms of fatalities and serious accidents. Now, along with 2Ws, 3Ws and 4Ws are responsible for the majority of the incidents. However, 2W users are impacted along with pedestrians. The share of 2W users being affected has increased from 28% to 50%. Looking at the location of incidents reveals that the accidents occurred on both major and minor roads.

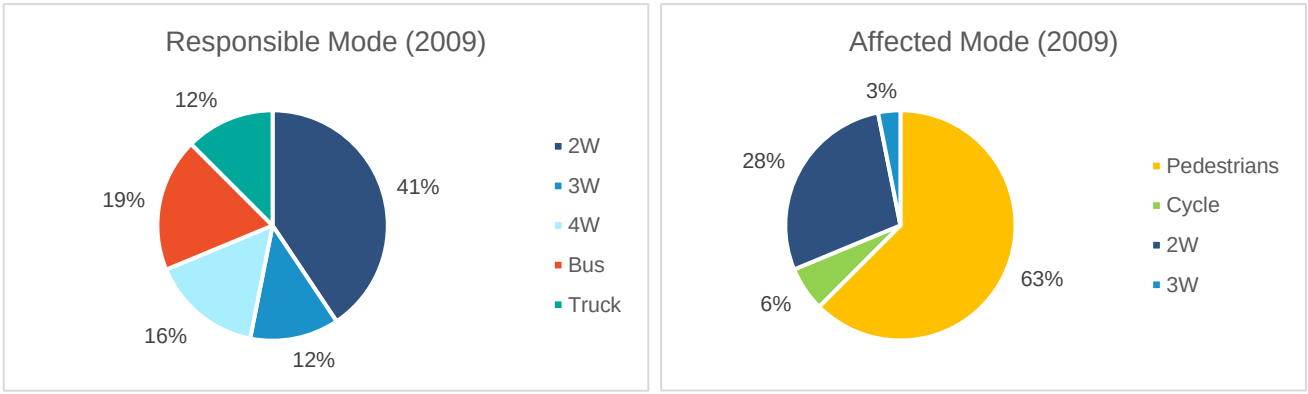


Figure 3-34 Incidents in the Walled City during 2009

Source: CoE-UT, CRDF

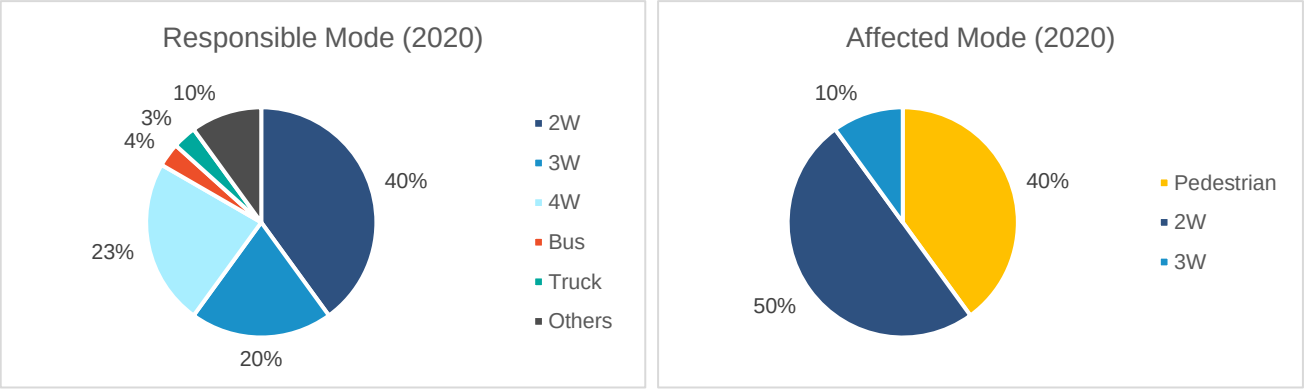


Figure 3-35 Incidents in the Walled City during 2020

Source: CoE-UT, CRDF

3.7 Perception of Residents

To understand the perception of residents of the walled city with respect to their mobility challenges, air quality issues and their awareness about EV, six Focus Group Discussions (FGDs) were conducted at residential neighbourhoods during September and October 2024. A total of six locations were considered for FGDs based on their socio-economic characteristics and proximity to public transport systems. The groups were formed based on the following guiding principles:

- A minimum of 7 to 10 participants per FGD and a few groups with only females to capture their perception.
- FGD participants to be mix of public transport users and non-users to bring out relevant perspectives.
- FGDs to be held in common or public open spaces to ensure neutrality and maximise participation.

The FGDs were conducted in the vernacular language and a semi-structured question checklist (Refer Appendix J) was prepared to note down their views. Ethics consent for photo and videos was taken prior to each meeting. A total of 68 person participated in the FGD, among which 39 were female. In terms of age-group, nearly 50% of them belong to age group of 35-60 years. The details of the neighbourhood are provided in Appendix K.

Table 3-16 List of Neighbourhood

S. No.	Neighbourhood Name	Location	Participants
1	Mahurat Pol	Biscuit Gally Road, Manek Chowk	15
2	Jugaldas Nu Dhelu	Dayanand Road, Sherkotda, Near Raipur Darwaja	11
3	Shahpur Pol	Shahpur Market, Shahpur Road	11
4	Mahalakshmi Pol	Halim Ni Khadki Road, Near Delhi Darwaja	7
5	Ranchod Khadi	Swami Narayan Mandir Road, Dabgarwad Police Chowk	9
6	Jagganath Ni Chhali	MB Kadri Road, Near Jamalpur APMC Market	15
		Total	**68**

Source: CoE-UT, CRDF

3.7.1 Mobility Challenges

Residents in the walled city neighbourhood face significant mobility challenges from high volume of vehicular traffic, parking unavailability and poor public transport connectivity. The walled city has

transformed its majority of residential buildings into commercial spaces which significantly worsen the parking issues, streets are clogged by the vehicles, disrupting residents' mobility and quality of life. Narrow streets and a lack of pedestrian infrastructure exacerbate the problem, making walking unsafe, especially for children and elderly residents. Women depend heavily on 2Ws, while children's school commutes require dependent involvement, highlighting gaps in safe and accessible mobility options.

Public transport options like Bus Rapid Transit System (BRTS) and Ahmedabad Municipal Transport Service (AMTS) buses are often inconvenient, and residents report issues like poor last-mile connectivity, driver misconduct and unsafe conditions. Despite the proximity of metro stations in some areas, access is hindered by unsafe streets, forcing many to rely on 2Ws or shared autorickshaw. In some locations, 3W drivers show reluctance and often refuse to provide service to the walled city during peak hours to avoid driving and frustrations of traffic congestion. Frequent traffic jams impede emergency services like ambulances and fire trucks, leaving residents vulnerable during critical situations. In addition, lack of enforcement of traffic regulations contributes to chaotic conditions in most areas.

The residents highlighted that heavy commercialisation in this area over the years has led to increase in volume of freight traffic throughout the day. Freight traffic significantly contributes to congestion and safety risks in the old city, with frequent loading and unloading of goods obstructing roadways and pedestrian pathways. This increased activity has led to a higher incidence of accidents, like death of three persons during September 2024, and minor accidents are very common.

3.7.2 Air Pollution and Health

Air quality has become a growing concern in the area, primarily due to heavy traffic, industrial emissions and dust from market activities. Residents have reported that 20 years ago the traffic and pollution was very low in this area. They highlighted health issues like dust allergies, respiratory problems like asthma and eye irritation. Some expressed concerns about the worsening air quality over the last four to five years with residents reporting experiencing discomfort, describing a sensation of dust particles in their throat. While the neighbourhoods benefit from a favourable microclimate with abundant trees, these positive effects are offset by emissions from a nearby crematorium and the chemical pollutants from gold workshops, further aggravating the issue. Residents who came from abroad highlighted that the local air pollution was severe, and they share concerns about its impact on their daily lives.

3.7.3 Awareness on Electric Vehicles

Within the neighbourhood, there is awareness about EVs and their environmental benefits. At present in two neighbourhoods, there are few households owning them. However, the community view it as expensive to adopt. Many are reluctant to purchase it due to high cost of purchase and investment in replacing the batteries after four years, which is seen as a poor trade-off compared to fuel savings. In addition, unavailability of charging infrastructure, frequent power cuts during summer and increase electricity charges deterred wider adoption. Despite this, concerns over safety and security such as short circuits during rains, battery theft and reports on EV related accidents and battery explosions has discouraged the residents in purchasing of an EV.

The FGDs highlighted several pressing challenges related to mobility and air quality. The increase in vehicular traffic impact on safety concerns, congestion and air pollution. Inadequate pedestrian infrastructure, poor public transport connectivity, illegal parking and chaotic freight traffic worsens the travel experience of the residents. This has limited the mobility impacting theirs travel routine and social lives. There is a stark contrast between the current mobility and environmental conditions and its past with rapid commercialisation of the locality. The discussion also outlined several financial and safety concerns over EVs, highlighting the importance of sensitising the community regarding the long-term benefits of EVs and awareness of its technology.

(a) Mahurat Pol

(b) Jugaldas Nu Dhelu

(c) Shahpur Pol

(d) Mahalakshmi Pol

(e) Ranchod Khadi

(f) Jagganath Ni Chhali

Figure 3-36 Glimpses of Focus Group Discussions with Residents

Credits: CoE-UT, CRDF

3.8 Air Pollution

The air quality within the walled city of Ahmedabad remains a critical concern, with pollution levels consistently exceeding the safe limits. This deterioration is largely attributed to high volume of passenger and goods vehicle trips, coupled with intensified commercial activities in the area.

3.8.1 Pollution levels in the Walled City

The monitoring station located at Raikhad, within the walled city of Ahmedabad, captures the worst AQI. In 2021, an AQI of 235, which is 15 times higher than WHO standards of 15 ug/m3 of PM2.5, was recorded at Raikhad(44) Analysis of Safar data in 2022 revealed that AQI in three areas of Ahmedabad – Lekawada, Raikhad and Bopal were among the highest in the country marking PM 2.5 levels of 368, 342 and 338 respectively in the evening(45). AQI of 229 was recorded in the walled city during November 2023 with an average indication of 229 PM2.5 and 216 PM10(37). Heavy movement of traffic and construction has contributed to air pollution.

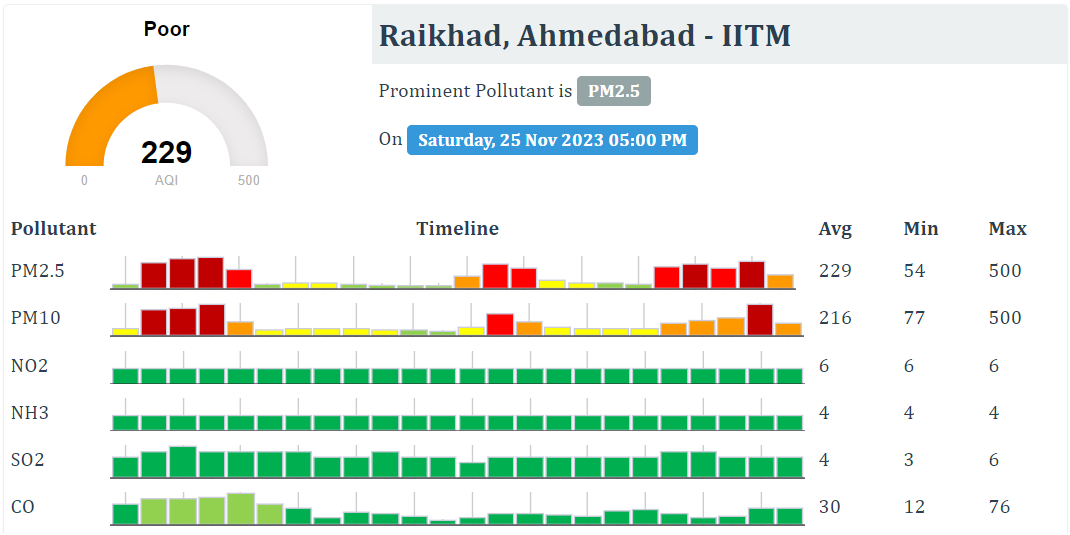


Figure 3-37 Recordings at Raikhad Station in November 2023

Source: National Air Quality Index (37)

The air quality data obtained from the Air Quality Management Cell (AQMC) under AMC presents that within a five km radius of the city, across monitoring stations including Navrangpura, Raikhial, Raikhad, and Maninagar, reveals that Raikhad consistently exhibits the highest daily PM2.5 levels during peak winter and summer periods. From December 2023 to February 2024, Raikhad experienced the highest PM2.5 levels for 50 days. Likewise, in April and May 2024, Raikhad recorded the highest PM2.5 levels for another 50 days. During the summer months, this station located within the walled city had recorded peak values of other pollutants such as PM10, NO, NO2, NOx and SO2. However, during the winter months, the other pollutant majorly recorded in this area is PM10. There are several days when this area falls under the Poor to Very Poor air quality category. Exposure of particulate matter to the high density of population and employees can significantly impact health, particularly to affect the respiratory and cardiovascular systems. A range of health issues from minor irritation to serious conditions can occur among people of the walled city. Hence, reducing exposure to these pollutants is crucial for protecting the public health.

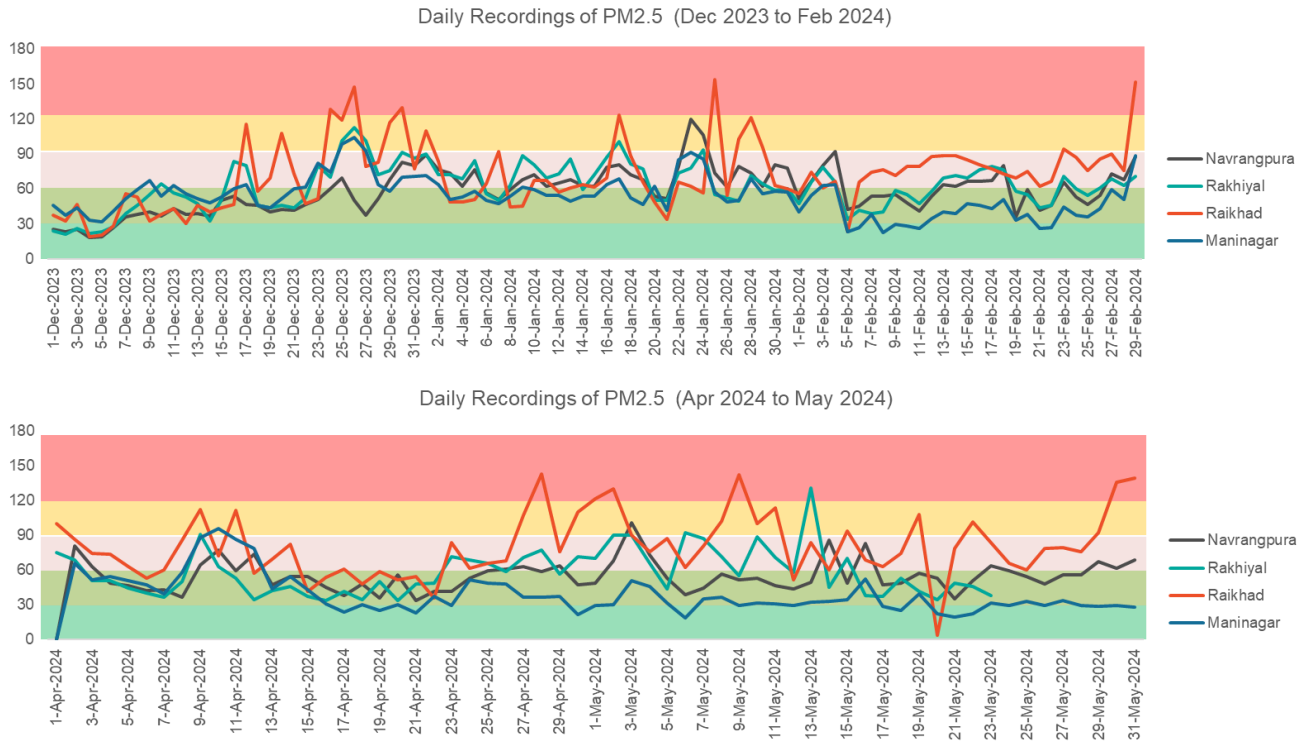


Figure 3-38 Daily Recordings of PM2.5

Source: Air Quality Monitoring Cell, AMC (2024)

3.8.2 Contribution by Vehicles

Air pollution and emissions from passenger traffic were assessed at both the city-wide and walled city levels to compare and comprehend the environmental conditions of the walled city. In addition, goods traffic air pollution and emissions were analysed for the core area. This assessment was conducted using the GHG Emissions Estimation Tool(23) of City Electric Mobility Strategy (CEMS) formulated by the Center of Excellence in Urban Transport (CoEUT), CRDF commissioned by Deutsche Gesellschaft fuer Internationale Zusammenarbeit (GIZ) GmbH and the Ministry of Housing and Urban Affairs (MoHUA), Government of India in 2022. The emission factors considered for this evaluation refers to standards including Automotive Research Association of India (ARAI), Central Pollution Control Board (CPCB) and factors modelled as part of Real-world motor vehicle exhaust emissions by ICCT.

The evaluation indicates that passenger traffic within the walled city contributes nearly 10% of the air pollutants found in the city as a whole. While analysing the impact of air pollutants and emissions per km within the walled city, it is evident that levels of CO, HC, NOx and CO2 are higher than the citywide averages and PM contribution is same as city level. In the walled city, NOx is 0.10 grams per km, compared to 0.07 grams per km across the entire city. Similarly, CO2 emissions are 52.58 grams per km in the walled city, whereas the citywide average is 48.62 grams per km.

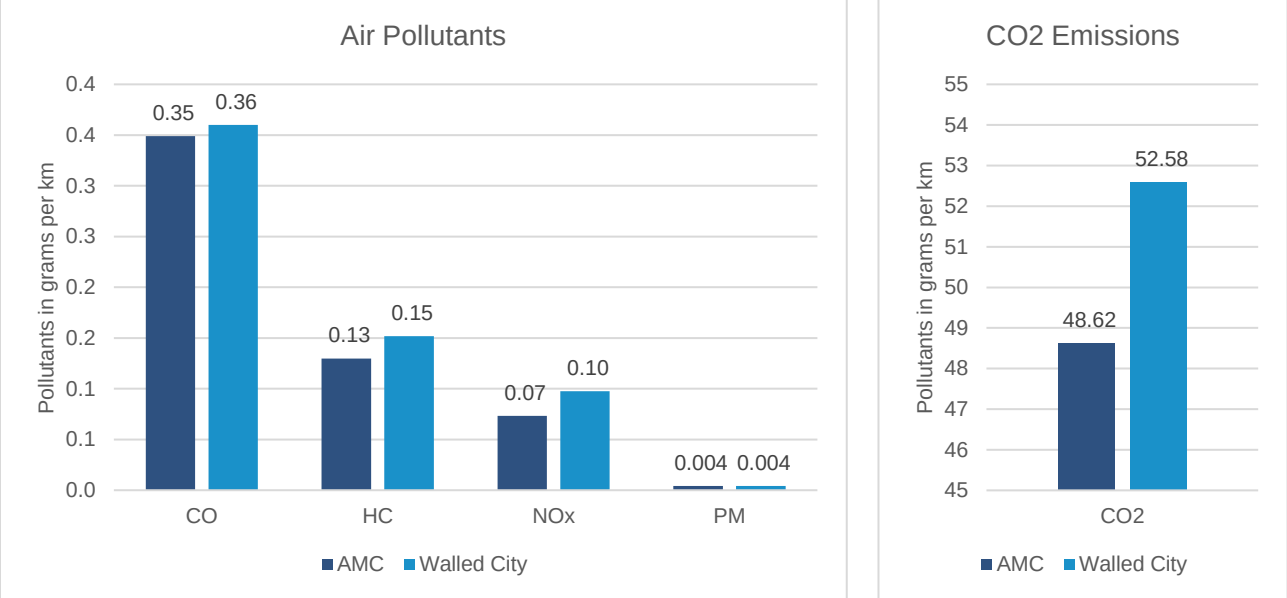


Figure 3-39 Composition of Air Pollutants and Emissions by Passenger Traffic in AMC and Walled City

Source: CoE-UT, CRDF

A comparison of air pollution and emissions by passenger and goods traffic in the walled city reveals distinct pattern. Passenger vehicles, including 2W, 3W, 4W and bus, which dominate 89% of total vehicle km travelled, significantly contribute to air pollution, accounting 60% to 80% of CO, HC, NOx, and CO_2 emissions, highlighting their significant impact. In contrast, goods traffic, comprising 2W, 3W, LCV, MCV and HCV, despite its 11% of vehicle km travelled, stands out to be the primary source of PM emissions, contributing 63%.

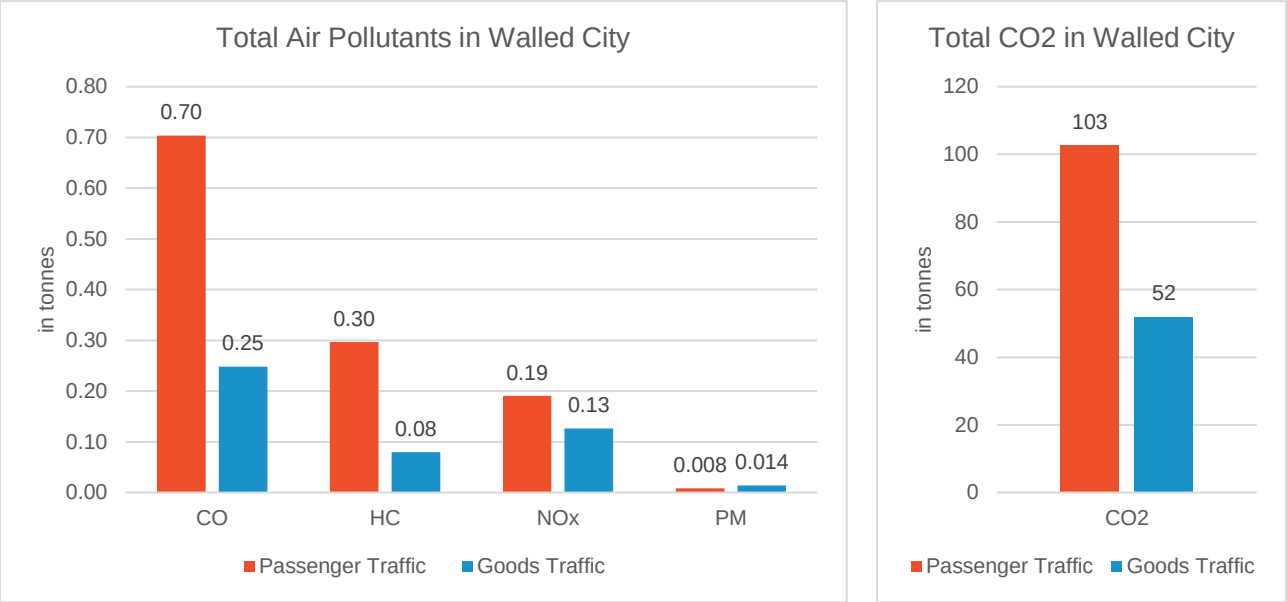


Figure 3-40 Composition of Air Pollutants and Emissions by Passenger and Goods Traffic in the Walled City

Source: CoE-UT, CRDF

However, the data on pollution and emissions per km indicates that goods vehicles emit nearly more than the double CO, HC and CO2 compared to passenger vehicles, comprising petrol, diesel and CNG fuelled vehicles. Alarmingly, their contribution to NOx emission is five times higher, while PM emissions rise steeply to 13 times that of passenger vehicles.

Table 3-17 Pollution and Emissions by Mix of Vehicle Types in grams per km

Contribution in grams per km	CO	HC	NOx	PM	CO2
Passenger Traffic	0.36	0.15	0.10	0.004	52.58
Goods Traffic	0.99	0.32	0.50	0.06	207.20

Source: CoE-UT, CRDF

While examining the contributions by vehicle type among passenger modes, 2Ws emerge as leading contributors accounting for nearly 74% of CO, 74% of HC, 76% of PM and 50% of CO2. Three-wheeler passenger vehicles also add to the pollution mix, contributing 23% of NOx and 13% of PM. While buses contribute 21% of NOx, in terms of goods vehicles, LCVs dominate the emission contribution, which is responsible for very high share of CO, HC and NOx by more than 80%, and PM and CO2 by 60%. This is followed by 3W goods vehicles that contribute 37% of PM and 36% of CO2. These findings highlight that targeted interventions are required to address pollution and emissions across both passenger and goods vehicle categories effectively.

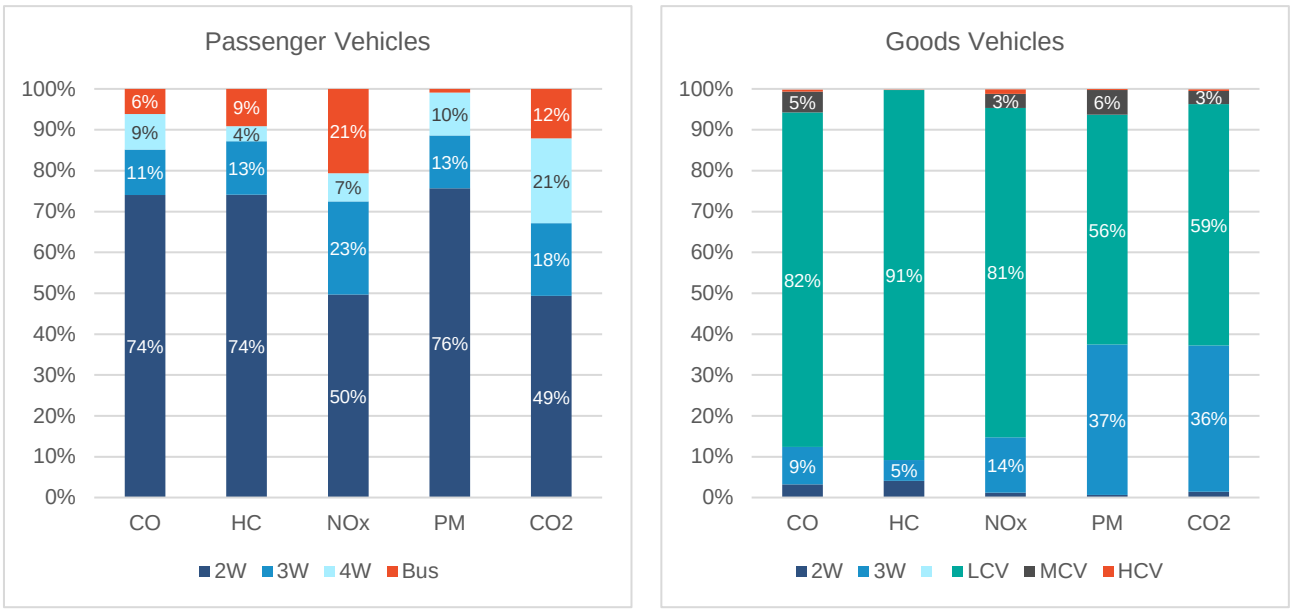


Figure 3-41 Contribution of Air Pollution and Emission by Vehicle Type

Source: CoE-UT, CRDF

3.9 Summary

The walled city of Ahmedabad is a vibrant hub of economic, social and cultural activities, featuring traditional residences, historic monuments, bustling commercial retails, office complexes, wholesale markets and religious sites. This heterogeneous mix of activities depicts 42% of residential land use followed by 17% of mixed-use and 16% of commercial use. However, the high concentration of economic activities in the core area has caused a notable decline in residential population, dropping from 11% of the AMC population in 1991 to 4% in 2021, as residents relocate to newer city areas for an improved quality of life. Those households which remain in the walled city belong to the poorest income group, with nearly 67% of households earning less than INR 20,000 per month. This income level also influences vehicle ownership with 87% of households owning 2Ws as this vehicle is affordable for all, irrespective of their income. Only among 13% of households, is there an ownership of 2Ws, 4Ws and a cycle.

The walled city situated between the Sabarmati River at its west and the railway line at its east is connected well by the roadway systems. The arterial roads that form the backbone of the city run along the periphery of the walled city and traverse through this area to connect the railway station, state transport bus terminal and industrial areas in the east of Ahmedabad. Relief Road and Gandhi Road connecting east-west direction serve as key economic corridors within the walled city. In terms of public transport, its coverage is significant and connects to different parts of the city. Public transport service comprises nine BRTS routes, 117 AMTS routes, three AMTS depots/terminals, three metro stations of east-west line and two regional transport nodes. In addition, 3W operations are predominant with seven autorickshaw stands in the walled city.

Due to the presence of several economic activities and connectivity to the walled city, this area attracts a surfeit of residents and jobs from different parts of the city, generating significant footfall and traffic. The core area accounts for 10% of AMC's employment. In terms of passenger travel characteristics, nearly 72% of trips taking place across the walled city are originating or destined to different parts and 56% of trips take place for work. Two-wheelers are the most used mode of transport, accounting for 42% of trips with an average trip length of 5.4 km. Due to the availability of public transportation and 3W services, people also utilised buses and autorickshaws for commuting. Three-wheeler trips mark 15% of passenger trips and it is 9% for public transport. For travelling within the walled city, people prefer to walk, and it accounts for 63% of the internal trips. The average passenger trip length within the walled city is 4.6 km, indicating that there is a significant potential for a shift to non-motorised modes of transport.

The numerous markets in the walled city function as distribution hubs that deal with of wide range of commodities such as textiles, electronics, vehicles/auto parts, food grains and oil and more. Each market generates significant freight vehicle traffic for receiving and distributing goods both within Ahmedabad and beyond. Over 40% of incoming freight trips are dedicated to textile markets while the remaining trips

involve electronics, vehicle/auto parts, food grains, etc. These specialised wholesale markets heavily rely on 3W goods vehicles for transporting commodities. Nearly 60% of the incoming freight traffic is accounted by 3W goods and this mode ply throughout the day. Based on the trip length, 3Ws and 2Ws account for a 5.5 km trip length. In terms of weight carried, 3W goods carry almost similar tonnage of commodities as LCVs towards the walled city. The predominant locations of arrival of 3W goods are along Relief Road and Gandhi Road.

The traffic mode share reveals the dominance of 3W segment in both passenger and freight movement. The operational characteristics reveals that CNG fuelled passenger 3W operates 80 to 100 km per day and good 3W of various fuel type runs 45 km per day on an average. Majority of the drivers belong to lower income group and earn less than INR 30,000 per month. The vehicles are purchased with the support of loans. While exploring their awareness regarding EV reveals that more than 70% of the drivers are aware of the EV, however, there is a significant knowledge gap in terms of its technology, availability of financial incentives and economic benefits.

The presence of these several commercial units and businesses within the walled city has led to spillage of activities onto the street that reduces the effective right of way and availability of pedestrian pathways. The roads and footpaths are encroachment by shops, street vendors and parking by 2Ws and 3Ws. This significantly compromises the walkability in this area and people are forced to walk on the road along a high incidence of vehicular traffic. Two-wheeler users and pedestrians are the most impacted groups in accidents and fatalities. Although the traffic department has introduced a one-way road system, parking on one side of the road for specific roads and provided off-street parking spaces, these do not resolve traffic and unauthorised parking challenges in the core area.

Discussions with the residents reveals that they face significant mobility challenges due to high volume of vehicular traffic, parking unavailability and poor public transport connectivity. Narrow streets and a lack of pedestrian infrastructure exacerbate the problem, making walking unsafe, especially for children, women and elderly residents, forcing many to rely on 2Ws or shared autorickshaw. Heavy commercialisation over the years has led to increase in volume of freight traffic throughout the day adding to congestion and its activities are obstructing the streets. Residents highlighted worsening of air quality over last four to five years and they experience discomfort and health problems. Yet, many of them are reluctant to purchase EVs due to the high cost, financial and safety concerns.

Moreover, a comparison of the air pollution levels across the walled city with the city-wide figures as well as the frequent highest recordings of PM2.5 indicates the necessity to manage traffic and curb air pollution. Two-wheelers significantly contribute for nearly 74% of 74% of CO, 74% of HC, 76% of PM and 50% of CO_2, and 3Ws emit 23% of NOx and 13% of PM in the core area. In terms of goods vehicles, LCVs dominate the emission contribution, which is responsible for very high share of CO, HC and NOx by more than 80%, and PM and CO_2 by 60%. This is followed by 3W goods vehicles that contribute 37% of PM and 36% of CO_2.

The base situation analysis has helped in understanding the mobility and air quality challenges in the walled city along with the economic importance of this area across the city. To improve the urban liveability, it is important to consider the mobility scope without disrupting the economic activities in the walled city and adopt interventions to reduce the pollutants.

4. Low Emission Zone Plan for Walled City of Ahmedabad

This chapter presents the approach, formulation of scenarios and their assessment, followed by the strategic plan for an LEZ for the walled city of Ahmedabad. The LEZ strategies aim to overcome the traffic and environmental challenges affecting the quality of life of people.

4.1 Approach

The presence of several activities in the core city area such as residential, retail businesses and commodity markets has led to a high volume of traffic movement causing problems such as passenger and goods vehicles conflicts for limited road space, blocking of traffic flow, improper parking, etc. leading to congestion and air pollution. Given the economic strategic importance of the walled city area, the LEZ strategy should ensure that there is minimum disruption to economic activities while addressing environmental concerns in the core area.

LEZ strategies in terms of Avoid-Shift-Improve framework are developed focussing on reducing motorised traffic, shifting towards sustainable transport modes and enhanced vehicles technology. This approach aims to ensure the core area's growth and liveability while adopting measures to attain better air quality.

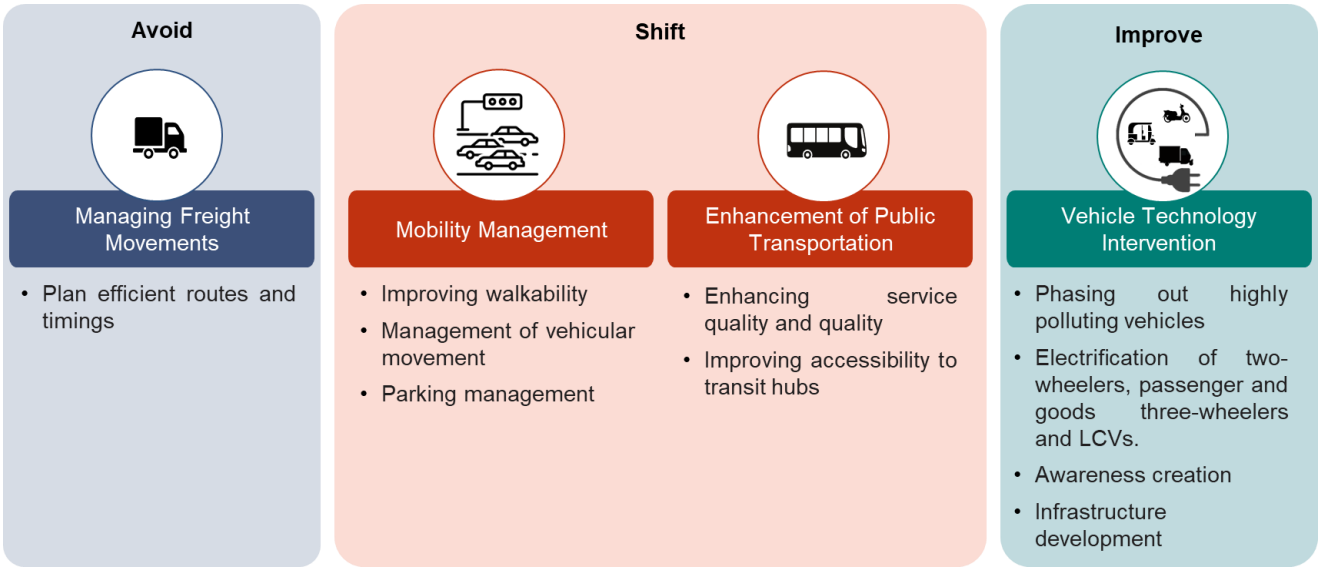


Figure 4-1 Approach for Strategy Development

- **Avoid:** The vehicle traffic data highlights the need for minimising the vehicle-km. The goods vehicles dealing with textiles arrive from warehouses located outside the walled city to the various trade centres within the core area throughout the day. These commodities are packed and further distributed beyond or within Ahmedabad. One-fourth of goods vehicles trips are empty runs. Managing freight movements by planning efficient routes and timings can reduce freight traffic and improve the efficiency in their operations.
- **Shift:** For travelling within the walled city, people prefer to walk, and it accounts for 63% of internal trips. However, pedestrians are the most impacted by road crashes, given the high intensity pedestrian and vehicular movement and the unavailability of safe pedestrian infrastructure. Mobility management plays a vital role to encourage walking by managing the vehicular movement and parking in the core area. In addition, the coverage of the public transport network is significant in the walled city as it marks LOS 1 as per SLB 2019. The people utilise bus service, contributing to 9% of passenger trips. Enhancing the public transportation by improving service quality and addressing accessibility will encourage people to switch to cleaner, more sustainable modes of transport.
- **Improve:** Among passenger traffic, 2Ws are the predominant mode of transportation, which also significantly contribute to air pollution and emissions, it is the 3Ws which are also responsible for this. In terms of goods traffic, LCVs followed by 3W goods dominate in emitting pollutants. Encouraging

transition from conventional fuel to electric variant can reduce emissions and improving the air quality in the walled city to a considerable extent. This complemented by efforts like phasing out highly polluting vehicles, infrastructure development for EVs and awareness creation to support the adoption of cleaner technologies can make the transition smoother.

4.2 Scenario and Assessment Framework

For shaping the trajectory of LEZ implementation, the scenario formulation focusses on a mix of strategies including mobility and clean vehicle technology. Interventions included enhancement of PT, improvement in NMT and electrification of vehicles. To evaluate the combination of strategies, assessment of air quality to reduce harmful pollutants were considered. This scenario development was focussed specifically on passenger modes due to the limitations in historical freight travel data available for the walled city.

4.2.1 Formulation of Scenario

Public Transport and Non-Motorised Transport Scenarios

The mode share of PT and NMT of trips across the walled city has been declining over the past decade. The declining quality of service during this period seems to have impacted the passenger ridership(18). The mode share of public transport has reduced more than half to 9% in comparison to 22% in 2012. In addition, the challenges posed by unsafe streets have significantly discouraged NMT users, leading to a decline in its mode share from 37% in 2012 to 30% in 2022.

Table 4-1 Mode Share of Trips across Walled City during 2012 and 2022

Mode Share	2012	2022
Walk	31%	28%
Cycle	5%	2%
2W	31%	42%
3W	8%	15%
4W	1%	4%
Staff Bus	1%	0.5%
Public Transport	22%	9%
All NMT	37%	30%
All Motorised	63%	70%
Overall	**100%**	**100%**

Source: Household Survey Data 2012 and 2022, CoE-UT, CRDF

The target mode share of the year 2032 was outlined with reference to the Sustainable Urban Mobility Plan for Greater Ahmedabad Region (SUMP) 2041 (17). A 10-year plan was developed for LEZ in Ahmedabad with consideration of intermediate year of SUMP. The Business as Usual (BAU) scenario indicates that over 10 years, the NMT share should decline to 22% and PT could increase to 10%.

The share of captive users that can shift to PT and NMT were identified in terms of mode of travel, distance travelled, vehicle ownership and income levels. This assessment indicated that the improvement in PT and NMT could encourage these captive users and has significant potential to reverse the mode share that is NMT up to 38% and PT up to 20%, close to its 2012 levels. Therefore, two different scenarios were considered for year 2032 with mode share of PT varying from 9% to 20% and NMT from 30% to 38%.

Electrification Scenarios

The next decision pertains to the level of vehicle electrification in passenger mode. Air pollution contribution by 2W is significant in the walled city; however, there is a larger group which lacks confidence in adoption of EV. In addition, electrification of private vehicles is likely to be a time-intensive process while compared to other modes. Prioritising the electrification of PT and IPT vehicles can play a pivotal role in building trust and encouraging the broader adoption of electric private vehicles.

The current electrification of PT is 19% in the city and IPT is negligible. At the national level, India has set a target of 40% of new buses being electric by 2030(46). The Government of India is committed to achieving 30% EV market share among new vehicle sales by 2030 and has projected a sectoral penetration rate of 80% for e-3Ws(47). Considering these targets and pollution contribution by these modes, electrification both PT and IPT by 50% and private vehicles by 10% is evaluated:

Table 4-2 Proposed Scenarios Based on Mobility and Electrification

Scenario	Share	Base Year	BAU	Alternate I	Alternate II
Facilitating shift to sustainable modes	NMT	30%	22%	35%	38%
	PT	9%	10%	10%	20%
Facilitation electrification of vehicles	PT	19%	19%	50%	50%
	IPT	0%	0%	50%	50%
	Private	0%	0%	0%	10%

Source: CoE-UT, CRDF

4.2.2 Assessment Framework

While strategies for sustainable mobility and electrification are important to achieve greener transportation and lower air pollution, it is important to assess which strategy has a more significant impact.

Assessment of Air Pollution and GHG Emissions

The GHG Emissions Estimation Tool of CEMS(23) was used to estimate the impact on air pollution and emissions for the year 2032. This tool was used for analysing the effect of the proposed mode share and electrification scenarios. A set of assumptions relating to composition of vehicles by different Bharat Stage technologies, emission factors by different vehicle standards for years up to 2032 (based on various secondary Indian reports) have been used. The tool requires inputs such as mode wise vehicle km travelled and share of vehicle technology and fuel type for the existing and future scenarios. The vehicle km travelled for the business-as-usual (BAU) scenario was computed based on the previous year's trends. Mode shares proposed were then applied to estimate the vehicle km travelled (VKT) for various alternative scenarios. For the assessment, nine scenarios of mode share and electrification are outlined:

Table 4-3 List of Formulated Scenarios

No.	Scenario Name	Description
1	BAU	Business as Usual
2	BAU-A	Mobility shares to continue with Business-as-Usual trend along with electrification of IPT and PT by 50%
3	BAU-B	Mobility shares to continue with Business-as-Usual trend along with electrification of IPT and PT by 50% and private vehicles by 10%
4	Alt1	Improvement in NMT Infrastructure and Facilities
5	Alt1-A	Improvement in NMT Infrastructure and Facilities along with electrification of IPT and PT by 50%

6	Alt1-B	Improvement in NMT Infrastructure and Facilities along with electrification of IPT and PT by 50% and private vehicles by 10%
7	Alt2	Enhancement of Public Transport Service
8	Alt2-A	Enhancement of Public Transport Service along with electrification of IPT and PT by 50%
9	Alt2-B	Enhancement of Public Transport Service along with electrification of IPT and PT by 50% and private vehicles by 10%

Source: CoE-UT, CRDF

Assessment indicates that electrification of vehicles has impact but only up to 18% of air pollution reduction on an average over 10 years compared to business as usual scenario; whereas PT and NMT improvement alone can reduce pollutants up to an average of 27%. Further, there is a significant impact of 43% pollution reduction with these three interventions. Refer Appendix L for pollutant wise reduction.

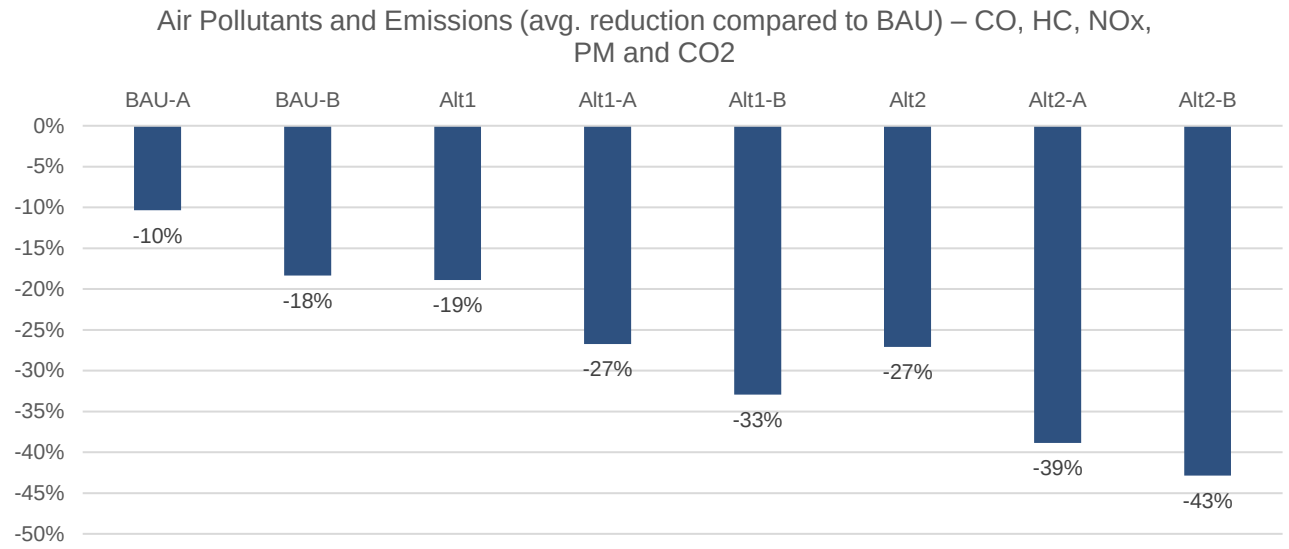


Figure 4-2 An average reduction in Air Pollutants and Emissions compared to BAU scenario

Source: CoE-UT, CRDF

The comparison of scenarios reveals that enhancing public transport and promoting NMT can result in a far more substantial reduction in pollution than solely relying on vehicle electrification. While electrification of vehicles plays an important role in cutting pollutants, the combined impact offers transformative improvement in overall air quality and urban mobility.

4.3 Stakeholder Consultation

To formulate LEZ for the walled city of Ahmedabad, knowledge exchange programmes were conducted with city officials and mobility experts to discuss the approach and identify feasible strategies, gain their inputs and to make recommendations. Workshops were conducted to inform advisory group members about Low Emission Zone and for awareness creation among local stakeholders on electric three-wheelers.

4.3.1 Workshop on Low Emission Zone for Ahmedabad

A workshop was organised for Advisory Group members of this project on the Low Emission Zone on September 9, 2024, at Ahmedabad Municipal Corporation, Gujarat. The workshop brought experts involved in the planning and implementation of LEZ in international and national cities to share their learnings and facilitate discussion among the key stakeholders to identify feasible strategies for the walled city of Ahmedabad. The event centred on defining LEZs in the Indian context that opened to a moderated

discussion to identify actionable strategies tailored to the challenges of the core area of Ahmedabad. The collaborative effort highlighted solutions such as integrated efforts to redesign streets, effectively manage traffic and parking in the core area, and push for the electrification of vehicles. The recommendations from the event served as a foundation for plotting strategy development for LEZs in Ahmedabad.

Figure 4-3 Glimpses of Workshop with Advisory Group on September 9, 2024

Credits: CoE-UT, CRDF

4.3.2 Awareness Workshop on Electrification of Vehicles for Stakeholders

An awareness workshop on e-3Ws was conducted for 3W drivers with the support of Ahmedabad Municipal Corporation (AMC), Ahmedabad Traffic Police, Regional Transport Office (RTO), nationalised banks, Original Equipment Manufacturers (OEMs) and 3W Drivers' Associations on October 13, 2024, at CEPT Research and Development Foundation, Ahmedabad, Gujarat. The event brought together about 100 3W drivers, who gained valuable insights from electric 3W owners, bank representatives and OEMs on the benefits, technology, financial incentives and loan options for EV adoption. The exhibition of electric 3W provided drivers with the opportunity to test-drive them, offering a first-hand experience. Awareness workshop drew passenger 3W drivers as they were registered in a formal association, and it was possible to reach and bring them on to a common platform. The drivers were positive about the event. However, it was difficult to gather feedback from all participants due to informal setting. Qualitative feedback was captured from few, and they appreciated the knowledge gained from the workshop.

While passenger three-wheeler drivers were engaged through their formal associations, sensitising goods drivers posed a challenge due to the lack of formal associations for them. To overcome this, FGDs with goods 3W drivers were conducts at four market areas in the walled city with a group of 4 to 6 people. During the discussion, drivers expressed concerns such as the load-carrying capacity as many drivers habitually overload their conventional vehicle to maximise the profit, the inadequacy of charging infrastructure, extended charging time that may affect operations and the high cost of batteries. However, these FGDs allowed informing participants about various goods electric 3W models available in the market, its technological and financial benefits compared to the conventional models in a long term and the city's effort in setting up charging infrastructure across the city.

Figure 4-4 Glimpses of Electric Three-wheeler Awareness Workshop and FGDs

Credits: CoE-UT, CRDF

4.3.3 Roundtable on Standardising Mobility Systems in Core Area of Indian Cities

As part of the 17th Urban Mobility India Conference cum Exhibition 2024, CRDF in collaboration with the Urban Catalysts organised a roundtable on Standardising Mobility Systems in the Core Areas of Indian Cities on October 27, 2024 at Gandhinagar, Gujarat. The roundtable discussion aimed to share evidence and knowledge based on the project and facilitate a discussion with city officials and mobility experts for standardisation of interventions to overcome air quality challenges in the context of core areas of Indian cities.

The roundtable discussion on adopting LEZ in the Indian context brought forward comprehensive strategies and critical considerations for effective implementation. It was emphasised that an area-wide approach was essential to converge fragmented mobility policies and regulations into a unified framework. Social and gender issues emerged as critical factors, with the need to prioritise functionality, accessibility and safety, ensuring equitable access to economic opportunities for women, children and vulnerable communities.

Discouraging the dependency on private vehicles in the core area was highlighted which is a vital step towards sustainability. Integration of IPT with metro and bus systems was recognised as vital for achieving seamless last-mile connectivity. The deployment of electric micro-buses was suggested to reduce reliance on shared 3Ws. The freight movement in core areas was also considered critical and recommendations to electrify freight vehicles and establish a robust charging infrastructure.

The role of a state nodal agency was emphasised to enhance development of charging infrastructure and promote collaborations between EV aggregators and the government. Initiatives like female driving courses and EV technician training programmes were recommended to build capacity and promote inclusivity in the workforce. In addition, remote sensing devices were advocated for monitoring urban emissions. Across the session, the discussion stressed the need for inclusive, sustainable and convergent policies to create effective LEZ s in Indian cities.

Figure 4-5 Glimpses of Roundtable on October 27, 2024

Credits: IUT 2024

4.3.4 Meetings with Advisory Group Members

The members of the advisory group comprising of 10 individuals were engaged during various stages of the project, including workshops and discussions on LEZ strategies. Their involvement has been instrumental in guiding the project, providing insights and serving as a reliable source of information and input. The strategies outlined for the walled city was discussed with advisory group members from Ahmedabad Municipal Corporation (AMC), Ahmedabad Janmarg Limited (AJL), Gujarat Metro Rail Corporation Limited (GMRCL), Regional Transport Office (RTO) and Heritage Department. Meetings were conducted with each organisation for their inputs and comments to finalise the strategic plan. These meetings were held during December 17 to 20, 2024 and January 3, 2025.

The members agreed to the three-pronged strategy of focusing on clean vehicle technology intervention, enhancement of public transport and traffic management. The members had suggested to improve the traffic and parking issues in the walled city. The key recommendation includes developing a holistic wayfinding plan and non-motorised transport plan, conducting parking demand-supply analysis and formulating parking management plan with push and pull measures to manage the demand in the limited area. They supported enhancing pedestrian experience by converting markets into pedestrian-only zones and implementing time-based restrictions for vehicles in select areas. Measures such as high parking charges could adversely impact those trying to earn a private vehicle, sticker-based vehicle access for residents and rerouting traffic near markets and heritage sites and provide circular routes and pick-up and drop-off service were suggested to manage congestion. The members also recommended planning EV charging infrastructure based on demand. In addition, alternative vendor spaces and no-honking zones in residential areas were highlighted to balance mobility and heritage preservation. AMC had expressed interest to carry forward the recommendation for the effective implementation of initiatives.

4.4 LEZ Strategies

The strategy defined for LEZ for Walled City of Ahmedabad includes measures such as clean vehicle technology intervention to limit the usage of conventional vehicles, enhancing public transport service, improving accessibility for pedestrians and transit users and parking management. The members gave a range of suggestions to address traffic and parking challenges in the walled city as discussed in sections 4.4.3 and 4.4.4.

4.4.1 Clean Vehicle Technology Intervention

The passenger and goods vehicles plying across the walled city significantly contribute to the air pollution. To address this issue, it crucial to limit the usage of highly polluting vehicles and promote the usage of electric vehicles. This section discusses the potential measures for implementing clean vehicle technology interventions to mitigate vehicular pollution.

4.4.1.1 Phasing Out Highly Polluting Vehicles

The contribution of air pollution based on vehicle technology indicates that pre-BS VI vehicles contribute more than 70% of the pollutants, comprising passenger and goods vehicles, as per the assessment on air pollution contribution by vehicles.

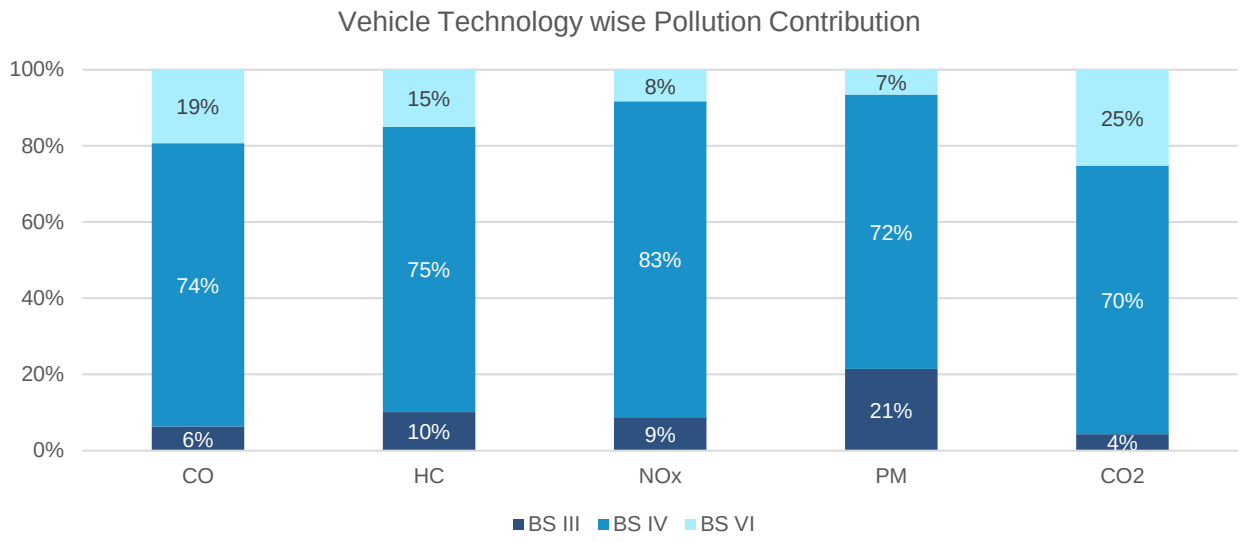


Figure 4-6 Contribution of Air Pollution and Emission by Vehicle Technology

Source: CoE-UT, CRDF

The comparison of emission factors across vehicles including 2W, 3W, 4W and LCVs highlights the significant pollution caused by older vehicle technologies. In terms of NOx pollution, emissions from 2W Petrol BS III are five times higher than that of its BS VI counterpart. Similarly, PM emission from 2W Petrol BS III is 23 times higher than that of its BS VI variant. Diesel fuelled LCV BS III are much worst which contributes up to 33 times the PM of its BS VI variant. Vehicles using technologies that are 19 years or older, such as BS I and BS II, contribute disproportionately higher emissions, further exacerbating air pollution. The comparison across the pollutants and technology indicates that 2W, 3W and LCVs of pre-BS VI technology are highly polluting. Refer Appendix M for the comparison of emission factors across vehicle type, fuel and technology.

It is important to note that the study by the ICCT on Real-world motor vehicle exhaust emissions in Delhi and Gurugram(48) convey that even BS VI vehicles, which are considered to be the cleanest technology, have emissions much higher than the type-approval limits(48). The NOx emissions were poor across the vehicles captured, particularly BS IV CNG private cars is 6.8 times more than its type-approval limits, taxis are 9.4 times, light goods vehicles are 14.1 to 25.6 times depending on its class category(48). The CO emissions was 4.7 times higher than type-approval limit for BS III 2W and 4.1 times for BS III CNG 3W(48).

In Ahmedabad, approximately 0.7 million BS IV vehicles, including 2W, 3W and LCVs, are registered with 90% of 2W Petrol. In addition, nearly 1.3 million BS III vehicles are registered and 0.2 million of BS I and BS II. Despite being over 19 years old—BS I vehicles dating back to post-2000 and BS II vehicles manufactured between 2000 and 2003—these outdated and highly polluting vehicles continue to operate on the city's roads. As part of the Freight Emission Index for the Heritage City of Ahmedabad, a survey of 500 freight operators within the walled city identified one BS I vehicle, three BS II vehicles, and 155 BS III vehicles in use (22). The city lacks effective regulations to phase out older vehicle technologies, and the Pollution Under Control (PUC) certification process does not reject vehicles based on outdated technology, and these high-emission vehicles continue to operate.

Table 4-4 Registration of Target Segment Vehicles in Ahmedabad (Till November 2024)

Implemented Year		2000	2003	2005	2010	2020	Total
Vehicle Type	Fuel Type	BS I	BS II	BS III	BS IV	BS VI	
2W	CNG	5	60	145	3	791	**1,004**
2W	Diesel	2	7	29	1	-	**39**
2W	Petrol	3,410	219,877	1,219,043	651,332	784,298	**2,877,960**
3W	CNG	67	8,244	49,574	42,639	52,705	**153,229**
3W	Diesel	77	4,150	31,645	13,519	9,897	**59,288**
3W	Petrol	9	3,735	22,348	34	-	**26,126**
LCV	CNG	2	105	123	725	7,352	**8,307**
LCV	Diesel	391	3,688	15,959	18,334	15,835	**54,207**
LCV	Petrol	3	42	80	293	1,229	**1,647**
Total		**3,966**	**239,908**	**1,338,946**	**726,880**	**872,107**	**3,181,807**

Source: Parivahan 2024

Recommendations

Given the significant contribution on environment pollution by the older vehicles, it is critical to eliminate the vehicles listed below in the city.

- **Phase Out Pre-BS IV Vehicles:** BS I, II and III vehicles that are 14 years older contribute largely to the air pollution. It is important to phase out these older and highly polluting vehicles.
- **Planning for BS IV Phasing Programme:** The vehicles that are manufactured between 2010 and 2020 (aged between 4 to 14 years), also account for higher than the newer technology variants. A phased programme that gradually eliminate BS IV vehicles should be developed for subsequent years, ensuring a seamless transition to new technology.

4.4.1.2 Electrification of LCV

Transitioning to EVs is a key step toward addressing the challenges pollution in this densely populated urban core. Though the share of LCVs among freight traffic is only 28%, this mode contributes a high share of air pollutants among freight trips, nearly 80%.

Market Assessment: There are six models of electric variant available below 3.5 tonnes. The LCVs operating within the walled city typically cover a maximum distance of up to 150 km, carrying an average payload of 570 kg. The available models are well-suited to these operational characteristics, offering adequate range and also payload capacity, which is similar to the conventional variant. Among the six models, only one model has the central government subsidy. PM e-Drive subsidy, launched during September 2024, includes the electric truck; however, its incentives have not been notified yet. Refer Appendix M for models of e-LCVs.

Financial Feasibility: The starting cost for this vehicle segment is INR 0.65 million, significantly higher than the INR 0.4 million for conventional vehicles. To assess the economics of electric and conventional LCVs, the total cost of ownership (TCO) was computed. TCO considers capital, operational and maintenance cost during the life of the vehicle. The assessment has been undertaken for LCV electric and conventional models with comparable payload capacity. The basic cost of the electric vehicle, comprising vehicle cost inclusive of battery and charger in case of EV and Goods and Services Tax (GST), is 63%

higher than that of its conventional counterpart. Considering FAME II subsidy of INR 0.19 million in the capital cost, this difference reduces, and the on-road price of the electric vehicle is 26% higher than conventional variant, which is nearly INR 0.15 million higher.

Table 4-5 Comparison of Capital Cost of LCVs

Purchase Cost	Conventional LCV	Electric LCV
Basic Cost (Inclusive of GST, Battery and Charger in case of E-3W)	534,000	872,000
Central Government Subsidy	-	190,000
Total Ex-showroom Price	534,000	682,000
Other Charges (Insurance, Registration, HSRP, Road and AMC Tax)	59,555	63,196
Actual (On-Road Price)	**593,555**	**745,196**

Source: COE-UT CRDF

TCO analysis has been undertaken considering daily operation of 80 km for a lifecycle of 10 years with escalated prices based on trend on all cost factors. In 10 years, TCO per km of electric LCV is 10% higher than its ICE counterparts. This increase is primarily due to the substantial vehicle cost, whereas operation cost of electric LCV is 2% cheaper than that of ICE variant.

Table 4-6 Total Cost of Ownership of LCVs

Overall Cost	Conventional LCV	Electric LCV
Total Operational Cost	20,72,556	20,41,270
Operational cost per km	**7.10**	**6.99**
Total Cost of Ownership	36,01,755	39,65,513
TCO per km	**12.33**	**13.58**

Source: COE-UT CRDF

Recommendations

The assessment of electric variant of LCVs reveals a critical gap that limited financial incentive is hindering transition to EV. Even with consideration of the central government subsidy, the e-LCV model is not financially viable.

- **Financial Incentive**: It is important for the government of Gujarat (GoG) to include provision of LCV segment in the state EV policy with considerations. It is crucial to provide subsidies for LCVs to reduce the upfront cost of electric LCV, making it more competitive with ICE variant.

4.4.1.3 Electrification of 3W

Passenger 3W is the primary mode of intermediate public transport comprising 16% of passenger trips which are majorly CNG fuelled vehicles. Goods 3Ws are dominant in the freight activity by 60% of freight trips. Transitioning conventional 3Ws to EVs can significantly reduce pollution in the core areas of our cities.

Market Assessment: There are different models of e-3W goods and passenger vehicles available in the market. These models offer adequate range and payload (for goods vehicle) indicating the suitability to the operational characteristics of 3Ws. The PM e-Drive subsidy by the central government and GoG EV Policy subsidy is available for all the models. The central government subsidy is directly paid to OEMs where GoG subsidy is paid to the 3W operator after the vehicle has been purchased which may take about three to six months to get credited to operators. Refer Appendix M for models of e-3Ws.

Financial Feasibility: The basic cost, comprising vehicle cost inclusive of battery and charger in case of EV and Goods and Services Tax (GST), of e-3W goods is approximately 43% higher than its CNG variants and for e-3W passenger is 45% higher than its conventional counterparts. The central government provides subsidy of INR 37,000 for goods vehicle and INR 50,000 for passenger vehicle, in addition, INR 48,000 subsidy by GoG per vehicle. With the support of this subsidy, the on-road price difference between ICE and e-3W reduces, and passenger are 8 to 9% higher than its CNG variant, which is nearly INR 26,000 to 30,000 more. However, while comparing diesel 3W goods vehicle with its electric counterpart, the on-road price is comparable.

Table 4-7 Comparison of Capital Cost of Goods 3W

Purchase Cost	CNG	EV	Diesel
Basic Cost (Inclusive of GST, Battery and Charger in case of E-3W)	273,663	390,129	302,948
PM e-Drive Subsidy	-	37,000	-
Total Ex-showroom Price	273,663	353,129	302,948
Other Charges (Insurance, Registration, HSRP, Tax)	43,535	44,064	46,452
Total On-Road Price	317,198	397,193	349,400
Government of Gujarat Subsidy	-	50,000	-
Actual (On-Road Price)	**317,198**	**347,193**	**349,400**

Source: COE-UT CRDF

Table 4-8 Comparison of Capital Cost of Passenger 3W

Purchase Cost	CNG	EV
Basic Cost (Inclusive of GST, Battery and Charger in case of E-3W)	281,905	408,837
PM E-Drive Subsidy	-	50,000
Total Ex-showroom Price	281,905	358,837
Other Charges (Insurance, Registration, HSRP, Road Tax)	33,470	31,145
Total On-Road Price	315,375	389,981
Government of Gujarat Subsidy	-	48,000
Actual (On-Road Price)	**315,375**	**341,981**

Source: COE-UT CRDF

For goods 3Ws, the TCO analysis was conducted considering daily operation of 50 km for a lifecycle of 10 years with escalated prices based on trend on all cost factors. In 10 years, TCO of goods e-3W is cheaper to CNG 3W by 18% and 26% than Diesel 3W. The operation cost of e-3W goods is 50% cheaper than its conventional counterparts.

Table 4-9 Total Cost of Ownership for Goods 3W

Vehicle Type	CNG	EV	Diesel

Total Operational Cost	917,120	445,149	1,107,344
Operational cost per km	**5.03**	**2.44**	**6.07**
Total Cost of Ownership	1,759,296	1,436,841	1,950,195
TCO per km	**9.64**	**7.87**	**10.69**

Source: COE-UT CRDF

In terms of passenger 3W, daily operation of 100 km for a lifecycle of 10 years was considered for TCO analysis. The operation cost of e-3W is significantly lower and 70% cheaper than CNG variant. The overall assessment revealed that passenger e-3W is 40% cheaper than its CNG variant.

Table 4-10 Total Cost of Ownership of Passenger 3W

Vehicle Type	CNG	EV
Total Operational Cost	15,28,537	4,20,039
Operational cost per km	**4.19**	**1.15**
Total Cost of Ownership	23,65,401	13,92,977
TCO per km	**6.48**	**3.82**

Source: COE-UT CRDF

The financial assessment indicates significant benefits to the operators or drivers of 3W in terms of income or savings and hence transition to electric 3W seems to be feasible in terms of cost and well as operational characteristics.

Recommendations

Central and state government incentives play a crucial role in accelerating this shift. However, the transformation goes beyond just financial support.

- **Raising awareness:** Designing and conducting awareness programme for drivers of 3W would play an important role in adoption of EVs in the core area. Targeted awareness programmes should focus on educating drivers about the economic and environmental benefits of EVs. The programmes could include workshops, targeted group discussions, demonstration of EVs and testimonials from early adopters. In addition, the presence of stakeholders of the EV ecosystem including city officials, traffic police, RTO, manufacturers and bank representatives would build trust and dispel misconceptions. Such programmes should highlight government incentives, various models available in the market, its technological characteristics, cost savings on fuel and reduced maintenance expenses. Exposure to different models and providing opportunity to test drive allow drivers to experience the performance, comfort and benefits first hand, build confidence in the technology and dispel doubts or misconceptions.
- **Setting up Charging Stations:** The passenger 3W operates maximum up to 120 km per day and goods 3W run up to 80 km per day. The EV provides range from 80 km to 170 km per charge and these vehicles would require access to stations for opportunity charging. However, many drivers may need to operate their vehicle beyond this limit which raises the concern on range anxiety and there is a requirement for setting up charging facility. Establishing charging stations in the locality of IPT stands and high 3W goods movement can further ease the transition to electric vehicle.

4.4.1.4 Electrification of 2W

The passenger transportation is dominated by 2Ws which account for 42% of the trips and are a leading contributor to air pollution up to by 68% on an average. Being private transportation, this is a larger group that needs to be targeted and currently the public confidence is low for adoption of the EV. The

electrification of buses in the city, followed by 3Ws, can serve as a catalyst to sensitise the public and build trust and familiarity on EVs. Complementing this transition, awareness campaigns on benefits of EV and setting up of charging stations will encourage this adoption.

4.4.1.5 Development of Charging Infrastructure

Potential Locations: The trips to establishments generating freight movement are concentrated within the central of the walled city. Refer Appendix O for locations of LCVs and 3W goods trip generators. Out of 41,229 LCV incoming trips, nearly 27% of the trips arrive along Relief Road and Gandhi Road towards Kalupur and Panchkuva Darwaja indicates 27% of incoming trips. Almost 37% of the trips are going to Gheekantha, Pankore Naka, Manek Chowk and Jamalpur.

Out of 87,852 3W goods trips, approximately 35% of the trips are concentrated along Relief Road, Gandhi Road and Dhalgarwad. Another 28% of the trips are directed towards Gheekanta, Manek Chowk and Panchkuva Darwaja. The locations reflect walled city's dominance in accommodating 3W goods and LCVs. In addition, 3W passenger vehicles largely cluster at IPT stands within and along periphery of walled city. These high-demand locations present significant potential for establishing charging infrastructure, supporting the transition to electric mobility while addressing the needs of 3W and LCVs.

Existing Charging Facility: At present, there are two EV charging stations Darwaja in the walled city located along Gandhi Road and near Raipur Darwaja. The Tankshal station along Gandhi Road is an onboard single-plug setup with 3.3 kwh power capacity, designed for slow charging. This type of station established for charging 2W and 3W is financially cheaper and requires no specialised infrastructure such as substations. The second station at Raipur Darwaja operates as a fast-charging facility for 4Ws, developed through public-private partnership (PPP) with a consideration capital investment as it requires substations and substantial space.

AMC has been setting up charging stations across the city to support the EV ecosystem that makes transition of electric mobility more practical for the people. Under its ambitious plan to set up 100 charging stations citywide, 15 stations are already operational which largely caters private vehicles. AMC is implementing these stations through a Public-Private Partnership (PPP) model, ensuring they cater to EVs of various makes, brands, and models. There are two charging station proposed at AMC Danapith and Railway Station. The operators have liberty to install types of chargers for 2W, 3W, 4W or battery swapping rack/station. However, the current charging facility presents some challenges. Most charging stations in the city are designated as either slow or fast charging points catering to specific modes. For example, the charging station at Raipur Darwaja exclusively serves 4Ws, equipped with charging guns but lacking provisions for 3W charging. Given the heavy reliance on 3Ws and LCVs, the limited number of charging stations, combined with their mode-specific focus, risks falling short of the growing demand.

(a) Charging Unit at Tankshals

(b) 4W Charging Station at Naranpura

Figure 4-7 EV Charging Station

Credits: CoE-UT, CRDF

In addition, the charging cost per units is INR 5 at home and whereas, at public charging charges INR 14 to 17 per unit. This cost discourages 3W users to depend on public charging stations as they would have to pay three times higher for charging their EV.

Table 4-11 Comparison of Charging Cost at Home and Public Facility

Parameter	Average VKT	Maximum VKT
Vehicle km travelled	100	200
Additional battery required (kWh)	2.2	10.3
Charging time (mins)	69	321
Charging Cost at home (INR)	**11**	**52**
Charging Cost at public facility (INR)	**37**	**175**

Source: COE-UT CRDF

Recommendations

To accelerate adoption of EV, it is important to set up charging facility for predominant commercial vehicles in the walled city.

- **Setting up Charging Stations:** With respect to availability of open space, the identified high demand locations for 3W and LCVs charging includes existing parking lots, transit hubs and locations with high flow of goods movement. In addition to four charging locations, five strategic locations within the walled city identified for establishing charging facility and they are Lal Darwaja Terminal, Gheekanta Metro Station, Shahpur Metro Station, Manek Chowk and Jamalpur APMC.

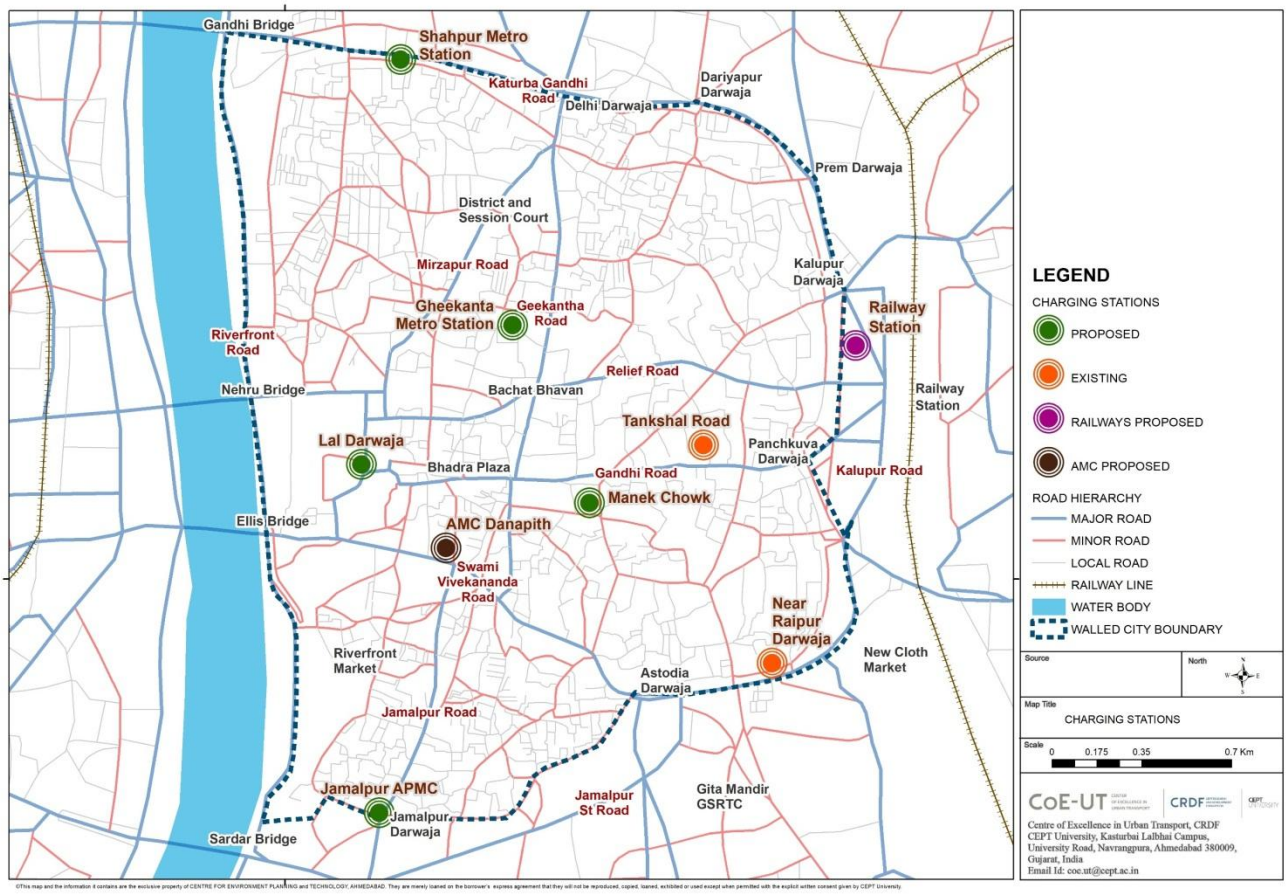


Figure 4-8 Location of Charging Stations

Source: CoE-UT, CRDF

- **Accommodate Interoperable Charging Facility:** The city should be able to adopt hybrid approach for setting up charging facility for both slow and fast charging that can serve both private and

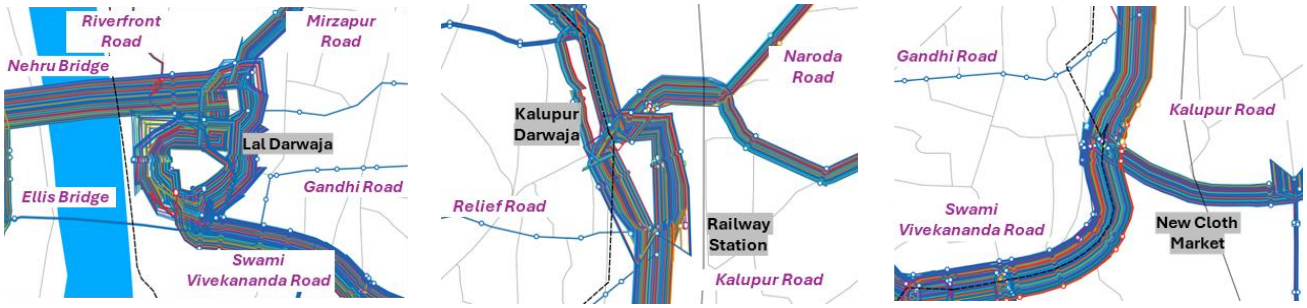
commercial EV users. Development of interoperable public charging facility that can accommodate 2W, 3W and 4W should be explored by the city. Transition to e-LCV is limited at present, the city should consider the future needs of this mode well while planning and implementing interoperable charging facilities.

- **Special Rates for Charging Infrastructure:** The cost of charging at public facility is higher and the city could adopt pricing mechanism with special rates to make it favourable for 3Ws.

4.4.2 Enhancement of Public Transport

AMTS and BRTS provide service across the arterial roads of the walled city and AMTS also operates along inner roads with RoW greater than 12 m. Though 78% of AMTS routes are operating across the walled city and well connected to different parts of the city, the trend of PT share has been declining over the years. The assessment of service quality and accessibility to public transport services was conducted to understand the challenges.

Route Structure: Terminals including Lal Darwaja, Sarangpur and Kalupur operate 84% of AMTS routes, resulting in a centralised route structure. However, as the city expands and new economic nodes emerge, the travel demand across the city has evolved. Despite this, the route structure remains largely outdated with new routes being added to serve emerging areas without modifying the route structure. This has led to overlapping of routes and in cases, underutilised supply. Moreover, from a user perspective, too many routes increase confusion for passengers.



(a) Lal Darwaja (b) Kalupur (c) Sarangpur

Figure 4-9 AMTS Service across the Terminals

Source: Adapted from Sustainable Urban Mobility Plan for Greater Ahmedabad Region, CoE-UT, CRDF (2023)

Service Headways: Passenger wait times are directly impacted by service headways, with longer headways resulting in increased waiting times for commuter. The headways of routes operating across the walled city are depicted in **Error! Reference source not found.**. Only 11% of the routes are high f requency routes and more than 62% of the routes operate with headways greater than 20 min. The coverage of network across the walled city is high, which caters 71% of its population and 66% of its employment within 500 m.

Table 4-12 Distribution of AMTS Routes by Headways

Headways	No. of Routes	Share of Routes
<= 10 min	13	11%
10-15 min	25	21%
15-20 min	17	15%
20-30 min	14	12%
60 min	48	41%

Source: Adapted from Sustainable Urban Mobility Plan for Greater Ahmedabad Region, CoE-UT, CRDF (2023)

Bus Supply: The allocation of buses indicates distribution of buses to meet the demand. It is observed that 534 AMTS buses are operating across the walled city, i.e. 77% of AMTS fleet size. Nearly 26% of

them operate along routes with headways less than 10 min and 23% of buses operate along low frequency routes. Prioritising low-frequency routes without considering the ridership patterns and operational efficiency leads to underutilisation of resources.

Table 4-13 Distribution of AMTS Buses by Headways

Headways	No. of Scheduled Buses	Share of Buses
<= 10 min	139	26%
10-15 min	183	34%
15-20 min	90	17%
20-30 min	55	10%
60 min	67	13%

Source: Adapted from Sustainable Urban Mobility Plan for Greater Ahmedabad Region, CoE-UT, CRDF (2023)

Bus Speed: The average bus speed in the core area of the walled city ranges from 9 to 12 kmph, depending on the route and traffic conditions. Buses operating on the circular route along Relief Road and Gandhi Road, connecting Lal Darwaja and Kalupur (Ahmedabad Railway Station), travel at an average speed of 10 kmph. Buses running from Lal Darwaja to Delhi Darwaja ply at a speed of 12 kmph. Buses along the routes from Lal Darwaja to Jamalpur, operate at an average speed of 11.5 kmph. The BRTS and AMTS route along Swami Vivekananda Road, spanning 2.6 km to Railway Station, has an average speed of 9 kmph. However, it is interesting to note that the inner road from Shahpur Metro to Lal Darwaja, buses travel at a higher average speed of 17 kmph, while the speed of buses from Shahpur to Railway Station, along arterial road, maintains to be 13 kmph. The stretch connecting Delhi Darwaja to Prem Darwaja operates at an average speed of 9 kmph, it could be due to the presence of Perishable Markets. However, buses within the congested walled city often face significant delays due to heavy traffic and narrow streets, leading to unreliable service. These challenges disrupt schedules, reduce overall efficiency, and negatively impact the dependability of public transportation for commuter.

(a) Gandhi Road

(b) Relief Road

Figure 4-10 Bus Operations in Walled City

Credits: CoE-UT, CRDF

Accessibility to Transit Hubs: This area has several transit hubs comprising railway station, GSRTC terminal, metro stations, BRTS and AMTS terminals. Accessibility to the transit hubs were explored by considering Gheekanta Metro station due to its strategic location in the walled city. This metro station is a significant transit hub along the Ahmedabad metro due to its proximity to economic hubs. The station accounts nearly 6% of daily ridership and marks second highest metro station in terms of ridership. Three exits of the station are accessible by walk and public transport with connectivity to nearby landmarks and transit facilities. AMTS is the available bus service near this station and the bus stop is located along Relief Road. The Krishna Cinema bus stop is approximately 100 m away from the Gate 2 of the metro station. This close proximity makes it easy for commuters to transition between metro and bus services. AMTS operates Route 3, a circular route connecting Lal Darwaja and Kalupur terminals and has a scheduled frequency of 15 min during peak hours. However, accessibility assessment to PT service at

this metro station reveals 14 to 18 minutes and it is due to the operation of only one route. In addition, the absence of basic infrastructure, such as bus stops, passenger information and signage, significantly impact user accessibility and convenience.

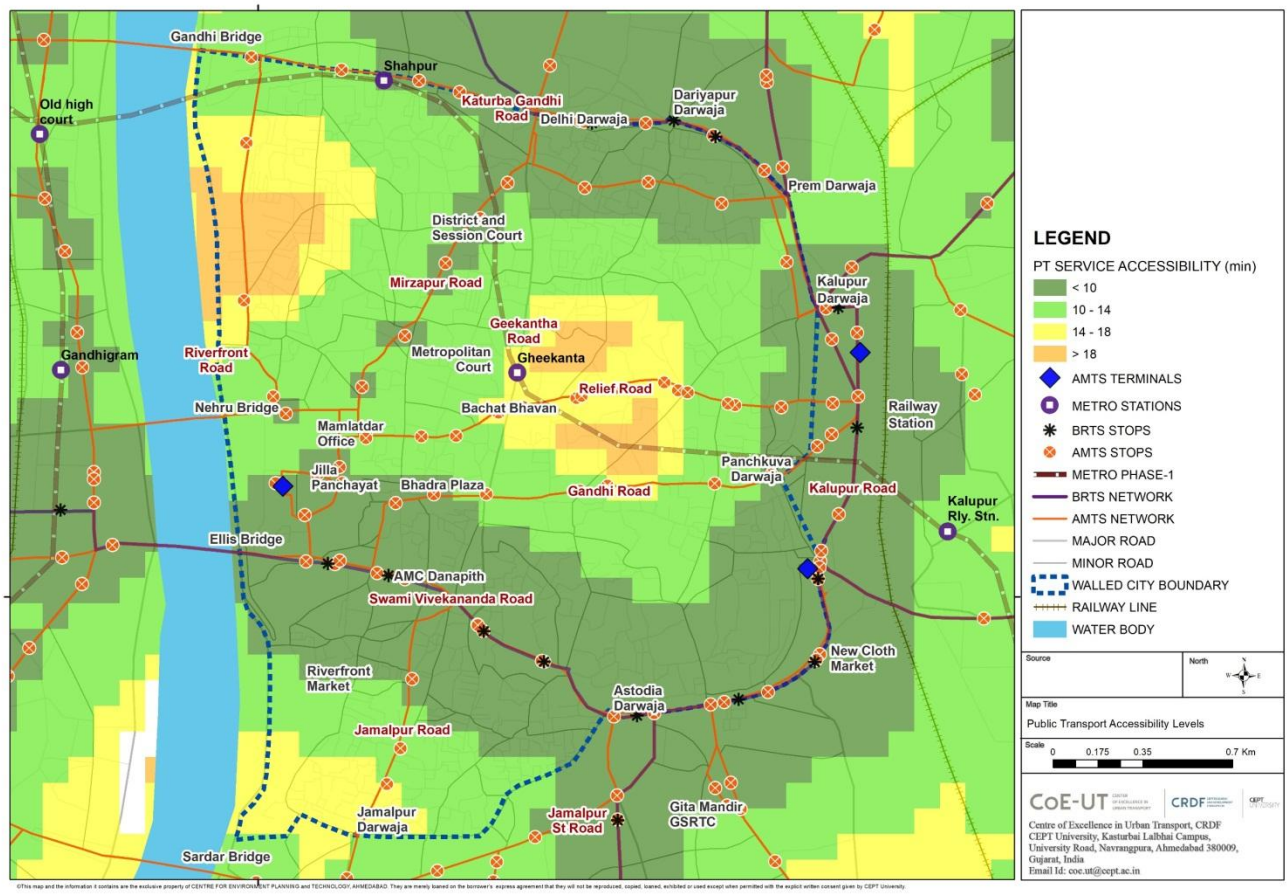


Figure 4-11 Public Transport Service Accessibility

Source: Adapted from UK PACT PT Accessibility Assessment 2022

Recommendations

The city bus service has very low service frequency and reliability due to which people are discouraged to use public transport and depend on private and intermediate transport modes. To encourage shift to public transport, it is essential to enhance the city bus service and accessibility:

- **Rationalisation of Bus Routes:** It is suggested that AMTS route structure be rationalised and consolidated in coordination with the BRTS network. Route overlaps should be minimised by consolidating the routes and measures such as adjusting headways, curtailing underperforming route sections or splitting routes to reduce redundancy.
- **Include Circular Routes:** To cater to the local demand, it is suggested to include circulate routes. These shuttle services would operate across the walled city, providing seamless connections to key transit hubs such as metro stations, bus terminals and railway station.
- **Enhance Fleet Size and Mix:** Increase the fleet size to cater the demand and enhance the fleet mix with electric minibuses (7 m length) to navigate along the narrow streets.
- **Enhancing Accessibility to Transit Hubs:** For seamless interchange, integrated public transport system with unified ticketing systems, real-time information, physical integration, wayfinding information and enhancing waiting areas with essential amenities can improve the commuter experience.

4.4.3 Street Accessibility Improvement

Streets in the walled city are characterised by bustling movement of people as well as vehicles. Achieving sustainable and efficient mobility requires enhancing the flow and accessibility for both vehicles and pedestrians, ensuring a harmonious balance between the two.

Critical Corridors: Across the walled city, 12 stretches of roads play a vital role in facilitating the traffic flow. These roads accommodate both through traffic and trips that originate or end within the walled city, driven by the presence of residential and economic activities. Among these, three roads towards Railway station i.e. Kasturba Gandhi Road (1a), Swami Vivekananda Road (1b) and Jamalpur St. Road (1c) serve as major roads, facilitating the movement of traffic across the East-West and North-South zones within the area. The remaining corridors (2a to 2i) cater majorly to internal and external vehicle movement, catering to localised traffic and connections to the periphery of the walled city. This distribution of traffic highlights the diverse functionality of the road network within the walled city, emphasising the need for targeted management strategies to address both through and localised traffic demands.

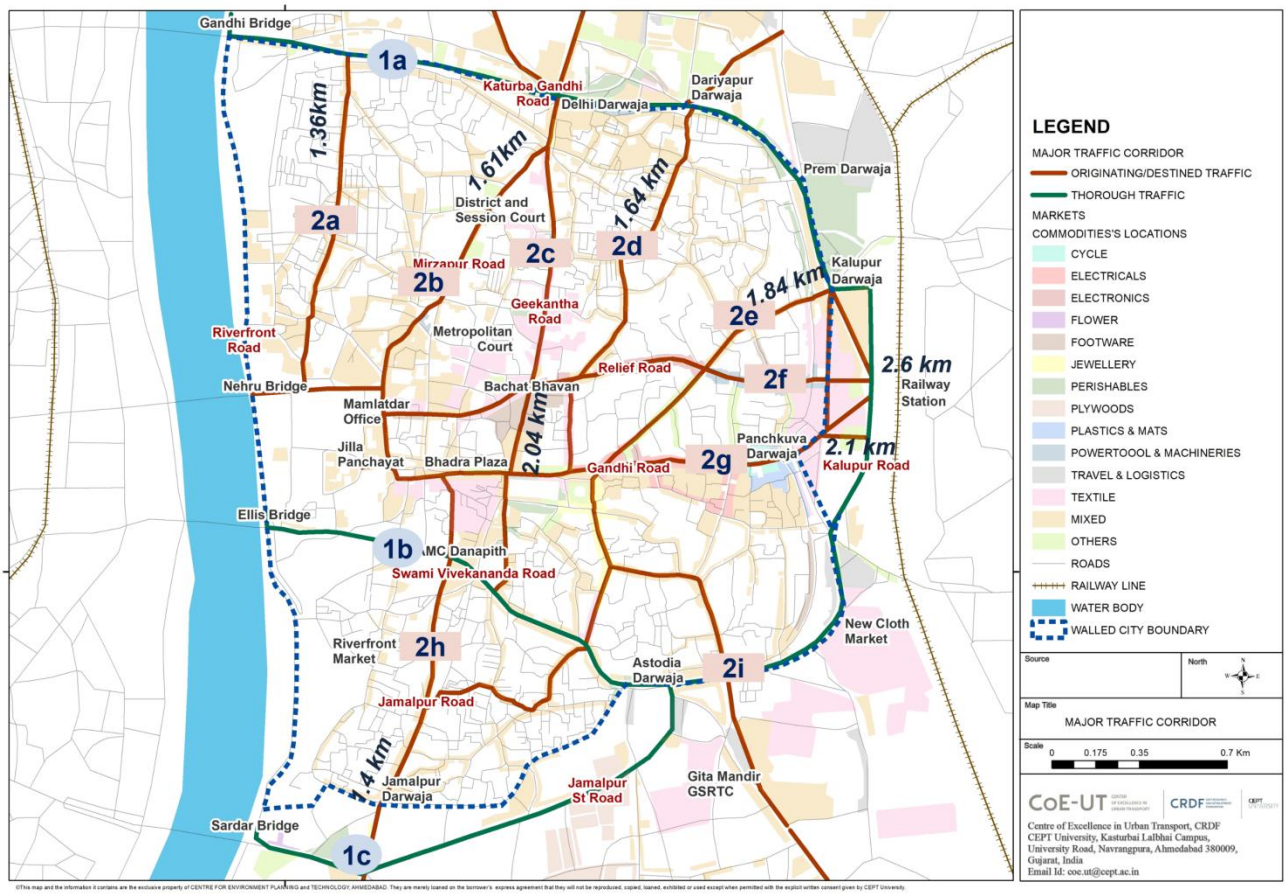


Figure 4-12 Major Traffic Corridors

Source: CoE-UT, CRDF

In addition to the critical traffic corridors, the walled city of Ahmedabad is home to three designated heritage walk routes, each weaving through approximately 2 km of historically rich pathways. These routes highlight ASI monuments and landmarks which narrate the history and culture essence of Ahmedabad. These heritages walks are not just tourist attractions but also vital to preserving the city's legacy. However, their coexistence with the bustling traffic corridors poses unique challenges.

To understand the challenges along these major roads, four corridors out of 12 were considered as critical due to significant amount of vehicle flow and they were studied in terms of land use, economic activities, pedestrian activity and parking. The critical corridors include Mirzapur Road, Relief Road, Jamalpur Road and Swami Vivekananda Road.

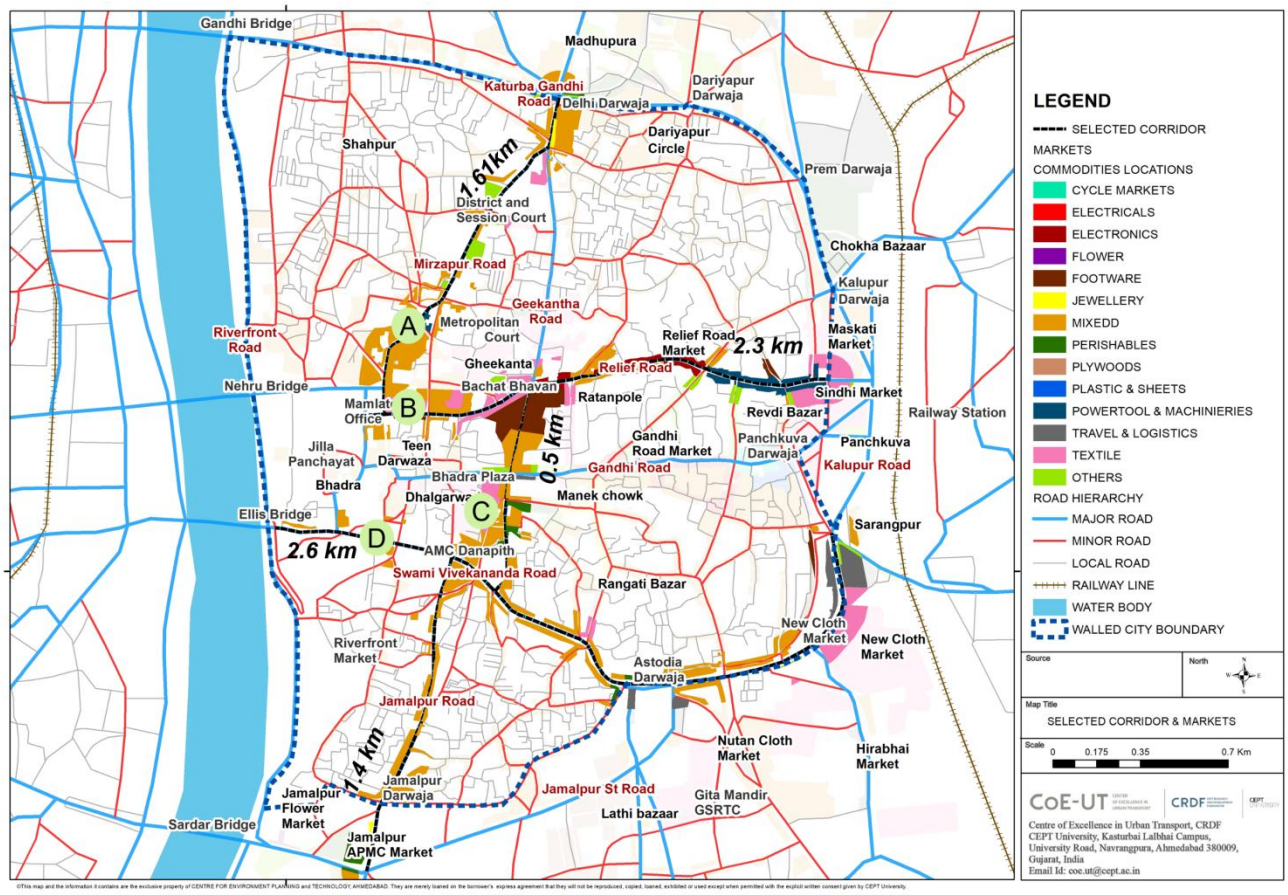


Figure 4-13 Land Use along the Selected Corridors

Source: CoE-UT, CRDF

Vehicle Composition: The selected corridors handle significant share of vehicle volumes. During peak hour, 3,900 Passenger Car Units (PCUs) per direction are recorded along Swami Vivekananda Road. However, the inner roads also handle high vehicle volumes which are merely 15 to 20% less than traffic plying along Swami Vivekananda Road, i.e. along Mirzapur Road peak hour volume is 3,360 PCUs and Jamalpur Road has 3,096 PCUs as peak hour volume. Relief Road, which faces on-street activities and congestion, handles 2,720 PCUs. The vehicle composition along these corridors is dominated by 2Ws as they comprise nearly 60% of the traffic. Passenger 3Ws constitute more than 30% of the total vehicle composition on both Relief and Jamalpur Road. Swami Vivekananda Road and Mirzapur Road, which cater to commercial and institutional activities, witness higher usage of 4Ws. In terms of total trips, the share of pedestrians is notable along inner corridors and accounts for up to 30% of trips along Jamalpur Road.

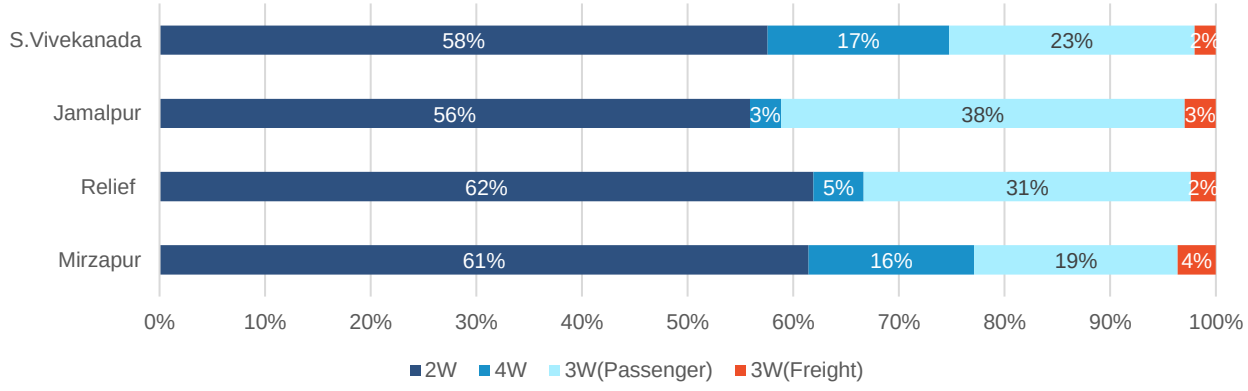


Figure 4-14 Vehicle Composition of Traffic along Selected Corridors

Source: CoE-UT, CRDF

These corridors face significant challenges that hinder efficient traffic flow and safety of road users:

- Encroachments: Vendors and shopkeepers encroach on the road that reduces the space for pedestrians and spillage of activities reduces the effective carriageway which further adds to the congestion. These affect the visual as well as physical accessibility to major economic hubs in the walled city.
- Parking Issues: Lack of organised parking facilities has led to vehicles parking haphazardly along the corridors, disrupting traffic and limiting the carriageway. These corridors, integral to the movement of both internal and external traffic, are currently plagued by parking issues that exacerbate congestion and hinder smooth traffic flow.
- Limited Right of Way (RoW): These corridors which largely serve commercial and mixed-use adjacent lands and are located along several markets. The RoW of Relief Road ranges 12 to 18 m, Mirzapur Road 9 to 26 m, Swami Vivekananda Road by 30 m and Jamalpur Road with 9.5 m lack in insufficient road space due to encroachment and parking issues making it difficult to accommodate the growing volume of traffic.

(a) High share of passenger three-wheeler along Mirzapur Road

(b) Conflict between pedestrians and vehicles along Gheekanta Road

(c) Vehicle traffic along Relief Road

(d) 3W goods to wholesale market in Relief Road

(e) 3W passenger at non-parking zone

(f) Inadeuate pedestrian footpath along Jamalpur Road

Figure 4-15 Glimpses of Vehicle Traffic along Inner Roads

Credits: CoE-UT, CRDF

Recommendations

To address the mobility challenges in the dense core of the walled city, interventions that enhance the accessibility are essential.

- **Adopt Complete Streets**: The city should prioritise the implementation of complete streets, which is an approach that requires streets to be planned, designed, operated and maintained to enable safe, convenient and comfortable travel and access for all users regardless of their mode of transport.
- **Restrict Entry of 4Ws:** It is suggested to restrict the entry of 4Ws on narrow roads (RoW ≤ 9 m) during peak hours. The entry restriction duration shall be explored based the operation of commercial activities along narrow streets. Strict enforcement mechanisms, including fines for violations, will ensure compliance.
- **Special Sticker Permit:** A special sticker permit system can be introduced for 4W of residents to access restricted areas during restricted hours. This system will help balance the needs of local residents while maintaining overall traffic control and reducing vehicular movement.

4.4.4 Parking Management

Existing Parking Facilities: The parking facilities are managed by AMC as well as private entities. AMC offers on-street as well as off-street parking including open plots and multi-level parking. Private entity parking is present majorly along Relief Road and it is underground parking which are restricted to the residents and shop owners. AMC provides both paid and unpaid parking facilities. For paid parking, the current fee structure includes a nominal charge of INR 5–10 for 2Ws and INR 20 for 4Ws.

(a) AMC Parking at Manek Chowk

(b) Private Parking at Relief Road

Figure 4-16 Parking Facilities in Walled City

Credits: CoE-UT, CRDF

High Parking Demand: Dedicated parking spaces have been designated at specific locations along the corridors. However, the demand for parking exceeds the available capacity, resulting in vehicles being parked outside the allocated spaces. Gheekanta Road, Relief Road and Gandhi Road are occupied more than 80% of its length. Gheekanta Road has highest share of parking coverage with 91% of its length. Swami Vivekananda Road which spans 2.3 km is occupied by vehicles for approximately 60% of the total length. Similarly, Jamalpur Road which is 1.4 km long, 69% is encroached upon. Relief Road has parking of 82% of its 2.6 km length, which includes designated parking space. However, parking in undefined spaces reduces the effective carriageway, obstructs pedestrian pathways and contributes to traffic congestion. On roads with the bus operations, this issue further compounds the problem by slowing down bus speeds, disrupting schedules, and diminishing the efficiency of public transport services.

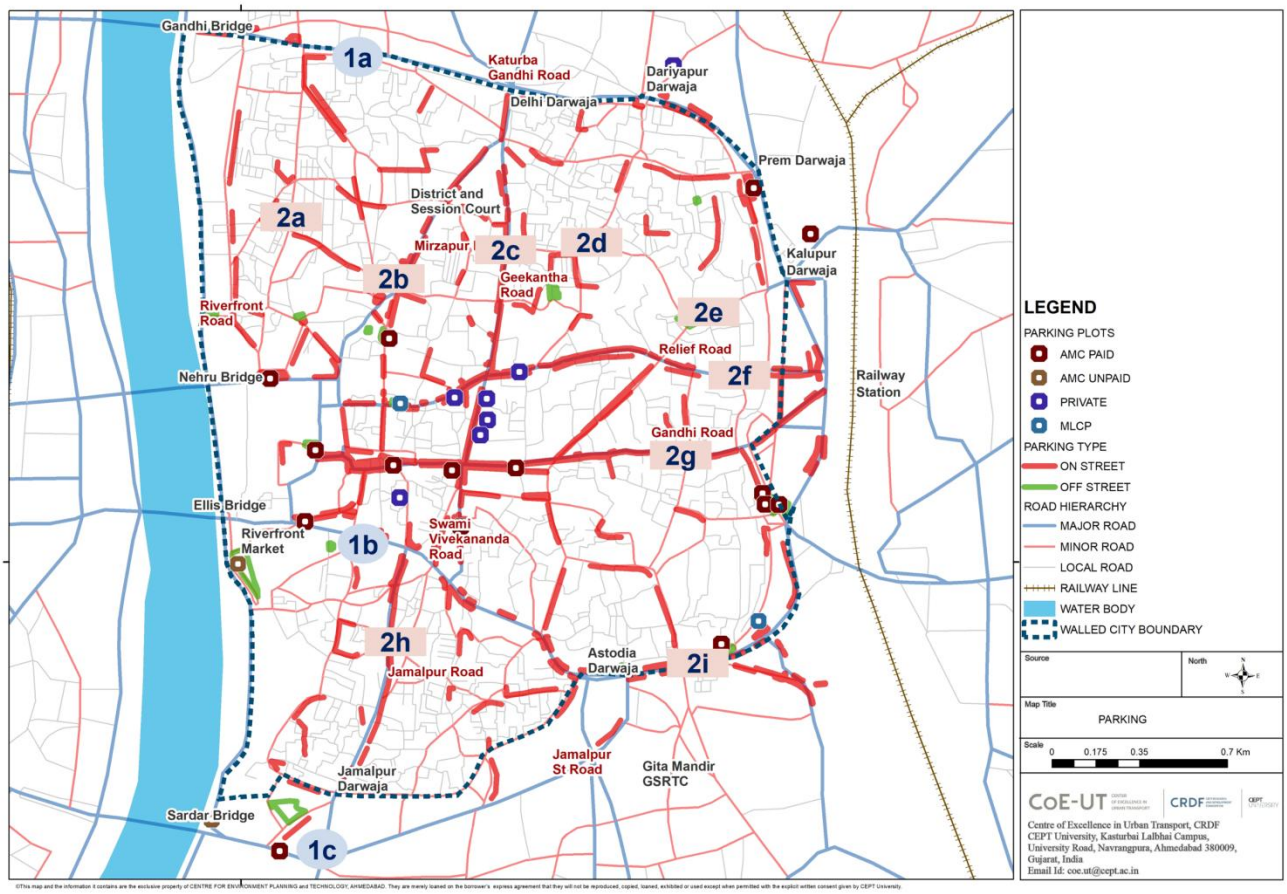


Figure 4-17 Parking along the Major Corridors

Source: CoE-UT, CRDF

Table 4-14 Characteristics of Major Traffic Corridor

Corridor	RoW (m)	Total Length (km)	Length of road by parking (%)	Bus Route	Land Use
1a	24-30	5.3	43%	Yes	
1b	24-30	2.32	60%	Yes	
1c	24-30	2.06	53%	Yes	
2a	12-18	1.36	22%	Yes	
2b	9-12	1.61	65%	Yes	
2c	3-9	2.00	91%	No	
2d	3-9	1.64	30%	No	
2e	3-9	1.84	64%	No	
2f	12-18	2.6	82%	Yes	
2g	9-12 /12-18	2.1	86%	Yes	
2h	9-12	1.4	69%	Yes	
2i	3-9	1.72	35%	No	

Commercial Institutional Mixed Use Residential

Source: CoE-UT, CRDF

Across the selected four corridors, the stretch is utilised for parking of 2Ws, 3Ws and 4Ws. More than 60% of the road length is occupied by 2Ws. Nearly 20% to 30% of road length is occupied by 3Ws, which largely includes passenger 3Ws. 4W parking are noticed on roads along commercial and institutional activities. This issue is consistent along all critical roads in the walled city. With the roads constrained in terms of road width, parking of 4Ws and also 3W at undefined area leads to further restricting the narrow carriageways, creating bottlenecks in traffic flow.

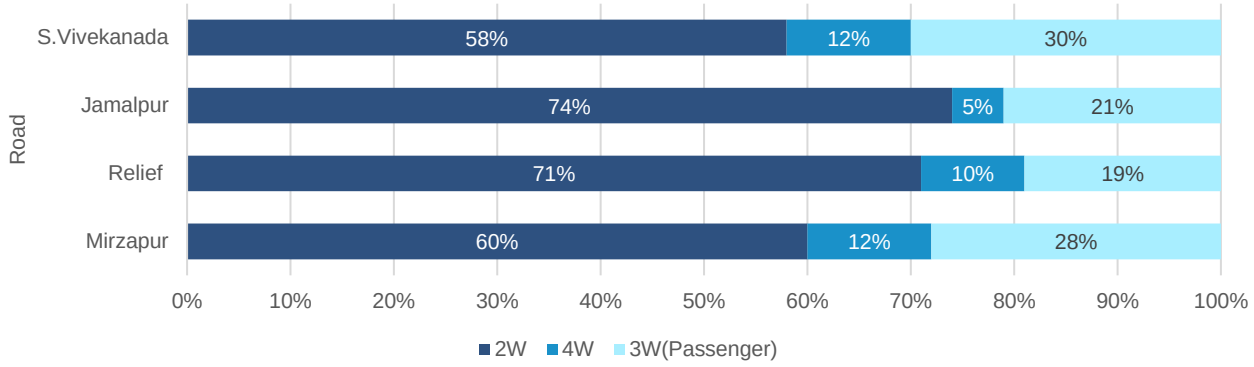


Figure 4-18 Composition of Vehicles Parked along Select Corridors

Source: CoE-UT, CRDF

(a) Four-wheeler Encroachment along Gheekanta Road

(b) Illegal Parking along Relief Road

Figure 4-19 Parking Issues in Walled City

Credits: CoE-UT, CRDF

Recommendations

The encroachment of road space by parking has resulted in reduction of effective carriageway, contributing to congestion. To ensure smooth movement of both vehicles and pedestrians, it is essential to manage parking.

- **Define Three-wheeler Stands:** Allocate defined space for 3Ws near high demand areas like transit hubs and markets. Ensure stands are well-integrated with public transport system for multimodal transfers. Use clear signages and ground markings for visibility and organised parking.
- **Restricting 4W Parking:** Designate no-parking for 4Ws along congested streets (Relief Road, Pir Mohd. Shah Road and Gheekanta Road). Define the street with clear signages and supported by enforcement with fines or towing for violations.
- **Limit On-street Parking:** Define existing on-street parking with clear signage and enforce strictly. Encourage private entities to develop parking space. Graduated parking charges should be designed to prioritise short-term parking along roads near markets and institutional buildings while discouraging long-term parking. This could be facilitated by time-based pricing, instead of flat rates, and adoption of dynamic pricing in future.

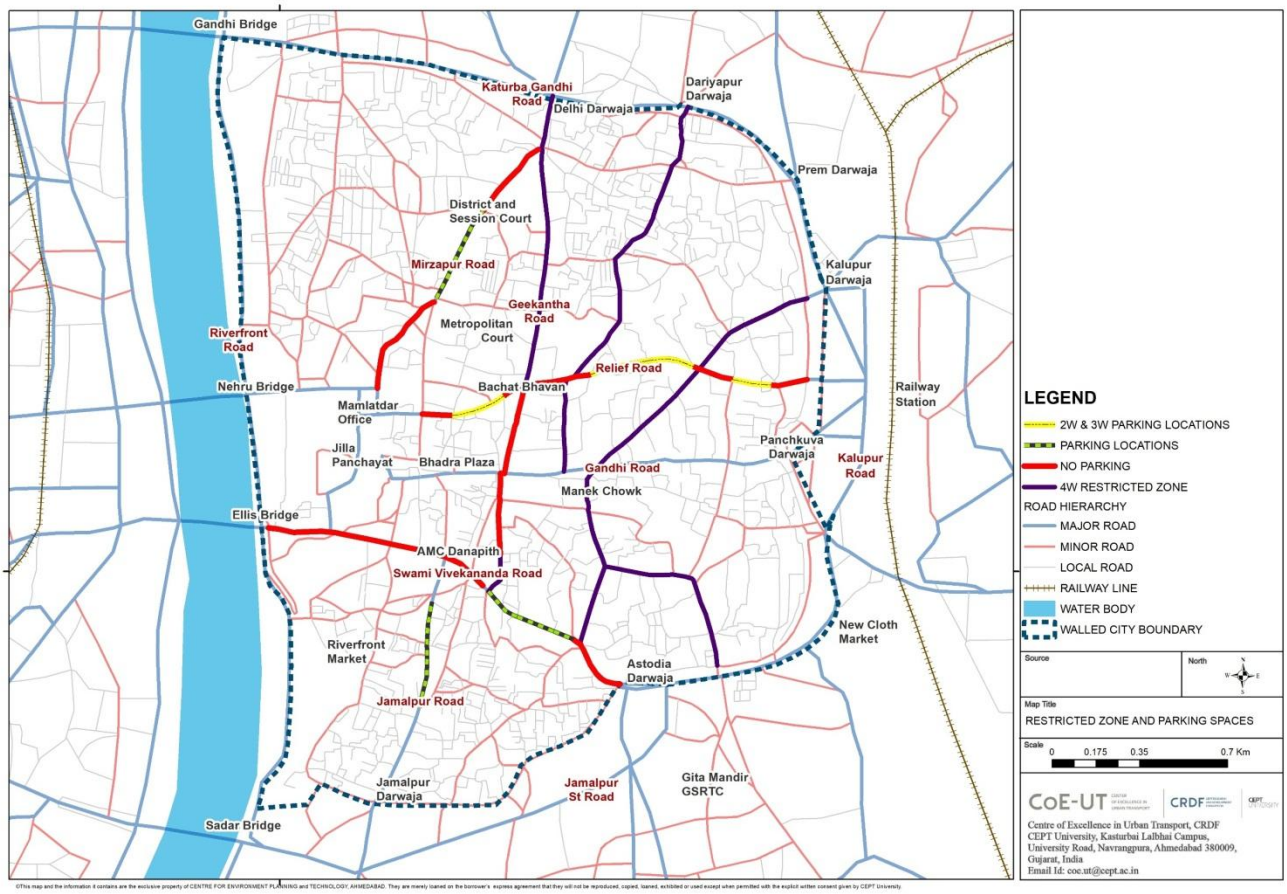


Figure 4-20 Restricted Zones & Parking Locations

Source: CoE-UT, CRDF

4.4.5 Pedestrianisation of Streets

The walled city of Ahmedabad, particularly its inner area, faces significant challenges in terms of pedestrian safety and convenience. The streets with high pedestrian footfall face several issues due to the presence of multiple activities and vehicle movement that hinder pedestrian movement. These issues not only compromise pedestrian safety but also degrade the overall urban environment.

(a) Pankor Naka

(b) Jamalpur Road

Figure 4-21 Streets with High Pedestrian Movements

Credits: CoE-UT, CRDF

- Parking: It is observed that a large share of shopkeepers involved in market use personal vehicles for daily operations, including transportation of goods. These vehicles are often parked in front of their shops which hinder the pedestrian space. In terms of 3Ws, they are present largely at entry and exit of

major streets and parked at these locations which add to the congestion and have high nuisance value for both pedestrians and other users.

- Shop Spill overs and Loading/Unloading Activities: Shopkeepers often encroach upon the footpaths, displaying goods and conducting business in public spaces. In addition, absence of dedicated loading and unloading space for freight activities further disrupts pedestrian movement, particularly during peak hours.
- Vehicular movement: Streets like Teen Darwaja, Pankore Naka, Dhalgarward, Ratanpol, Manek Chowk and Sindhi Market experience high pedestrian volumes. However, the absence of regulations on vehicle movement along these streets creates frequent conflicts between pedestrians and vehicles, raising significant safety concerns for road users.

(a) Jamalpur Road (b) Gandhi Road (c) Gheekanta Road

Figure 4-22 Conflict between Pedestrians and Vehicles

Credits: CoE-UT, CRDF

Recommendations

To address these issues a multi-faceted approach focussing on pedestrian safety, space management, and regulatory enforcement is essential and strategies include:

- **Transforming Key Markets into Pedestrian Streets:** Streets which handle high pedestrian movement (Teen Darwaja, Pankore Naka, Dhalgarward, Ratanpol, Manek Chowk and Sindhi Market) could be transformed to pedestrian-only zones during the operation hours of market. The restrict time to be explored needs to be specific to each market. This effort could restrict the entry of vehicular traffic and ensure safe and smooth movement for all users, including vulnerable groups such as children and the elderly.
- **Regulated Vehicular Access:** To accommodate the operational needs of the establishments, a regulated time system to be implemented which allow freight vehicles to access these markets during designated time slots. This system can allocate specific windows — preferably one hour each in the morning and evening outside peak traffic hours — for loading and unloading goods, ensuring minimal disruption to overall traffic flow. However, buses and 3Ws must be allowed to operate along Gandhi Road to provide connectivity.

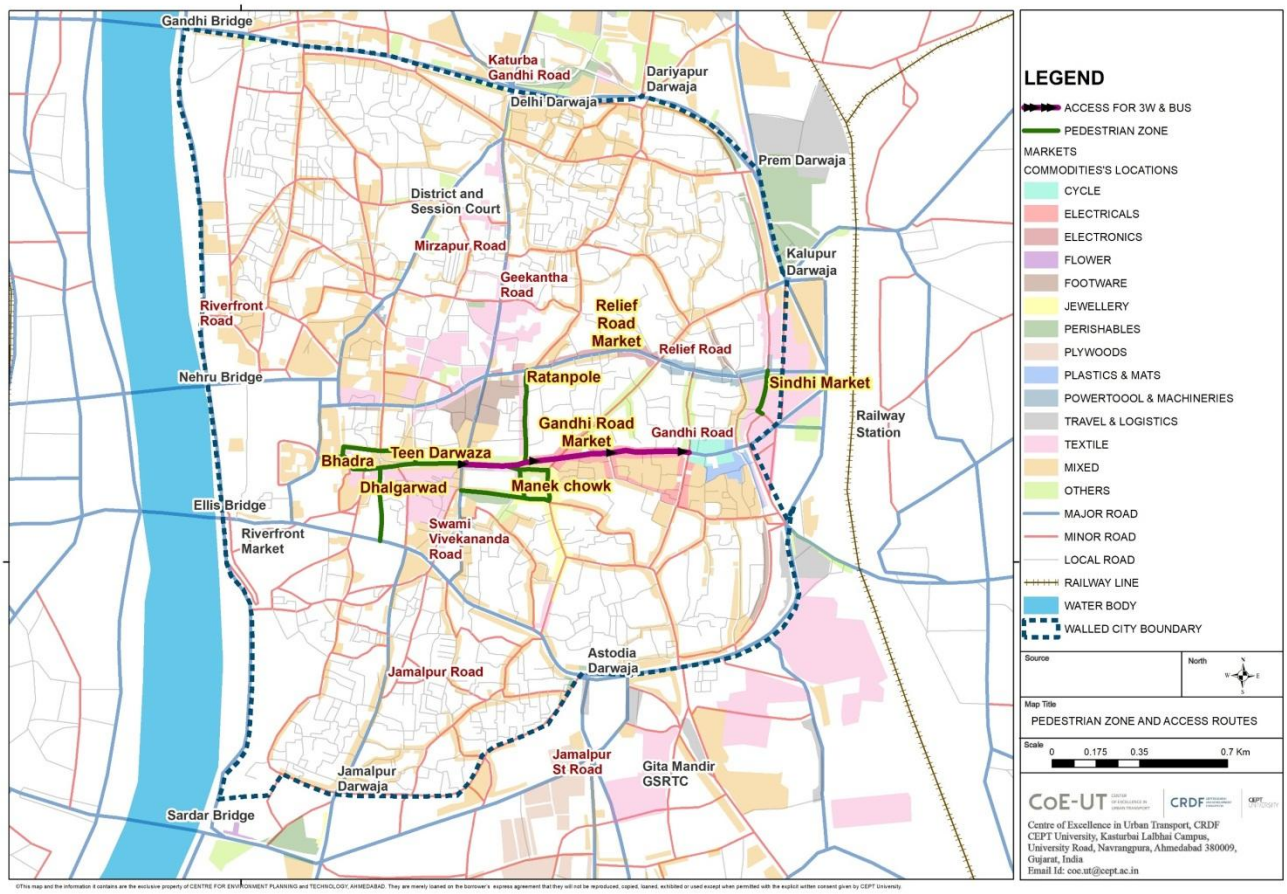


Figure 4-23 Streets with High Pedestrian Footfall and Access Route for PT and IPT

Source: CoE-UT, CRDF

4.5 Summary

LEZ for walled city of Ahmedabad has been designed with strategy considering the Avoid-Shift-Improve framework to achieve significant benefits like mode shift, reduction in vehicular traffic, shift to sustainable modes and clean vehicle technology. This approach minimises the disruption to economic activities while addressing the environmental concerns in the core area. The strategic plan includes managing freight movement, mobility management, enhancement of public transportation and vehicle technology intervention. As part of plan formulation, meetings with advisory group and roundtable with city officials and mobility experts were conducted to discuss the approach and identify feasible strategies, gain their inputs and recommendations.

A mix of mobility and clean vehicle technology strategies is considered to formulate scenarios for shaping the trajectory of LEZ implementation. In case of mobility interventions, facilitating shift to sustainable modes by improvement in NMT and enhancement of public transport is considered and it aimed mode shift from 9% to 20% and NMT from 30% to 38%. Considering the national level target and pollution contribution, electrification both PT and IPT by 50% and private vehicles by 10% is defined.

The impact of NMT improvement, PT enhancement and electrification of vehicles were assessed based on reduction in air pollutants and emissions. The assessment indicates that electrification of vehicles has impact but only up to 18% of air pollution reduction on an average; whereas PT and NMT improvement alone can reduce pollutants up to average of 27%. Further, there is a significant impact of 43% pollution reduction with these three interventions. This has guided the way to formulation of LEZ strategies based on combined consideration of all interventions to achieve improvement in air quality and enhanced urban mobility. The strategies are outlined as follows:

- Given the significant contribution on environment pollution by the older vehicles, it is critical to phase out pre-BS IV vehicles and plan phased programme that gradually eliminate BS IV vehicles for subsequent years, ensuring a seamless transition to new technology.

- Promoting electrification of LCVs, 3Ws and 2Ws can significantly reduce pollution. Raising awareness and setting up of charging infrastructure and electrification of the buses and IPT by the city can sensitise the public to adopt EV. In addition, it is important for the state government to implement targeted policies including financial incentive to encourage the transition to the electric LCV segment.
- The declining service quality of buses has discouraged people from using public transport. To enhance shift to public transport, it is essential to improve the service quality by rationalising the routes, including circular routes, enhancing fleet mix with minibuses and enhancing the accessibility to transit hubs by integrating public transport systems.
- Streets in the walled city are characterised by bustling movement of people as well as vehicles, hence, it is important to enhance the accessibility by adopting complete streets with continuous footpath and safe crossing, restricting entry of 4W on narrow roads and provide special sticker permit for residents to access during restricted hours.
- The encroachment of road space by parking has resulted in a reduction in effective carriageway, contributing to congestion. To ensure smooth movement of both vehicles and pedestrians, it is essential to manage parking by defining 3W stands, eliminating 4W parking along congested roads and limiting on-street parking with time-based parking fee structure.
- Walkability is compromised, specifically along streets with high pedestrian footfall and measures focusing on pedestrian safety are essential. Markets with high pedestrian volume could be transformed to pedestrian only zones with time regulated entry for goods vehicles and access for buses and 3Ws for connectivity.

4.6 Way Forward

The study has identified the next steps for improving the traffic and environmental conditions in the walled city. It is suggested that specific studies to be taken up by the respective agencies in order to outline an implementable plan and financing:

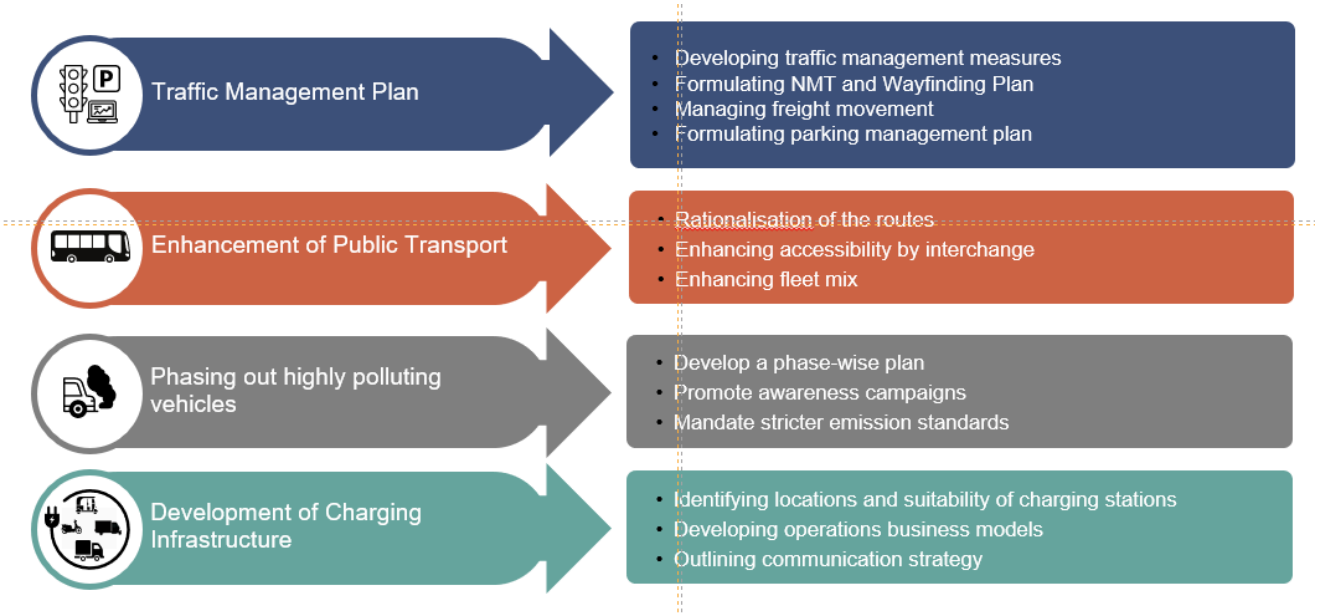


Figure 4-24 Action areas of LEZ

Source: CoE-UT, CRDF

The meetings with advisory groups have been instrumental in informing city officials and agencies about potential action areas that can be adopted to enhance ongoing initiatives in the walled city and Ahmedabad at large. The actions to be taken forward are as follows:

- **Phasing out highly polluting vehicles:** It is identified that phasing out pre-BS IV vehicles and plan phased programme that gradually eliminate BS IV vehicles for subsequent years is important. The city could share details of highly polluting vehicles with Climate State Level Committee, constituted to

ensure effective implementation of National Clean Air Programme, and State Transport Commissioner to take necessary actions.

- **Promoting electric vehicles:** The city could undertake promotional activities to enhance the adoption of e-3W. In the current context, TCO of electric LCVs are not comparable with conventional variant and the city could recommend the state government to adopt appropriate policy measures for e-LCV in Gujarat EV Policy.
- **Establishing charging infrastructure:** It is important to develop charging infrastructure as per the demand in the walled city, the city could explore the possibility of setting up 3W charging stations, including a detailed assessment of economic viability, operation model and suitable locations. In addition, the city could adopt pricing mechanism with special rates to make it favourable for 3Ws. The recommendations could be incorporated to term of reference of project on development of charging infrastructure by AMC.
- **Enhancing public transport:** The city intends to develop service and business plan for bus operations in Ahmedabad, including the walled city, hence, this plan could consider enhancing the fleet mix with electric minibuses and establishing circular routes to improve connectivity across the walled city.
- **Improving street accessibility:** The city could recommend AUDA regarding the major corridors within the walled city and conduct street development to improve the street accessibility and integrate proposals in the development plan and local area plans.
- **Traffic Management Plan:** The city could develop traffic management plan collaboratively with the Traffic Police by incorporating the suggestions from this study including restricting entry of 4Ws, managing freight movement, formulating NMT and wayfinding plan, and parking management.

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6. Appendix

APPENDIX A: STAKEHOLDER MAPPING AND CONSULTATIONS

The stakeholders at the local city level are key players and have varied roles and responsibilities for the planning and implementation of LEZ for the walled city are mapped. The roles and responsibilities of each stakeholder are identified along with extending their engagement to influence this project.

Table 6-1 Stakeholders involved in the project and their roles

Organisation	Present Roles of the Organisation	Expected Roles of the Organisation	Responsibilities in the Project
Primary Drivers: Key actors who will have a direct role in the development and implementation of LEZ in the walled city. The stakeholders will have domain knowledge and reflect high levels of interest to actively seek and engage in the project development and influence the decision-making process.			
Ahmedabad Municipal Corporation (AMC)	Manages the civic infrastructure and administration of the city of Ahmedabad.	Key player in guiding and supporting in formulating LEZ project initiatives. Primary role in planning and execution of LEZ plan for Ahmedabad.	Project implementation and coordination with relevant government stakeholders.
Secondary Drivers: The actors who will support primary actors in creating a low emission zone framework. They are highly influential stakeholders, and it is necessary to engage with them because of their influence over key decisions in the sector**.**			
Ahmedabad Urban Development Authority (AUDA)	City development in the agglomerated areas of Ahmedabad.	Provisioning of land for relocation of markets/ warehouses, setting up charging stations, designing of road section in consideration of NMT.	Infrastructure planning and development aiding in land use reform, mobility interventions and deployment of charging infrastructure for 3W and freight vehicles.
City Planning Department, AMC	Ensure development across the entire urban area.		
Regional Transport Office (RTO)	Issues driving licenses, vehicle registration and responsible to inspect vehicle condition.	No realignment	Managing vehicle registration for EVs and conventional fuel vehicles.
City Traffic Police	Enforces traffic rules and regulations.	Participate in the planning and implementation of traffic and parking solutions.	Support in the management of vehicle flow within the core area.
Gujarat Metro Rail Corporation Limited (GMRCL)	Provider of public transport service in the city and manages the fleet operations.	Provides crucial inputs to influence the improvement of public transport operations, last-mile connectivity and roadmap for PT and IPT electrification.	Support in developing the action plan for accessibility improvement through pedestrianisation of streets and transition to EVsfor PT and IPT.
Ahmedabad Janmarg Limited (AJL)			
Ahmedabad Municipal Transport Service			

Organisation	Present Roles of the Organisation	Expected Roles of the Organisation	Responsibilities in the Project
(AMTS)			
Other Stakeholders: These stakeholders represent different sections of society and indirectly impact the implementation of project initiatives.			
Heritage Department, AMC	Involved in physical conservation and restoration of heritage buildings and leads in the preparation of the Heritage Management Plan of the city.	Contribute to the city initiatives of planning and implementing LEZ.	No direct role in the project.
Traders' Association	Represents specific commodity markets and links traders with brokers, transportation and labourers.	No realignment	Participate in primary interviews to understand the operations, supply chain and vehicle usage in each market.
User Group: User groups are the end users and an integral part of the project. Their perspective towards bus operation service levels and expectations from the same will guide the project development and strategy formulation.			
Freight Operators or Drivers	Drivers of freight vehicles that transport different types of commodities.	Key beneficiaries of execution of LEZ plan in the walled city.	Participate in primary surveys or focus group discussions. Share their expectations from the project. Contribute to awareness workshops and meetings to support the implementation plan.
3W Operators or Drivers	Drivers of passenger 3W vehicles operating across the walled city.		
Residents	Communicates the needs and concerns through their associations which act as liaison between the community and authorities.		

Table 6-2 List of Stakeholder Consultations

S. No.	Stakeholder/ Organisation	Date	Summary of Discussion
1	Municipal Commissioner, AMC	12 June 2024	Briefed about the project, approach and interventions, and preliminary findings of base situation assessment
2	Deputy Commissioner, East Zone Ahmedabad Traffic Police	5 June 2024	Detailed discussion on traffic and parking management measures and regulations with specific to the walled city including one-way system and stationing traffic police at major junctions.

S. No.	Stakeholder/ Organisation	Date	Summary of Discussion
			Highlighted issues related to parking, lack of consideration for pedestrians in planning measures, and poor awareness among people on EVs.
3	Autorickshaw Drivers' Cooperative Society	8 June 2024	Discussed the operational characteristics of 3Ws in the walled city, locations of pick-up and drop-off, their concerns and challenges, and awareness about electric 3Ws .
4	Chokha Bazar Traders' Association	6 June 2024	Extracted details about operations of the market, supply chain and types of vehicles used for movement of commodities.
5	New Cloth Market Traders' Association		
6	FGD with Residents	September-October 2024	Focus Group Discussions (FGDs) were conducted at six neighbourhoods to assess residents' perceptions of mobility challenges, air quality issues, and EV awareness. Locations were chosen based on socio-economic diversity and proximity to public transport.

APPENDIX B: DATA COLLECTION

Table 6-3 List of Data Collection

S. No.	Data	Information	Primary Source	Secondary Source
1	Spatial Development	Administrative Boundary Land Use Road Network Industries & Warehouse		SUMP
2	Heritage Context	Heritage Monuments Heritage Routes		CHC, CRDF
3	Demography	Population Employment		SUMP
4	Socio-Economic Characteristics	HH Income		SUMP
5	Vehicle Registration	No of Vehicle Fuel Type Technology		SUMP, Parivahan Dashboard
6	Travel Characteristics	Travel Mode Origin-Destination Trip Length I-E, E-I & I-I Movement	FGD with Residents	SUMP Household Survey Data 2012
7	Street Usage & Pattern	Activities Involved Vehicle and Pedestrian Flow Traffic Management Plan	On-site Observation CVC	Traffic Police
8	Freight Operation	Freight Access Route Logistics Hub Markets Centers Operation Time Type & Capacity Average Trip Length Activity & Freight Operators	On-site Observation Freight Driver Survey Activity survey	Traffic Police
9	Accidents	Number of Accidents Locations		Traffic Police
10	Parking	Parking Locations	On-site	

		Charges Key Encroached Locations	Observation	
11	Intermediate Public Transport	IPT Stands Awareness of EV's	IPT Driver Survey	SUMP UK PACT
12	Public Transport	Routes & Bus stops Frequency		SUMP UK PACT
13	Air Quality	Air Quality Index Monitoring Locations		Air Quality Monitoring Cell, AMC

APPENDIX C: INTERNATIONAL CASE STUDY

Amsterdam

Contextual Information

The implementation of LEZs in The Netherlands was initiated between 2007 and 2009, and at present, around 15 Dutch Municipalities have environmental zones for diesel trucks and four cities (Amsterdam, Arnhem, The Hague and Utrecht) have environmental zones for passenger cars and vans.(49) This initiative was initiated due to the then widespread non-compliance of Dutch cities with EU air quality directives. Of the Dutch cities, Amsterdam was the first city to implement LEZs and is now among the cities transitioning towards a zero-emission zone (ZEZ).

Amsterdam, located at the mouth of Amstel River, has a current population of around 1.2 million(50). Presently, Amsterdam features different environmental zones for different vehicles. The LEZ was established in 2008 and initially imposed restrictions on diesel trucks with Euro 2 standards or lower within the city centre(23). In 2019, more vehicle types were included, prohibiting entry to all diesel vehicles not conforming to Euro 4 standards. Table 2-2 shows the restrictions of the LEZ in 2008 and 2018 (51). The future plan of Amsterdam is to make the city a zero-emission zone, completely banning diesel and petrol vehicles within the city by 2030.

Table 6-4 Restrictions of Low Emission Zone and Clean Air Zone in Amsterdam

Zone	Year	Restricted Vehicles
Low Emission Zone	2008	• Objective was to restrict the highly polluting diesel trucks. • Diesel trucks with Euro 2 standards or lower were restricted. Covered only Amsterdam city with high congestion.
Environmental Zone	2018	• Taxis with diesel engine and admission date older than 2008. • Scooters and Mopeds older than 2010. The zone for these vehicles is larger than that for the other vehicles. • Diesel buses and coaches older than January 2005.

Policy and Governance

In 2019, air pollution was the third largest contributor to health issues in Amsterdam with significant increase in the amount of nitrogen dioxide (NOx) and particulate matter (PM10, PM2.5). Furthermore, the mobility sector accounted for 9% of the CO2 emissions(52). The Clean Air Action Plan was developed to increase the average life expectancy of the inhabitants in Amsterdam by three months in 2030. Several key sources were identified where interventions could yield significant improvements. These sources included road traffic, passenger vessels and pleasure craft, mobile machinery, and the combustion of biomass and wood(52). Moreover, it was forecast that the implementation of traffic-related measures would further reduce the concentration of atmospheric particulate matter (PM2.5) below the WHO's guideline of 10.0 µg/m3 (microgram per cubic metre) by 2030(52). Hence, the action plan focussed on three major aspects including the phase-wise restriction of polluting vehicles within the city, facilitation of the use of EVs and improvement of electric charging infrastructure to support EVs.

The action plan adopted a strategy of 'centre-out' to plan and implement LEZs in Amsterdam city. The initiation of vehicle restrictions commences in the central business district (CBD) and gradually expands to the outskirts of the city(52). The action plan's objectives regarding vehicle restrictions within the city were:

- In 2022, the city centre will be emission-free for buses and coaches.
- In 2025, the area with the A10 ring road will be a zero-emission zone for road traffic (except for passenger cars, motorbikes, and pleasure crafts).
- In 2030, only emission-free vehicles will be permitted within built-up areas.
-

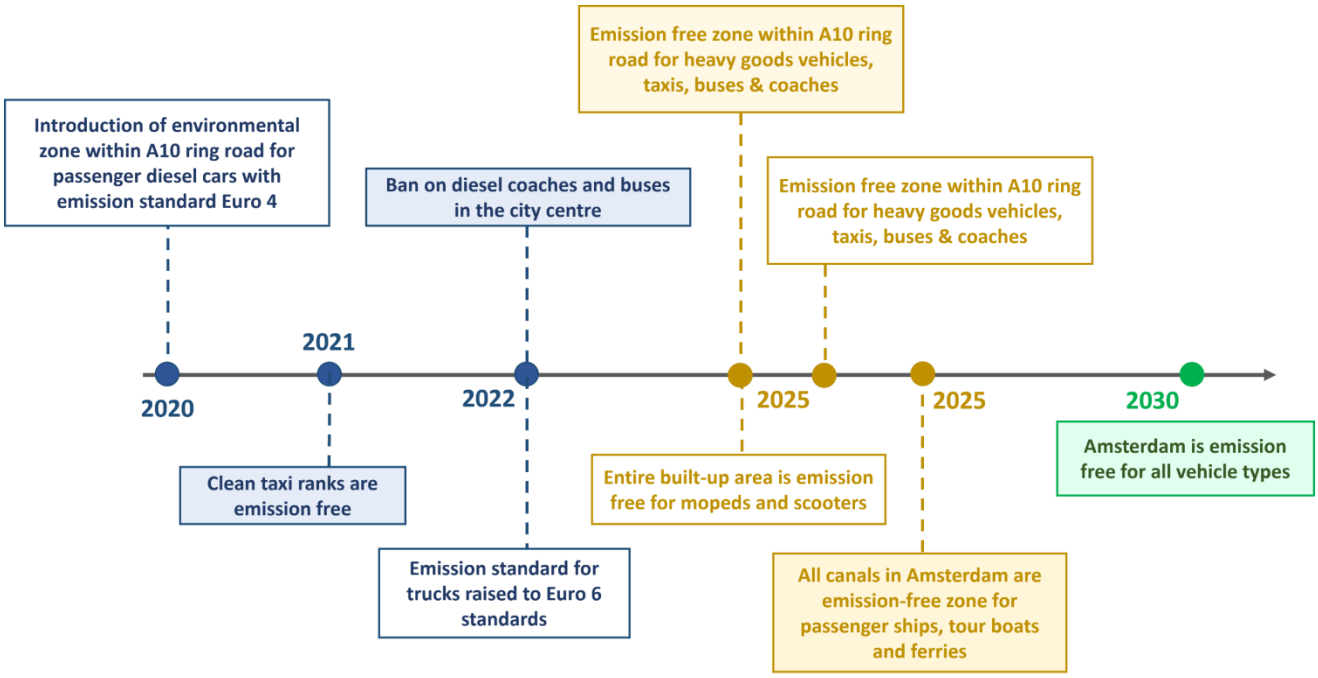


Figure 6-1 Timeline for Zero-Emission Zone in Amsterdam's Clean Air Action Plan

Source: Adapted from Clean Air Action Plan 2019 (52)

These goals are pursued through four main measures:

- **Communication:** A campaign was launched to raise awareness among the public about the importance of clean air and to provide information to businesses and residents regarding the adoption of electric transport.
- **Stimulation:** Subsidies were extended to diverse target demographics, along with supplementary benefits such as parking permits for EVs vehicles, to encourage emission reduction initiatives and foster public acceptance of these measures. The national Electric Vehicle subsidy provided 4,000 Euros and 2,000 Euros for the purchase of new and used EVs respectively which accounted for about 10-30% of the price of the vehicles(53). Furthermore, the Amsterdam city provided incentives for taxis, vans, and buses and a scrappage bonus of 500 Euros for scrapping the old diesel vehicles(53).
- **Facilitation:** To increase the popularity of EVs, emphasis was given to expanding the charging infrastructure for EVs. The e-mobility communities were included when planning the charging points i.e., anyone owning an EV was able to apply for a charging point in their neighbourhood. An exclusive charging infrastructure plan was prepared to plan and implement the development of charging infrastructure for e-vehicles. Furthermore, charging points were strategically planned considering different users such as taxis, private vehicles, and buses.
- **Regulation:** The city implemented environmental zones, initially limiting diesel freight vehicles, coaches, and old mopeds. These limitations are intended to expand gradually, eventually including all internal combustion engine (ICE) vehicles to achieve a fully emission-free zone.

Interventions

Current Regulations of LEZ (2023)

Table 6-5 Status of Low Emission Zones in Amsterdam (54)

Zone	Vehicle Type	Engine Type Restricted	Restrictions - Spatial Extent
Low Emission Zone	Cars	Diesel – Euro 0, 1, 2, 3	Restrictions are within the A10 ring road. Petrol Cars are allowed.
	Heavy Goods	Diesel - Category N2 & N3 (> 3500kg) – Euro 0, 1, 2, 3, 4 &	Within A10 ring

	Vehicles	5)	
	Vans	Diesel - Euro 0, 1, 2 or 3	Within A10 ring
	Coaches & Buses	Diesel - Euro 0, 1, 2, 3, 4 and 5	Within A10 ring
	Mopeds and Motorised Bikes	Before 2010	Within A10 ring & built-up areas outside A10
	Campers and Motorhomes	Emission standard Euro 3 or lower	Within A10 ring

In addition to the introduction of area-based vehicle restrictions, several complementary strategies were implemented in Amsterdam to facilitate easier adaption to the restrictions imposed. The complementary strategies included charging infrastructure roll-out and promoting cycling, public transport, and walking.

Complementary Measures

Expansion of Charging Network

As of 2021, Amsterdam boasts 6,600 charging stations per million people, with a target of reaching 82,000 charging stations by 2030(55). The city has devised a robust charging infrastructure strategy, outlined in its Strategic Plan for Charging Infrastructure 2020–2030 to achieve its targets(55). The plan emphasises the concept of the 'right-to-charge', aiming to provide residents with access to reliable, accessible, and affordable charging facilities(55). It consists of three main components: demand-driven public charging, fast-charging initiatives facilitated through concessions, and a specific focus on enhancing charging options for taxis within the city(56).

Additionally, financial support is provided to private companies for the installation and operation of city-owned chargers, fostering collaboration between the public and private sectors(55). Moreover, Amsterdam is committed to expanding publicly available fast-charging stations for taxis at strategic locations, further enhancing the accessibility and usability of EV charging infrastructure throughout the city.

Promoting PT, Cycling and Walking

By 2025, Amsterdam plans to eliminate 10,000 car parking spaces to promote equity for non-motorised transport users in road space allocation(55). A budget of 54 million Euros has been designated in the bicycle plan to enhance bicycle infrastructure(55). The city is striving to expand the car-free Green Network, transforming it into an extensive cycle network.

Technology and Infrastructure

An automated enforcement system is implemented as a surveillance mechanism for effective monitoring and controlling of the entry of polluting vehicles into the LEZ. Advanced RADAR technology is utilised to generate digital records, which is integrated with the office system of the council(57). A network of 53 cameras is strategically positioned across the zone to detect the vehicles(57). The system then correlates the captured vehicle data with the office system, enabling the imposition of penalties for the entry of polluting vehicles.

Stakeholder Management and Public Awareness

The measures were implemented by collaborating with various municipal departments including the Mobility and Public Space, Surveillance and Enforcement departments and other planning and sustainability departments. During the preparation of the Clean Air Action Plan, various participation programmes including an online community platform and knowledge market were planned to acquire inputs of the community and were incorporated into the plan.

Monitoring and Evaluation

For measuring and monitoring the air quality across the Netherlands, the Dutch government launched an Air Quality Cooperative Programme (NSL) in 2009(58). They collaborated with the provincial and local governments to improve the air quality(58). The air quality was measured by the National Institute for Public Health and Environment (RIVM) and compiled with the measurements acquired from the local governments(59).

In Amsterdam, air quality undergoes periodic assessment through the Amsterdam Air Quality Monitoring Network, which includes several street-level and background monitoring stations(60). As of 2014, the network comprised a total of 14 monitoring stations situated throughout the city(60). Annual reports are generated to facilitate a thorough analysis of the effects of implemented action measures over time(60).

Pavlos Panteliadis (2014) conducted research comparing differences between a street frequently used by heavy-duty vehicles and an urban background location(60). The study revealed that the regulation on heavy duty vehicles in environmental zone in Amsterdam led to a reduction in traffic-contributed PM10 and NOx by 5.8% and 4.9%, respectively(60). Additionally, the implementation of LEZs resulted in a 12.8% decrease in elemental carbons (EC)(60).

London

Contextual Information

The Greater London Area, with a current population of about 9.7 million is the largest urban agglomeration in the United Kingdom(61). At present, London has three zones including the congestion charging zone, low emission zone (24-hour) and ultra-low emission zone (24-hour) for improving the air quality within the city.

In the early 21st century, London emerged as a pioneer in Europe for the implementation of LEZs aimed at improving air quality within the city. In response to concerns about poor air quality in the Greater London Area in 2003, the UK and European Union enacted legislation to establish a LEZ, which placed restrictions on lorries, London buses, coaches, and taxis. London imposed a daily charge for the vehicles entering the city during a specified period.

At present new ULEZ has been implemented in London which has also introduced daily charges for cars, motorcycles, vans, specialist vans (up to 3.5 tonnes) and minibuses.

Policy and Governance

Planning of Congestion Charging Zone

Before 2003, the city was clogged with private vehicles on the road and the time lost to congestion cost the economy up to £4 million per week(5). To overcome the chronically bad traffic situation in central London, Congestion Charge (CC) was introduced in the large area of Central London in 2003 for the management of vehicular traffic. The scheme included charging cars, vans and lorries a charge of 5 GBP (now increased to 15 GBP) for entering the Central London area(62). The scheme operational hours were between 7 am to 6 pm on weekdays and 12 noon to 6 pm on weekends and bank holidays(62). The scheme was enforced by a number plate recognition system which identifies the vehicles entering the zone and is matched with the database to apply the appropriate charges(62). Furthermore, a penalty of 90 GBP to 180 GBP is charged for the non-payment of the entry charges(63). While introducing road pricing, on the first day, 300 new buses were deployed along new routes to provide more frequent services and 8,500 park-and-ride spaces gave drivers additional travel alternatives(5).

Table 6-6 Timeline of Congestion Charging Zone

Year	Vehicle Type	Daily Charges	Spatial Extent of Restrictions
2003	Combustion engine cars, vans and lorries	5 GBP per day	Within Inner ring road of London
2005		8 GBP per day	Within Inner ring road of London
2007		8 GBP per day	Inclusion of Western Extension (Scrubs Lane, Harrow Road, Park Lane, etc.)
2011		10 GBP and Auto Pay system was implemented	Western extension of the zone was removed (Scrubs Lane, Harrow Road, Park Lane, etc.)
2014		11.5 GBP per day	Within Inner ring road of London
2024		15 GBP if paid on same day, 17.5 GBP if paid before third day of entry.	Within Inner ring road of London

The implementation of congestion charging zone reduced the traffic by about 20%, substantially reducing the congestions on the roads. In addition to this, the city also witnessed a total reduction in NOx and PM10 of 12% and 11.9% respectively(62). The crucial success factors in the scheme planning and implementation were clarity in the objectives, effective strategic project governance, robust and consistent stakeholder and public consultations, research and monitoring, effective supplier and contractor management and targeted public campaigns and media relations(62).

This significant experience and the achievements of the Congestion Charging Scheme motivated the local government in London to implement further air quality measures. Building on this success, the city introduced the LEZ for freight vehicles in 2007 and later expanded it. The LEZ, launched in 2008 and continuously upgraded, aims to restrict vehicle access based on emission standards and encourage the adoption of cleaner vehicles through incentives and enforcement measures. Additionally, the city implemented the ULEZ in 2019, further enhancing its commitment to reducing emissions and improving air quality.

Planning of Low Emission Zones

Similar to the planning of the Congestion Charging Scheme, London's implementation of LEZs involved distinct phases of planning, implementation and monitoring. The main objective of the scheme was to restrict heavy polluting vehicles to enter London and encourage diesel vehicles inside the London area to satisfy the air pollution standards through vehicle upgrading or retrofitting(64). Unlike the congestion charging scheme, the LEZ's core idea was to prevent the entry of heavily polluting vehicles into London and not to collect fees or impose penalties(64). This focussed on pushing the polluting vehicles to convert into pure gasoline engines with a spark ignition, install exhaust filters or buying vehicles that met the requirements.

During the planning phase of LEZs (2008), the London government considered several aspects to ensure its effectiveness and success. A feasibility report was prepared in 2003 to investigate the costs and benefits of LEZ, targets that can be achieved and how it can be implemented(65).This report considered crucial aspects including the study area of LEZ, vehicles included, required technology for enforcement, implementation date, emission criteria, stakeholder consultations, cost and the air quality benefits(65). A strategic review of the feasibility study was undertaken to review the findings of the study and determine the earliest implementation date for the LEZ. The review focussed on(66):

- Legal options in the implementation of LEZ
- Analysis of the enforcement options;
- Building of the certificate database for LEZ;
- Investigate methods for identifying various types of vehicles;
- The views of the various stakeholders involved;
- Investigating the developments in emission technology;
- Review of the cost and benefits associated with the strategy.

The revised strategies underwent additional consultation with the London Assembly Environment Committee, the London Assembly, GLA Functional Bodies, and relevant stakeholders. Subsequent adjustments were made based on the feedback received. From the feasibility study and the review report of the third party, the decision to implement LEZ was taken by Transport for London (TfL) Board, after which the implementation responsibility was taken up by the operational teams within the TfL Surface Transport(66).

This implementation team consisted of project management experts, legal and technical professionals to carry out the implementation of LEZ(66). The division responsible for the LEZ implementation reported to a steering committee established to oversee the project. This committee included representatives from TfL senior management, the GLA, and other interested parties(66).

Once the LEZ was implemented, the impacts were measured by periodically monitoring the air quality within the zone to determine the actual benefits of the scheme. Annual reports were published to determine the compliance rates within the LEZs and the direct and indirect impacts that are received from the scheme.

To further reduce air pollution within London City, an ULEZ was launched in the year 2019. The ULEZ imposed a charge on all the vehicles (cars, vans, motorcycles, etc.) that do not meet the emission requirements. The scheme was initially launched in Central London, however, was expanded to all the

boroughs, presently covering about 18 times the original area and 44% of London's population(67) in 2023. The ULEZ does not function in isolation but works in tandem with the London-wide LEZ. In March 2021, tougher emission standards for the LEZ were enforced, marking the first change since 2012. Currently, the LEZ standards align with the ULEZ standards for most large and heavy vehicles(67).

It is worth noting that expansion of ULEZ has been met with significant protest and opposition from public as well as politicians as drivers in outer London are bound to pay charges daily if their vehicles do not meet the required emissions standards. However, the London Mayor had ruled out making changes to ULEZ policy and assured the residents that it is for the people's benefit (68).

Interventions

Implementation Timeline and Regulations of LEZ and ULEZ

Table 6-7 Implementation Timeline and Restrictions for Low Emission Zones In London(69,70)

Year	Zone	Vehicle Type	Daily Charges	Spatial Extent of Restrictions
2008	Low Emission Zone	Lorries, London buses, coaches, and taxis	• 100 GBP for vans (over 1.205 tonnes up to 3.5 tonnes GVW) • 100 GBP for HGVs, lorries, vans & specialist vehicles (over 3.5 tonnes), coaches, buses (over 5 tonnes) • 300 GBP HGVs, lorries, vans, and specialist heavy vehicles over 3.5 tonnes as well as buses/minibuses and coaches over 5 tonnes which do not meet Euro IV (PM)	Greater London Area
2019	Ultra Low Emission Zone (ULEZ)	Euro 3 - motorcycles, mopeds, motorised tricycles and quadricycles Euro 4 - petrol cars, vans, and other specialist vehicles Euro 6 - diesel cars, vans, and other specialist vehicles (up to and including 3.5 tonnes) & minibuses up to and including 5 tonnes GVW)	12.5 GBP	Central London Area
2021			12.5 GBP	First Expansion up to North and South Circular Roads
2023			12.5 GBP	Covers all Boroughs

Complementary Measures

Healthy Streets

London adopted a healthy streets approach to bring more people to sustainable modes of transport such as walking, cycling and public transportation(71). The main objective of the Healthy Streets plan was to create more pleasant, safe, and attractive streets for people to experience the city of London.

Scrappage Scheme

The Mayor of London allocated £210 million to a scrappage scheme aimed at assisting Londoners, small businesses, sole traders, and charities in transitioning to cleaner modes of transportation(72). Funding is available to any London resident with an eligible non-compliant car or motorcycle. Additionally, small businesses (with fewer than 50 employees), sole traders, and registered charities operating in London qualify for support(72).

Strategies for Taxis

The following strategies were developed to eliminate the old taxis from London roads and promote clean air technology for the taxi owners(73).

- In 2012, licenses were not renewed for taxis over 15 years old, and new taxis purchased must meet at least Euro 5 standards.
- Initiatives were launched to develop affordable taxis with 60% better fuel economy by 2015 and zero emissions by 2020, with financial incentives for driver-owners purchasing compliant taxis.
- Efforts were taken to promote taxi sharing and required eco-driving courses for new drivers.
- Since January 2018, London has implemented licensing regulations aimed at reducing emissions from the taxi fleet by gradually eliminating diesel taxis and augmenting the presence of zero-emission-capable taxis in the city.

Electric Vehicle Charging Infrastructure

In parallel with the implementation of ULEZ in 2019, London's EV infrastructure delivery plan was developed to bring all the new cars on the roads to zero emission by 2030. The report acknowledges that infrastructure and limited supply of EVs in the UK pose a barrier to the transition EVs.

Go Ultra Low City Scheme

The Go Ultra Low City Scheme aims to provide funding to local authorities in the UK that encourages thousands of people to consider switching to an electric car(74). London was awarded the bid, and the funding was utilised for on-street residential and car club charge points, rapid charge points, community charging points and other supporting measures(74).

Technology and Infrastructure

Transport for London utilises Automatic Number Plate Recognition (ANPR) cameras to identify the entering of vehicles into the LEZ and ULEZ. Around 1,500 cameras have been fixed and operational to monitor vehicle entry within the congestion charging zone, LEZ, and ULEZ(75). The primary reasons for selecting ANPR were, firstly, the system's ease of installation and rapid operational start up, and secondly, its minimal impact on the aesthetics of the city's historic buildings and sites(64). While planning for the infrastructure and technology to be used for monitoring, the field-verified technology was preferred more than any new ground-breaking technology as it had to be practically feasible and be made operational in a short period(64).

Monitoring and Evaluation

To assess the impact of LEZ on air quality, air quality data from roadside monitoring stations was analysed over 12-month periods, to equate the annual change(76). Air quality is continuously monitored at 100 strategic locations managed by the respective London boroughs(76). Greater London Authority has collaborated with Imperial College London to make this data accessible to the public. This initiative aims to empower schools, care homes, and other community groups to take a more active role in reducing air pollution.

According to TfL monitoring reports, the LEZ led to a 20% reduction in PM10 emissions, a 27% reduction in PM2.5 emissions, and a 25% reduction in NOx emissions from 2008 to 2013(77).However, this reduction was not enough to achieve the legal limits and WHO recommended targets for PM10, PM2.5 and NOx emissions. This was the main reason to launch the ULEZ and tighten the requirements of existing LEZ in the year 2019. A one-year report on the impact evaluation of ULEZ and LEZ indicated that around 95% of the vehicles complied with the ULEZ requirements (an increase from 39% in 2017), reduction of kilometres driven by diesel cars from 32% to 25% in inner London, and an overall reduction in the traffic flows by 3-5 %(67). This resulted in substantial reductions in NO2 concentrations, with a 56% decrease in Central London and 47% in Inner London, alongside a 41% reduction in PM concentrations in both Central and Inner London(67). At central London, 44,100 fewer vehicles emitting pollutants were being driven within the zone on a daily basis(9). Furthermore, the LEZ and ULEZ combined had

significantly improved the air quality within London, reducing long-term health problems by 4.5% and an 8% decrease in respiratory issues like Asthma and Bronchitis(78).

Beijing

Contextual Information

China has been preparing and implementing five-year plans since the 1950s for enhancing economic and social development. In the 1990s, environmental protection was included in the five-year plans which primarily focussed on controlling air pollution(79). Beijing, China's capital is situated in the north of China and has a current population of 22.18 million. Beijing has been devising five-year plans for more than two decades and by 2012, had implemented 18 phases of air pollution control initiatives(79).

The air pollution implemented control programmes focussed on different aspects such as new vehicle standards, fuel quality standards, alternative fuel vehicles, vehicle population control and in-use vehicle emission control in Beijing (80). The first traffic restriction programme was launched in the year 2003 for the movement of yellow-lable vehicles (light-duty vehicles below China I & heavy-duty vehicles lower than China III emission standards) (80). (81)Additionally, the in-use vehicle usage programme for private vehicles was implemented in the year 2009 after the Olympic Games which restricted them to operate only on odd or even days based on the last digit of their license plate number (80).

In 2013, with escalating concerns over air pollution, Beijing initiated the Clean Air Action Plan (2013-17) and intensified its efforts in implementing vehicle emission control measures to address air quality challenges (80).

Interventions

Low Emission Zone Implementation Timeline

Over the past decade, Beijing has progressively extended its LEZ, initially imposing restrictions within the 2nd ring road in 2003 and subsequently expanding the vehicle restrictions to the 6th ring road by 2017. The table below outlines the timeline for various restriction programmes implemented in the city of Beijing.

Table 6-8 Low Emission Zone Timeline for Beijing City (79,81)

Year	Vehicle Types	Spatial Extent of Restrictions
2003	YLVs	Forbidden within 2nd ring road
2009	YLVs	Forbidden within 5th ring road
2009	YLVs	Forbidden within 6th ring road
2009	Private Vehicles	Odd Even policy within 5th ring road
2010	Non-Local Passenger Vehicles	A seven-day pass is required to drive into 5th ring road
2014	Non-Local Passenger Vehicles	A seven-day pass is required to drive into the 6th ring road
2014	Non-Local Trucks	Allowed between midnight and 6 am
2017	Heavy-Duty Freight Vehicles (Below China IV Standard)	Banned from entering the city

YLVs: Yellow Lable Vehicles (light-duty vehicles below China I & heavy-duty vehicles lower than China III emission standards)

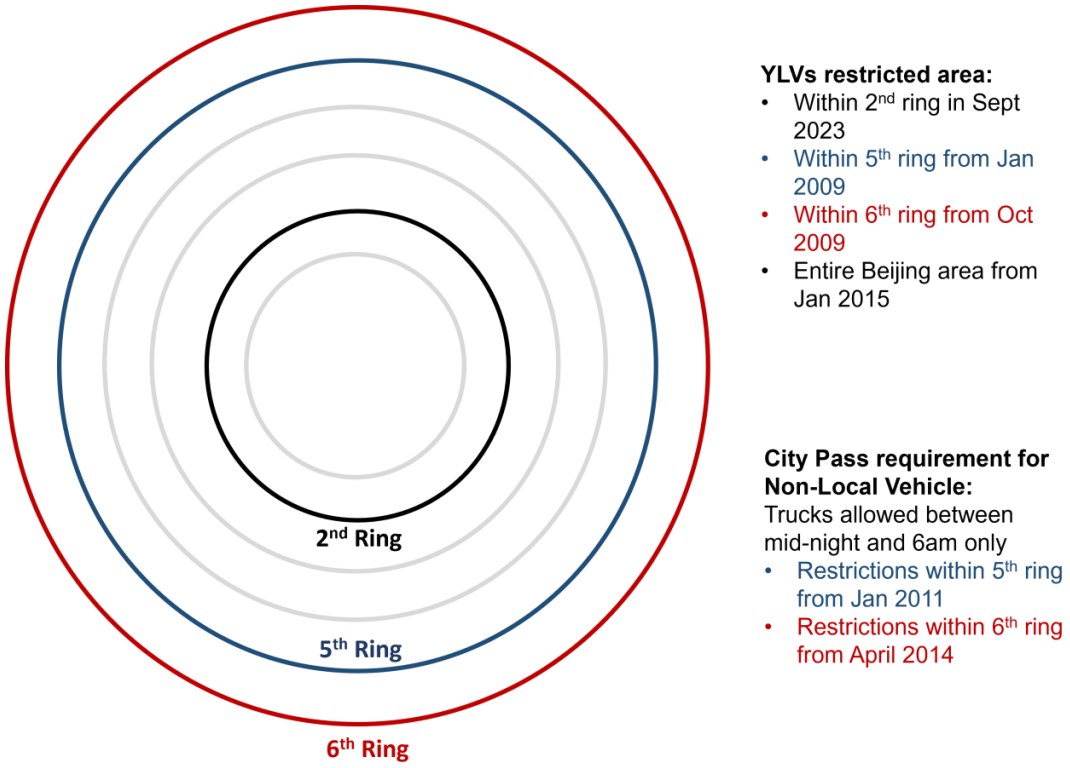


Figure 6-2 The Spatial Extent of Vehicle Restrictions Planned in Beijing.

Source: Review of Beijing's Comprehensive Motor Vehicle Emission Control Programs (80)

The Clean Air Action Plan (2013-17) primarily focussed on three aspects(80):

- **Vehicle Restrictions:** Reducing vehicle emissions in urban areas through LEZs, congestion charging, and vehicle usage restrictions.
- **Compliance:** Maintaining the emissions within certified levels through inspection, maintenance and remote sensing.
- **Vehicle Modernisation:** Reducing vehicle emissions by scrapping, replacing, or retrofitting older vehicles.

In addition to vehicle restriction programmes, complementary strategies including adherence to emission standards, retrofitting, scrappage and replacement initiatives, promotion of alternative fuel vehicles, and vehicle population control measures were concurrently implemented in Beijing. These push strategies incentivised consumers to purchase more emission-free vehicles as part of efforts to reduce air pollution.

Maintenance and Inspection

Beijing implemented inspection and maintenance (I/M) programmes to manage vehicle emissions in Beijing. The certification and issuance of I/M lables are managed by the Beijing Bureau of Transportation Management, overseeing 43 inspection stations employing ASM tests for gasoline vehicles and LUGDOWN tests for diesel vehicles. The city meticulously executed this initiative to ensure cost-effectiveness and public support.

Scrappage Policies

Parallel to the implementation of vehicle restriction measures, schemes were provided for the scrappage of old vehicles. The scrappage programmes have been practised in Beijing since the 1990s.

- Between 1996 to 2000, Pre-China 1 vehicles were scrapped;
- From 2005, gasoline-powered buses were replaced or scrapped;
- Between 2008 and 2010, YLV owners were provided compensations between 800 and 25,000 RMD for scrapping their vehicles;
- In 2011, the scrappage programme was aimed at eliminating the China I and II vehicles;

- In 2014, Beijing widened its target of eliminating YLVs and older vehicles specified in the Clean Air Action Programme (2013-17).

Retrofitting

The prohibition of pre-China I vehicles within the city (within the 2nd ring road) prompted some owners to retrofit their older vehicles to obtain a green lable, enabling access to the city centre. Moreover, various initiatives were introduced to incentivise taxi operators to convert their vehicles from gasoline-powered to flexible-fuel vehicles capable of running on both gasoline and LPG.

Promotion of Alternative Fuels

Beijing started promoting new energy vehicles extensively in the year 2009. The local government provided generous subsidies for the early adoption of New Energy Vehicles (NEVs) within the cities. However, only 3,400 vehicles were added to the city roads at the end of the programme.

The NEV programme was launched again in 2013 with revised subsidies which ranged from 35,000 to 500,000 RMB. At present, Beijing is providing consumer subsidies and tax exemptions to over seven new energy vehicle models. In addition, as part of the Clean Air Action Plan (2013-17), Beijing has also included NEVs in the government fleets.

Monitoring and Evaluation

Over the past four decades, Beijing has consistently expanded and enhanced its air quality monitoring capabilities. In the 1980s, the city installed its initial automatic monitoring system consisting of eight stations measuring SO2, CO, NO2, and TSP pollutants(79).

Over time, the infrastructure has been upgraded to include approximately 35 stations covering the entire Beijing area and the particulate matter measuring equipment was also added to the station(79). Additionally, the city has deployed over 1000 PM2.5 monitoring sensor stations across the urban landscape to pinpoint areas and timeframes with elevated PM2.5 concentrations(79). In preparation for the Olympics, Beijing began publishing daily air quality reports and forecasting the pollution index range.

Studies indicated that the total vehicle emissions in Beijing plummeted during the 1998-2013 period due to the implementation of integrated vehicle emission control measures. The total CO, THC, NOx and PM2.5 vehicle emissions were reduced by 76%, 72%, 40% and 70% respectively(82).

According to the reports by the Beijing Municipal Environmental Protection Bureau between 1998 and 2014, the average annual CO concentration in Beijing decreased from 3.3 mg/m3 in 1998 to 1.4 mg/m3 in 2012, marking a reduction of 58%(78). Conversely, the decline in NO2 was more gradual, with levels decreasing by 30% from 74 µg/m3 in 1998 to 56 µg/m3 in 2013(82).

Seoul

Contextual Information

Seoul, the capital city of the Republic of Korea, is in the north-western part of the country on the Han River. The city is an important cultural, economic, and political hub of South Korea, the metropolitan area extending to 605 sq. km. The city has a current population of 9.9 million, with an average density of 17,500 people per sq. km(83). Seoul, one of the most populated cities in the world, has always been facing challenges in air pollution, GHG emissions, congestion, and road accidents. From early 1990s, the city witnessed a significant increase in car registration that spiked from one million in 1990 to two million by 1995 and caused congestion along city's arterial roads. To manage the demand, congestion impact system was introduced along with tunnel congestion charge, charging of parking lots, bus priority lane, extension of metro network and car-sharing programme. This had had lowered the share of private cars in Seoul and increased public transport share from 61% in 2004 to 66% in 2012(10). Despite these efforts, the contribution by transportation to city's GHG emission was significant. For instance, a report by OECD showed that Seoul's fine particle (PM10) level in the early 21st century was two-three times that of London or Paris(84). The main cause of this was the increase in diesel-powered vehicles which emitted significantly higher fine particles than the other gasoline vehicles.

To improve air quality in Seoul, various programmes were launched to promote CNG vehicles, low emission devices for older diesel vehicles and retrofitting. Concurrently, efforts were also made to enhance the city's public transportation system. At the ICLEI World Congress in 2015, the Seoul Metropolitan Government (SMG) adopted an extensive climate strategy known as the 'Promise of Seoul.' This initiative aimed to reduce greenhouse gas (GHG) emissions by 40% by the year 2030, in comparison to levels recorded in 2005.

Transportation contributed significantly to Seoul's GHG emissions, accounting for approximately one-fifth of the city's total emissions, which amounted to 9,056 tonnes of carbon dioxide equivalent (CO2eq) in 2018(85)(61). With the efforts to enhance air quality within the walled city, a Green Transport Zone was established by the Seoul Metropolitan Government in the year 2019.

Policy and Governance

The Green Transportation Area was formulated and implemented by the Seoul Metropolitan Government (SMG) within the walled city with the aim of reducing air pollution and traffic congestion in the downtown area. A Green Transportation Area is defined as a designated special countermeasure zone established under Article 41 of the Sustainable Transportation Logistics Development Act(86). This act states that, in cases where transport logistics zone is deemed to have difficulty maintaining sustainable transport logistics systems, falling short of sustainability management criteria set by the Ministry of Land, Infrastructure, and Transport, the minister can designate a specific area as a 'special measure area' after consultation with the residents, relevant experts and other stakeholders(87).

The Green Transportation Area is designated to transform an area characterised by heavy traffic congestion and high GHG emissions into environmentally sustainable zones(86). This is achieved through the promotion of eco-friendly transportation methods, the enhancement of public transportation services, the establishment of green spaces, and the effective management of transportation demands.

The policy formulation process for Green Transportation Area involves several key steps(86):

- Identification of the target area afflicted by high traffic congestion and air pollution as the Green Transportation Zone.
- Discussion of overarching strategies to be implemented in the designated area. These strategies may include the introduction of advanced technologies like self-driving buses and Mobility as a Service (MaaS), as well as initiatives to promote eco-friendly transportation such as dedicated lanes for low-speed and environmentally friendly vehicles, and restrictions on high-emission vehicles.
- Engagement with experts, residents, businesses, and other stakeholders to develop comprehensive and detailed plans based on the broad strategies outlined.

Interventions

The interventions implemented within the Green Transportation Area aimed to enhance sustainable modes of transport and improve air quality in the city centre. These were developed according to the principle that focussed on A (Accident-Free), B (Barrier-Free), C (Congestion-Free), D (Disorder-Free) and E (Emission-Free) neighbourhood. The interventions formulated inside the Green Transport Zone are:

Ban on High-Emission Vehicles

The Seoul Metropolitan Government (SMG) established the Green Transport Zone within the walled city area in downtown Seoul in the year 2019. Covering an expanded area of 16.7 sq. km., this zone prohibits the entry of Grade 5 vehicles (diesel vehicles before 2002 or 2005 depending on size) and petrol cars manufactured before 1987 from 6 am to 9 pm(88). This ban on high-emission vehicles within the zone was one of the many strategies formulated within the Green Transportation Zone as part of the efforts to reduce air pollution and traffic congestion.

The enforcement on the high-emission vehicles were based on a report commissioned by Seoul institute in 2016. The study revealed that car emissions contribute to 25% of the fine dust pollution in Seoul(88). Of these emissions, over half originate from Grade 5 vehicles, despite comprising only 10 % of the country's total vehicle fleet(88).

A fine of 250,000 won ($212) is imposed for operating a high-emission vehicle within the zone. Owners of high-emission vehicle models that are not compatible with emission exhaust filters are granted a one-year exemption to replace their vehicles with more eco-friendly alternatives(88).

Promotion of Active Transportation Modes

Creating a fair road-use city centre involved the reorganisation of Seoul-style road space to align with the traffic characteristics of each main road(89). This included the establishment of 'Seoul-style space utilisation' standards to prioritise road space for the green transport modes(89). To create a more equitable road within the city centre, Seoul reorganised some of the arterial roads to make them more public transport and pedestrian-oriented based on their purpose and the land use around them(89).

The promotion strategy focussed on parallel reorganisation of public transportation and pedestrian-oriented road spaces, annual road space reorganisation linked with major urban projects, and pedestrian-oriented use of idle space on roads and sidewalks(89). One of the measures was to create a comfortable and enjoyable walking environment that involves constructing a three-dimensional pedestrian network connecting above-ground, underground, and aerial pedestrian paths(89).

In addition, the Green Transport Area Promotion Plan encompassed the expansion of cycling infrastructure and maintenance of existing bicycle facilities. These collective efforts were aimed not only at expanding the network of active transport modes but also to stimulate the local economy(89).

Enhancing Public Transport Network and Shared Transportation

To improve transportation within Seoul's walled city, post the Grade 5 vehicle ban, several measures were adopted to enhance public transport and shared mobility(89):

- Establishment of four new public bus routes within the designated area, offering a 50% discounted fare compared to regular services(88);
- Installation of exclusive median bus lanes to streamline bus operations and improve efficiency;
- Introduction of low-floor and 3-door buses in the fleet to encourage public transportation usage;
- Enhancement of the public transportation environment by deploying Bus Information Terminals (BITs) at bus stops, providing real-time usage information;
- Accessibility improvement within a five-minute radius by expanding shared car services, enhancing user-centric offerings, and increasing downtown shared parking lot availability;
- Expansion of public bicycle facilities and bolstering operational efficiency by adding more bicycle road safety features and cracking down on illegal parking in designated areas.

Technology & Infrastructure

Seoul’s Transport Operations & Information Service (TOPIS) oversees the comprehensive management of traffic volume and conducts real-time monitoring of the Green Transport Zones established within Seoul’s downtown(90). To enforce and monitor the entry of Grade 5 vehicles, 45 gateways leading in and out of the zone were installed with surveillance cameras(90). The system automatically detects the Grade 5 vehicles, and the owner incurs a penalty(91). The CCTV system identifies license plates and cross-references them with a database of eco-friendly grade vehicles, verifying vehicle ownership through the Ministry of Land's registration records within five seconds(91). TOPIS also leverages data on entering vehicles within Seoul city walls to inform city management policies, utilising comprehensive analysis to optimise urban governance(91).

Stakeholder Management and Public Awareness

As part of Seoul’s urban development initiatives, a practical governance framework was proposed to implement transportation policies, with a focus on engaging all relevant stakeholders and consulting experts. This framework emphasised collaboration among experts, organisations, and citizens to improve policy effectiveness and expertise(89). This involved the formulation of an Administrative Working Council, comprising delegates from Urban Transportation Headquarters, governmental bodies, and civic groups, tasked with promoting policies and initiating major projects(89). Additionally, an Expert Advisory Group consisting of experts from various fields was formed to provide comprehensive advice on policy direction and specific projects(89). Citizen-participation was encouraged through forums, public hearings, and online platforms to ensure inclusive governance and transparency.

Additionally, a public relations plan was proposed in promoting transportation strategies related to green transportation, pedestrians, and urban regeneration. The promotion strategies were created and shared through different media platforms to reach a wide range of people and achieve a broad consensus(89). To further enhance the public relations strategies, promotional activities were linked with related projects, collaborating with media outlets for early public opinion dissemination(89). Moreover, public campaigns were planned with specific themes to facilitate presenting transportation policies in a positive and appealing manner to the public.

Monitoring and Evaluation

In 1973, Seoul was equipped with only four air pollution measurement stations. At present, the city operates a network of 45 stations comprising 65 distinct air pollution measurement networks(92). Of the 65 networks, there are 25 city-based stations, 14 roadside stations, 10 photochemical stations, five

stations for heavy metals, 10 stations for acid deposition, and a singular station for visible distance measurement(92). These measurement stations measure air quality 24 hours and are strategically located to represent the specific characteristics of the area(92). The measured results are sent directly to the Seoul Public Health and Environment Research Institute and are released to the public. Seoul's comprehensive air quality monitoring system has significantly enhanced the city's understanding of local air pollution. This enabled the authorities to prepare effective air quality improvement plans and policies in reducing the air pollution levels. Furthermore, the regular dissemination of air quality data also helped heighten public awareness regarding the current situation, thereby justifying the introduction of LEZ within the city.

APPENDIX D: CHARACTERISTICS OF WALLED CITY

Heritage Structures

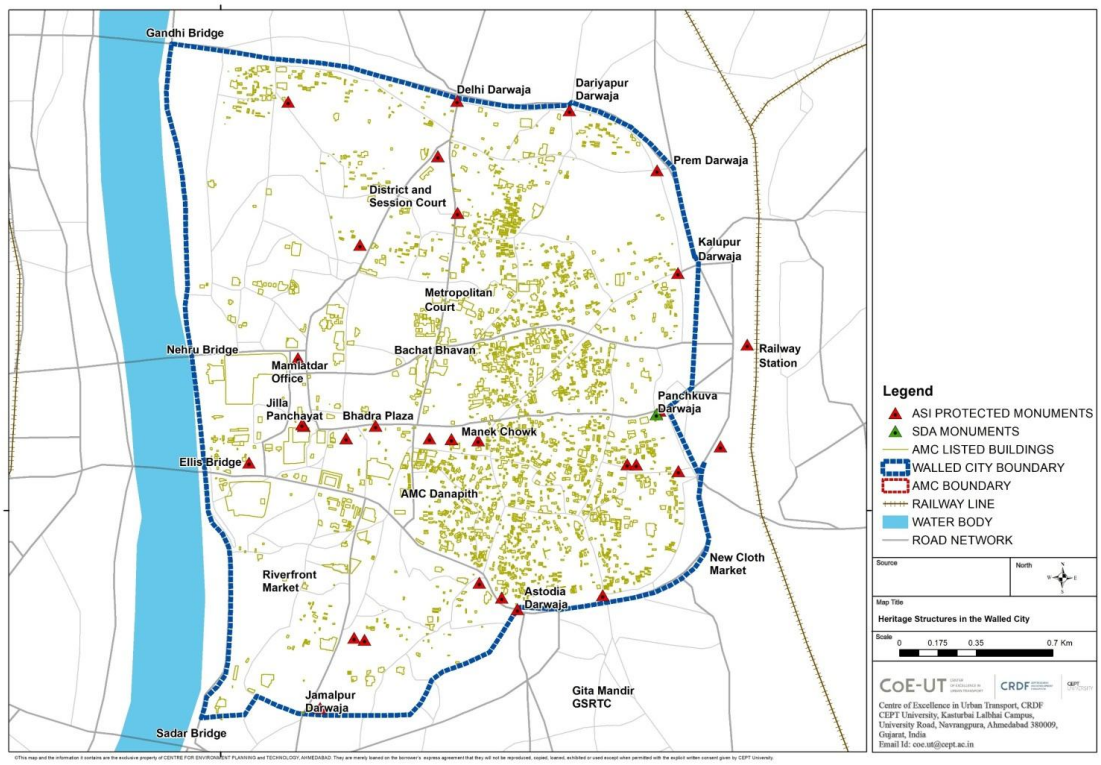


Figure 6-3 Heritage Structures in the Walled City

Source: CHC, CRDF

Population Density

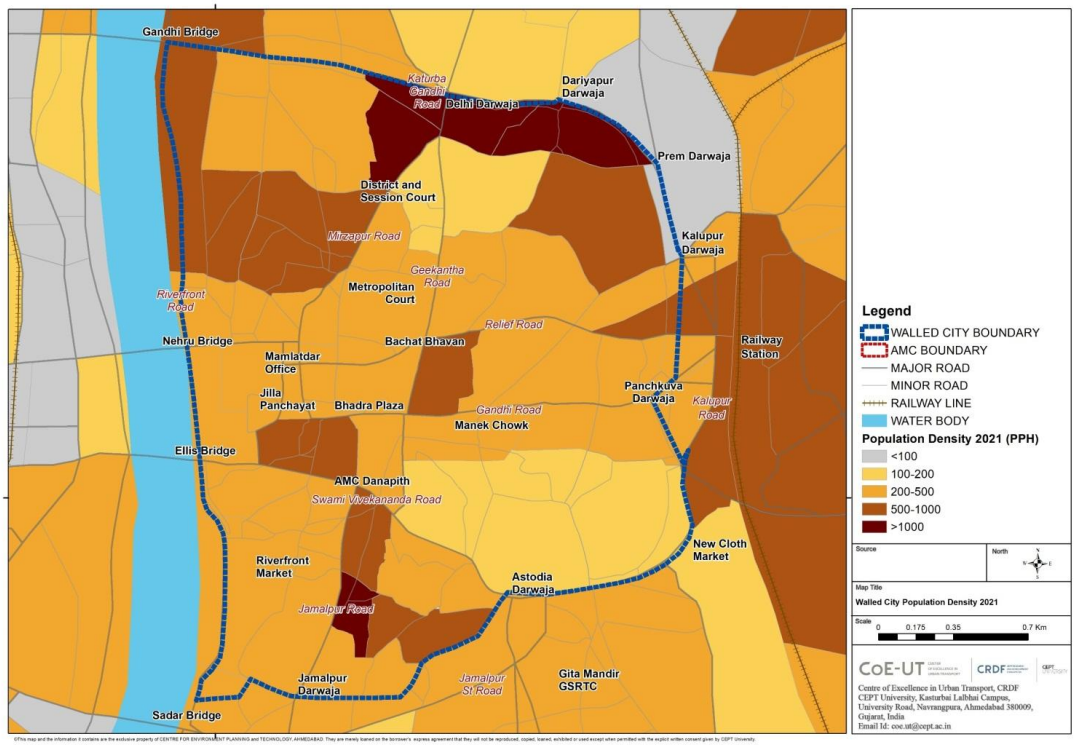


Figure 6-4 Population Density (PPH) in the Walled City of Ahmedabad 2021

Source: CoE-UT, CRDF

Employment Density

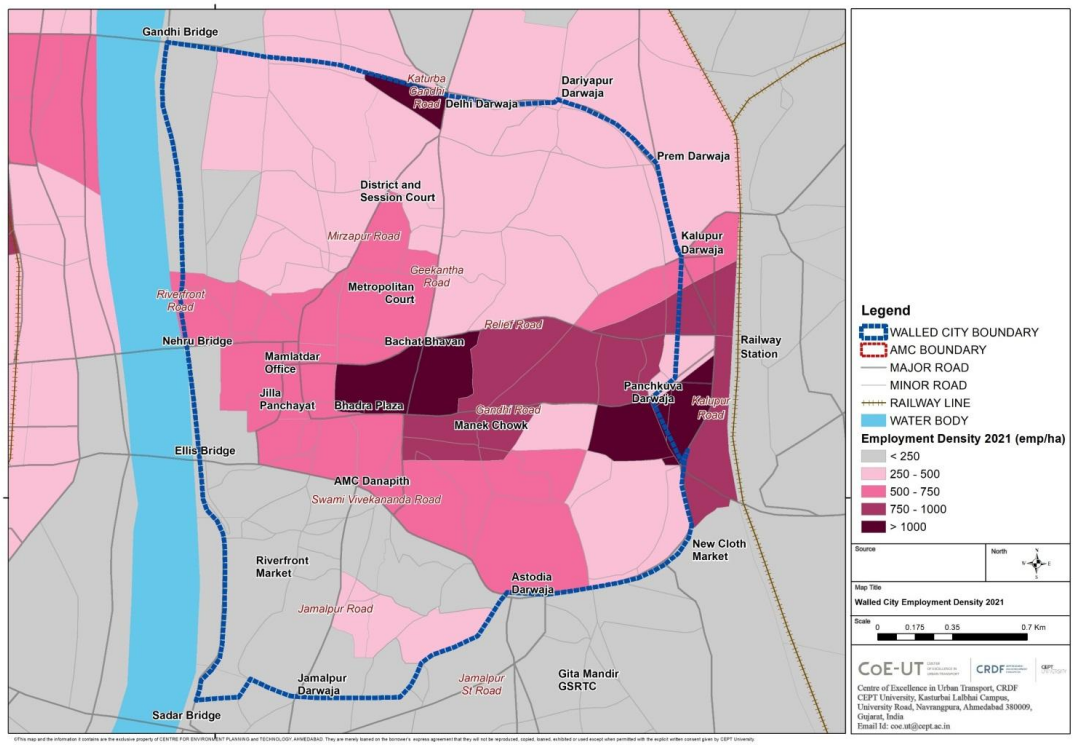
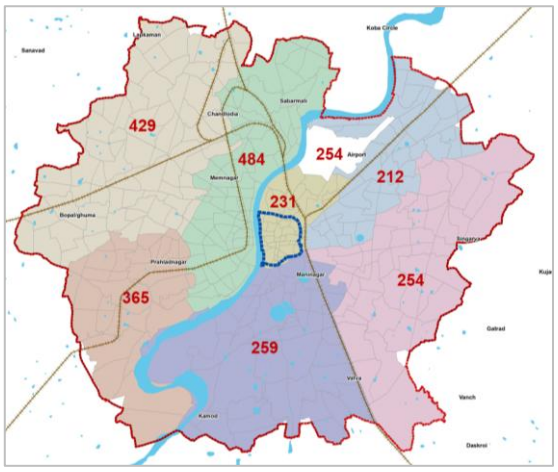


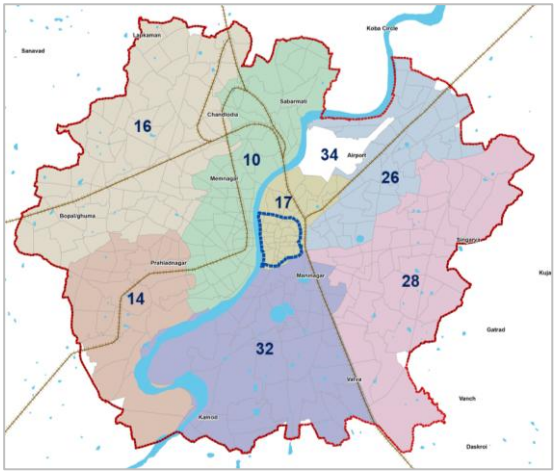
Figure 6-5 Employment Density (emp/ha) in the Walled City of Ahmedabad 2021

Source: CoE-UT, CRDF

Vehicle Ownership



Private Vehicle Ownership per 1000 people



Cycle Ownership per 1000 people

Figure 6-6 Vehicle Ownership across Ahmedabad City (2022)

Source: Household Survey Data 2022, CoE-UT, CRDF

Freight Generating Areas in Ahmedabad

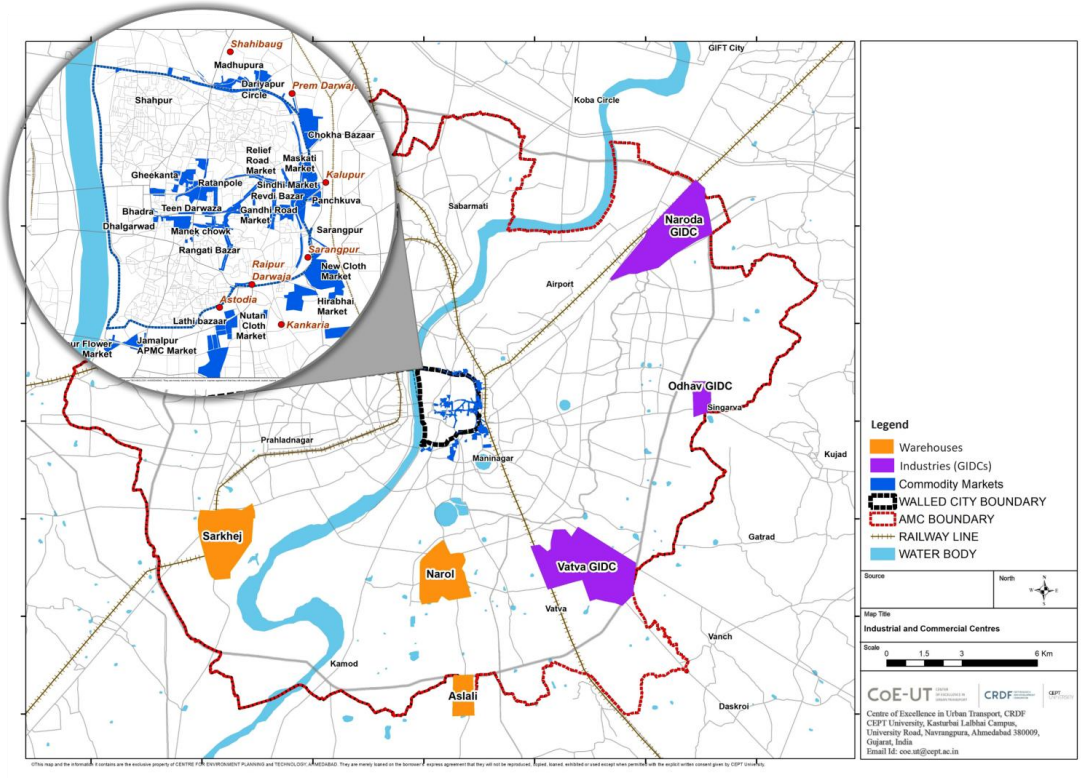
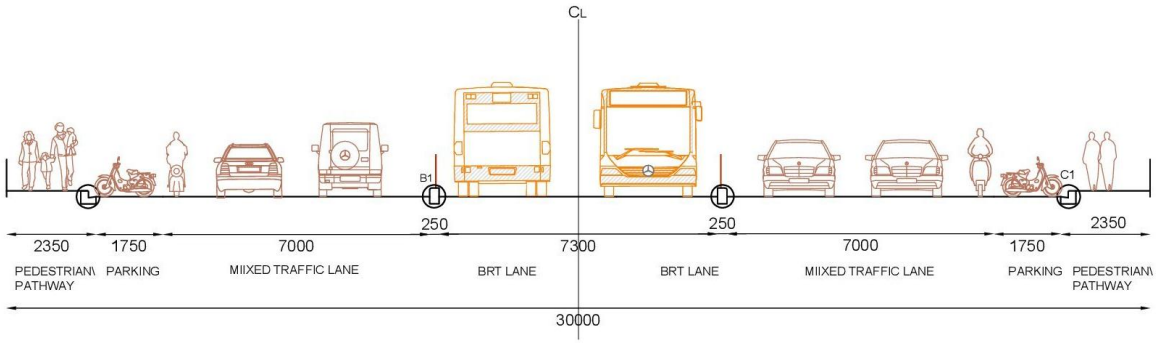


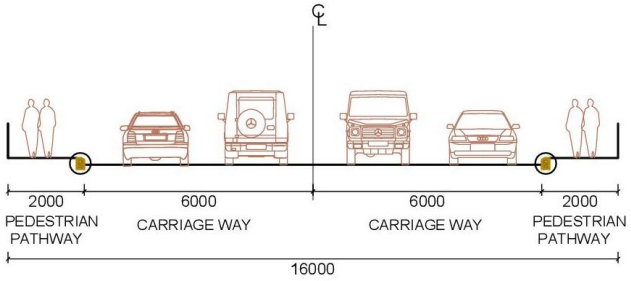
Figure 6-7 Freight Generating Areas across the City of Ahmedabad

Source: Primary Survey

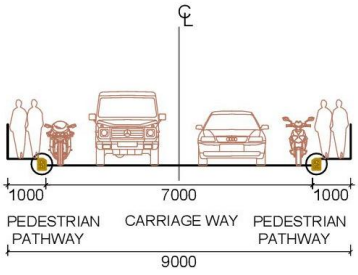
APPENDIX E: MAJOR ROAD SECTIONS



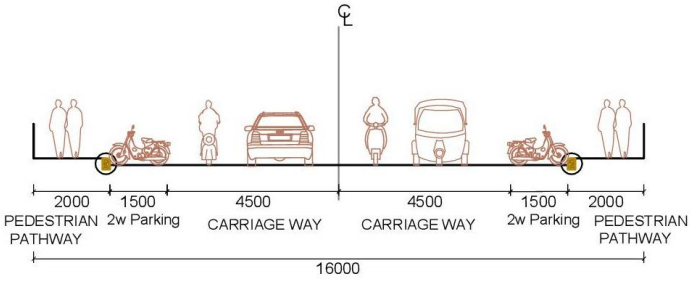
Cross-section of Swami Vivekananda Road 30M ROW



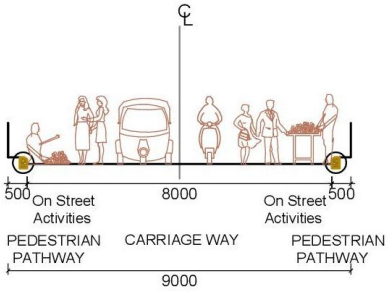
Cross-section of Mirzapur Road 16M ROW



Cross-section of Gheekanta Road 9M ROW



Cross-section of Relief Road 16M ROW



Cross-section of Gandhi Road 9M ROW

APPENDIX F: COMMERCIAL MARKETS LOCATED WITHIN AND AROUND THE WALLED CITY

Agricultural Produce Market Committee Jamalpur

Agricultural Produce Market Committee (APMC) Markets are state-established markets located in different parts of the state to provide a platform for all the farmers to sell their produce (vegetables, fruits, other perishables) by auction to the traders. This system was established to prevent the exploitation of farmers by any wholesaler or large retailers. Jamalpur market, located in the south of the walled city is a large APMC yard for selling vegetables, fruits and other perishables in Ahmedabad. Farmers from various villages in the Ahmedabad district transport their commodities to the market using trucks or LCVs. These commodities from the market are then bought by semi-wholesalers/retailers within the city of Ahmedabad and transported in LCVs, 3W cargo or open trucks. From these semi-wholesalers, the perishables are either sold to small retailers or directly to consumers. Most of the commodity distribution predominantly relies on LCVs and 3W cargo, making it a significant freight generator near the walled city.

Figure 6-8 Supply Chain of Jamalpur APMC Market

Source: Primary Survey

Chokha Bazar

Chokha Bazar, a wholesale market for grains, spices, and dry fruits situated in Kalupur, towards the north-east of the walled city, includes around 200-250 shops which operate from 10 am to 8 pm. The market sources grains from regions including Haryana, Punjab, Uttar Pradesh, Bihar, Bareja, Jetalpur, Himmatnagar, processed flour from Kalol and nearby villages, while pulses are obtained from Valsad, and dry fruits are imported from Goa and Nashik via multi-axle trucks. The arrival of these trucks typically occurs during the late hours of the night, between 12 am and 6 am, as daytime entry into the city is limited for these vehicles. Upon arrival, the trucks are unloaded, and the commodities are stored in warehouses within the market. Subsequently, these goods are distributed to retailers across various areas of Ahmedabad, such as Paldi, Maninagar, Drive In, and Bopal, utilising 3W cargo and LCVs for transportation.

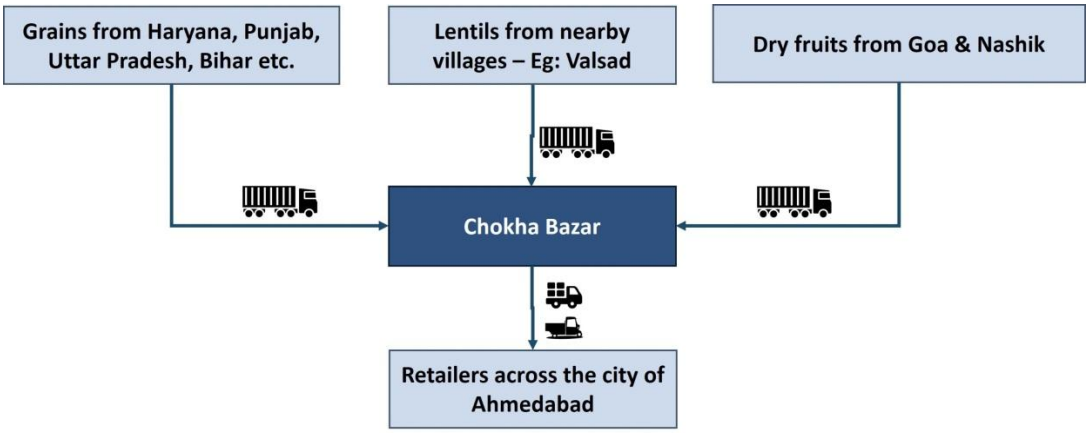


Figure 6-9 Supply Chain of Chokha Bazar (Wholesale Grain Market)

Source: Primary Survey

Gheekanta Market

Gheekanta market, located in the centre of the walled city near the Gheekanta metro station, is a wholesale market for readymade textiles and exports to various cities across India. The market consists of

15 major complexes around the metro station with a total of around 1000 wholesale textile shops. These shops receive goods from various parts of India, which are then sold to local retailers in Ahmedabad as well as to other states across the country. The market operations start at 10 am and continue till 8 pm.

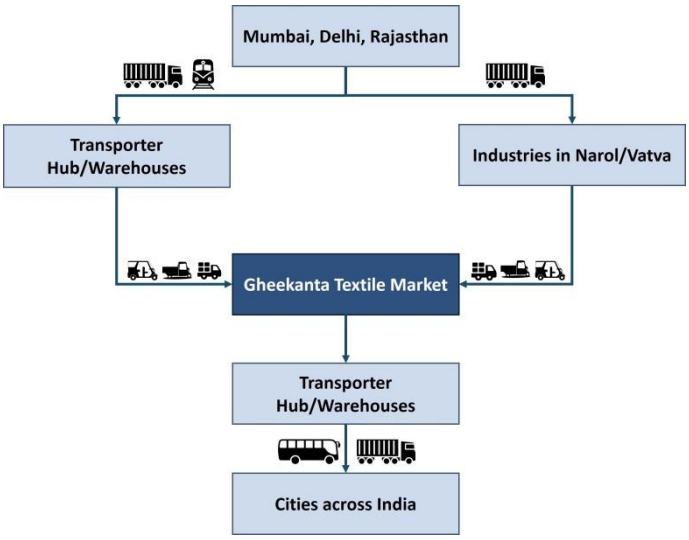


Figure 6-10 Supply Chain of Gheekanta Clothing Market

Source: Adapted from CEPT Directed Project Report on Feasibility Study on Urban Freight Vehicles: A Case of Ahmedabad by S. Narasimhan et al, 2023 (20)

The clothes transported by rail, truck, or bus from various parts of India, such as Mumbai, Rajasthan, and Delhi, are received at transporter hubs outside the walled city (in Kalupur, Sarangpur, Madhupur, Prem Darwaja and Kankaria). From there, these are transhipped to 3W cargo for delivery to the market, as heavy commercial vehicles cannot navigate the old, narrow streets. If grey material is procured, it is sent directly to Narol or Vatva for washing, stitching, buttoning, and pressing. These garments are then brought to the Gheekanta market for packing, storage, and distribution. Approximately 95% of these goods are transported out of the state to various parts of India via truck or bus. The textile commodity movement within the city relies heavily on 3W cargo, while the transport of goods between different textile complexes in the market is handled via cycle carts.

Lati Bazar

Lati Bazar, located in the southern periphery of the walled city near the Gita Mandir bus stand, is a wholesale plywood market in Ahmedabad. The market consists of five zones, with around 500 – 600 wholesale/retail shops in these zones. This market handles various commodities including plywood, laminates, doors, wooden rails, veneers, etc.

Most of the shops in the market are distributors of plywood in and around Ahmedabad. However, the distinction lies in the materials received and the activities conducted within the establishments. The finished plywood in the wholesale shops is received from Yamuna Nagar (Haryana), Bareli or Uttar Pradesh and is stored in a warehouse behind the shops. Due to the lack of enforcement on restricted entry of heavy vehicles during daytime, the majority of unloading activities in the market occur during night time hours between 11 pm and 7 am. In the event that the trucks arrive in Ahmedabad during the daytime, the trucks are unloaded in warehouses near Aslali and are then transhipped to the market in smaller vehicles. In addition to storing plywood, some shops utilise their own cutting and wood surface smoothing equipment in their warehouses to produce minor products like doors, panels, and packaging boxes.

Figure 6-11 Storage and Processing of Wood in Lati Bazar Wholesale Shop

Credits: CoE-UT, CRDF

A few other shops receive raw teak and timber wood from Latin America and Eastern Africa through Mundra port. These are transported through multi-axle trucks to Lati Bazar and are processed into plywood of different sizes according to the client's requirement. These finished goods are distributed across the city of Ahmedabad to contractors/retailers in different vehicles including 3W Autos, 3W Cargo, Tata Ace and Bolero depending on the destination locations and weight of the commodity to be transported. The detailed supply chain of Lati Bazar is shown in the below figure.

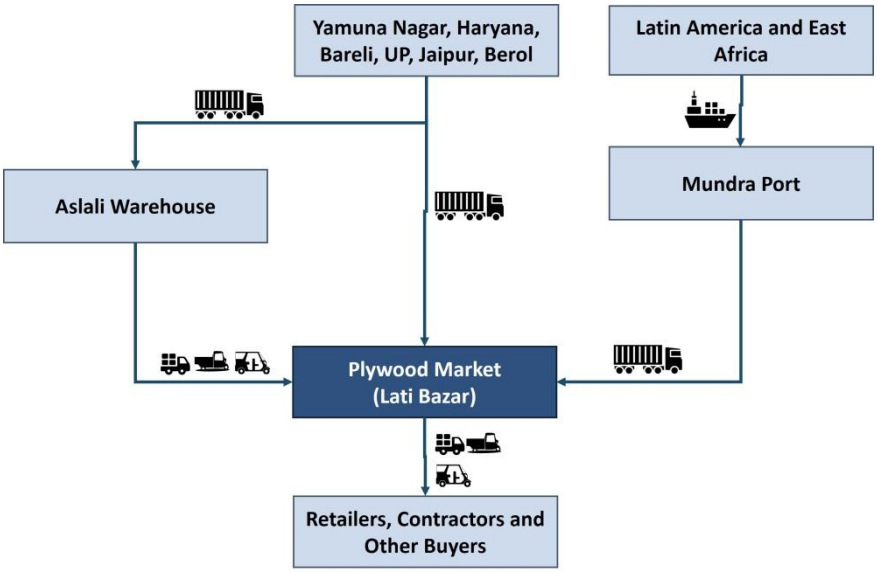


Figure 6-12 Supply Chain of Plywood Market

Source: Adapted from CEPT Directed Project Report on Feasibility Study on Urban Freight Vehicles: A Case of Ahmedabad by S. Narasimhan et al, 2023(20)

Madhupura Market

Madhupura Market, located in the north of the walled city near Delhi Darwaja entrance is the largest distributor of grains, spices, and dry fruits in Ahmedabad, consisting of wholesalers, retailers, transporters, and warehouse owners. The market operates from 9 am until 7 pm. The commodities are imported from various parts of India such as Punjab, Haryana, Bihar, Rajasthan, etc. via road and rail. Commodities arriving by rail are stored in cold storage facilities at the Sabarmati rail yard, while those arriving by road are unloaded at Transport Nagar in Narol and then transhipped to cold storage in Naroda GIDC via smaller vehicles.

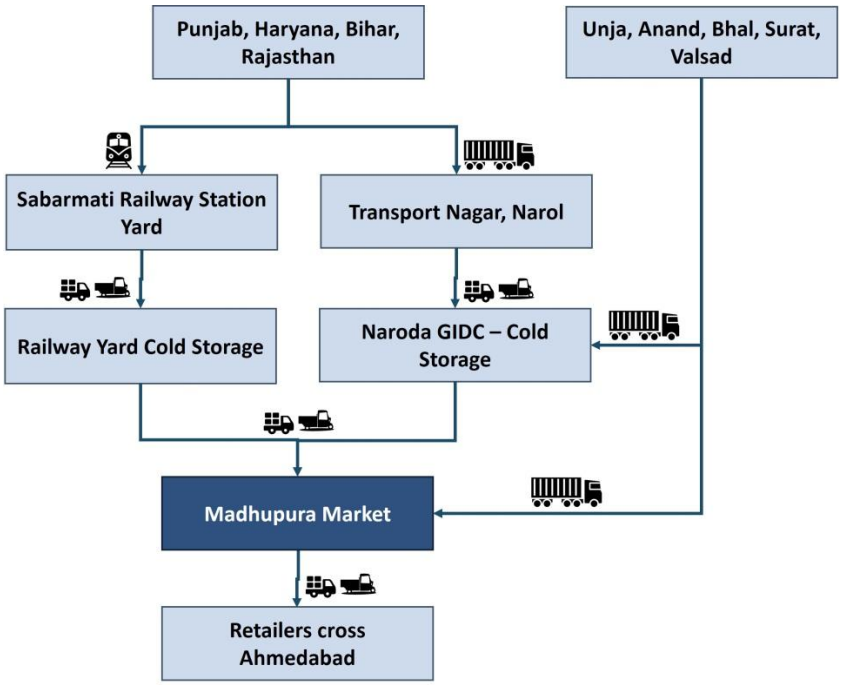


Figure 6-13 Supply Chain of Madhupura Perishable Market

Source: Adapted from CEPT Directed Research Project on Electrification of Urban Logistics: Case of Ahmedabad City by A S Gajjar and S. Swamy, 2021 (19)

These goods are collected by wholesalers and retailers in 3W cargo from the cold storage facilities. Furthermore, goods are also received from nearby villages like Unja, Bhal, Anand, Valsad and Khadiyaval which are either directly unloaded in the Madhupura market or sent to Naroda GIDC cold storage. Subsequently, the perishable goods stored within the confines of Madhupura market are distributed across the city via 3W cargo and LCVs, covering retail shops spanning 7-10 km from the market.

New Cloth Market

The New Cloth Market in the south-eastern periphery of the walled city serves as a significant wholesale textile market, consisting of approximately 1500-2000 shops that specialise in processed fabric textiles rather than readymade garments. The shops in the market complex houses offices of traders that handles sales and accounting, operating from 11 am to 8 pm. Office staff and visitors use personal vehicles such as 2Ws and 4Ws to reach the market.

Figure 6-14 Parking at New Cloth Market

Credits: CoE-UT, CRDF

The materials namely grey cloth, which is a raw, unprocessed fabric directly from the loom, is sourced from Tirupur or Erode are transported to industries in Narol, Danilimda and Vatva through multi-axle trucks, where they are subsequently stored in warehouses near the industrial facilities. Within the Narol region, the raw fabric undergoes crucial processes such as dyeing and printing before being dispatched to various cities across the nation through trucks with a notable 90% of the commodity movement happening

directly from the industries in Narol. A portion of the processed fabric is transported to the New Cloth Market via 3W cargo/LCVs, facilitating distribution to retail outlets within Ahmedabad through the deployment of 3W cargo and LCVs. The infrastructure of the market predominantly features textile wholesaler offices for handling paperwork and administrative duties, as well as fabric showrooms designed to showcase the available textiles to the clientele. Notably, the processed fabric transportation from Narol is efficiently organised through truck coordination with the assistance of transporters.

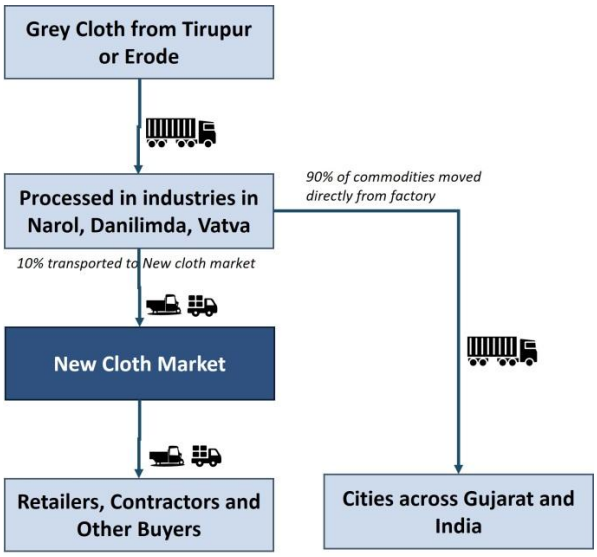


Figure 6-15 Supply Chain of New Cloth Market

Source: Primary Survey

Sindhi Market/ Revadi Bazar

Sindhi Market, also known as Revadi Bazar, located in the eastern periphery of the walled city is a wholesale/retail textile market of raw fabrics and readymade garments. This market is situated near the Panchkuva Darwaja along Reid Road and Revadi Bazar Road and operates between 11 am and 9 pm. Revadi Bazar functions as an aggregator, facilitating the processing of raw fabric and the trading of finished textiles in the city.

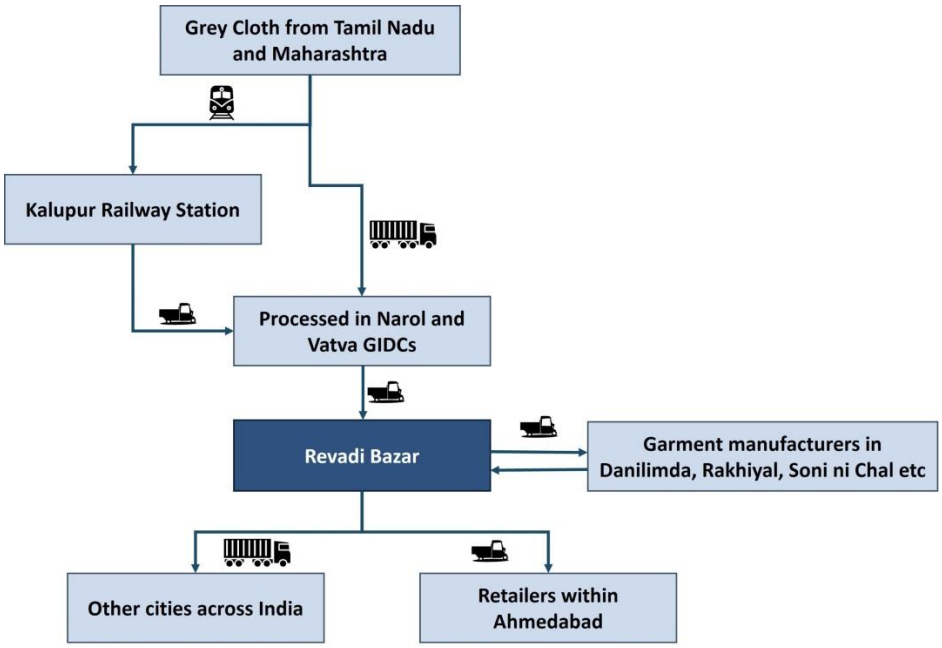


Figure 6-16 Supply Chain of Revadi Bazar/Sindhi Market

Source: Adapted from CEPT Directed Research Project on Electrification of Urban Logistics: Case of Ahmedabad City by A S Gajjar and S. Swamy, 2021(19)

The raw material, also known as the grey cloth, is received from Tamil Nadu and Maharashtra via rail and trucks. Commodities received via rail are moved to industries in Narol and Vatva using 3W cargo, while the material arriving by trucks is directly unloaded at the industries. The grey cloth undergoes processing (bleaching, dyeing, printing) in Narol and Vatva GIDCs and is then transported to Revadi Bazar via 3W cargo. The processed fabric received in Revadi Bazar is sent to garment manufacturers near Danilimda, Soni ni Chal and Bapunagar. After the processed fabric is stitched, buttoned, and embroidered, it is returned to Revadi Bazar for packaging and distribution. The packed garments are then transported to other retail markets in Ahmedabad like Ratanpol, Dhalgarwad, Lal Darwaja, etc. and other cities across India. Due to narrow roads, HGVs do not operate in this market; instead, most trips to and from the market are made using smaller vehicles, and transportation within the market is done using hand or cycle carts.

Other Retail Markets

In addition to the wholesale markets, commercial areas in the walled city are characterised by rows of mixed small-scale shops along main streets, and sometimes clustered as specific commodity retail markets(16). The walled city includes a variety of retail markets, including Ratanpol (wedding dresses), Relief Road (electronics, footwear, and textiles), Gandhi Road (electrical goods, cycles, mats, plastic sheets, and power tools), and Manek Chowk (jewellery). These markets attract a substantial number of customers daily, making the walled city a significant commercial hub.

Figure 6-17 Retail Shop and Street Vending Activities in Manek Chowk

Credits: CoE-UT, CRDF

The supply chain within the commercial markets has naturally evolved into a hub-and-spoke model, with various specialised wholesale markets serving as distribution hubs for different types of commodities such as fabrics, readymade garments, spices, and perishables. These specialised wholesale markets within and around the walled city generate majority of the freight trips, heavily relying on light commercial vehicles (especially 3W cargo) for the distribution and transhipment of commodities from the warehouses located outside the walled city. Due to the varying operating hours of each market, the wholesale activities attract a substantial number of LCVs entering and exiting the walled city throughout the day. In addition to this, the walled city also includes a variety of specialised retail markets that attract freight vehicles for stocking up commodities and a significant number of customers daily. Therefore, the presence of the wholesale and retail markets makes the walled city a major generator of trips across Ahmedabad.

APPENDIX G: ACTIVITY SURVEY FORM

Non- Residential Property/ Activity Survey
By CoE-UT, CRDF, CEPT University
Low Carbon Emission Zone - Walled City of Ahmedabad

Interviewer Name:		**Date**	_ _ / _ _ / 2024
Location of Survey & Ward No.		**Time:**	

1. Details of Property/Establishment

S. No		**Property Name**		**Respondent Name**		**Contact No.**	
Establishment Address							
Type of Establishment Example: Retail, Warehouse, Factory				**Type of Commodities** Example: Textile, Electronics			
No. of employees	**M**		**F**		**Total**		
Processes that happen in the establishment?				**Peak hour of market** Example: 11am – 1pm			

2. Details of incoming materials/ goods (for the last working day or the day goods arrived)

Frequency of Incoming material	◯ Daily ◯ Weekly ◯ Twice a week ◯ Thrice a week ◯ Monthly ◯ Twice a Month ◯ Thrice a Month ◯ Once in 2 Months ◯ Once in 3 Months
Availability of Warehouse (Yes / No): _____	**Warehouse Location**

S No	**Commodity Type**	**Origin** (Landmark & Area Name)	**Destination** (Landmark & Area Name)	**Arrival Time**	**Vehicle Type** *(*Codes given at the end)*	**Weight Received** (in tons)	**Time Duration & location of Loading/Unloading** (mins)	**Time Taken for Trip** (mins)	**Trip Cost** (Rs)
0 (Eg)	Textile, Grey Cloth	Near CEPT University, Navrangpura	Zaveriward, Relief road	10 am	3	1 ton	20, Roadside	20 mins	Rs 1000
1									
2									
3									
4									
5									

3. Details of outgoing materials/ goods – Within Ahmedabad (for the last working day or the day goods arrived)									
Total number of distribution trips from the establishment today:									
Total number of customers visiting per day:									
S. No	**Commodity Type**	**Origin** (Landmark & Area Name)	**Destination** (Landmark & Area Name)	**Arrival Time** (eg:10am)	**Vehicle Type** *(*Codes given at the end)*	**Weight Carried** (in tons)	**Time Duration & location of Loading/Unloading** (mins)	**Time Taken for Trip** (mins)	**Trip Cost** (Rs)
1									
2									
3									
4									
5									
6									
7									
8									

Vehicle type

1	**2W**	**2**	**Auto**	**3**	**3W Cargo**	**4**	**Pedal Rickshaw /Handcart**	**5**	**Tempo (LCV)**	**6**	**Truck**	**7**	**Multi - axle Truck**	**8**	**Tractor**

APPENDIX H: PASSENGER THREE-WHEELER SURVEY FORM

Walled City Passenger Three-Wheeler Drivers' Survey

By CoE-UT, CRDF, CEPT University
Low Emission Zone - Walled City of Ahmedabad

Interviewer Name:		Date	_ _ / _ _ / 2024
Location of Survey		Time:	

1. Personal Information			
Respondent Name:		Mobile No.	
Residential Location:		Age:	
Address:		Personal Accident Insurance:	1. Yes 2. No

2. Choice of Occupation				
Household Members	Male:	Female:	No. of Earning Members:	

Household Income:

1.	Below 20,000
2.	20,001-30,000
3.	30,001-40,000
4.	40,001-50,000
5.	Above 50,000

Personal Earning:

1.	Below 20,000
2.	20,001-30,000
3.	30,001-40,000
4.	40,001-50,000
5.	Above 50,000

Education Level:

1.	Illiterate
2.	Up to Class V
3.	Class VI to IX
4.	Class X pass
5.	Class XII pass
6.	Graduate

Household Vehicle Ownership:

Type	Yes/ No	Number
Car		
Eco		
Auto		
2W		
Cycle		

Type of House:

Owned	1.	Bungalow	5. Chawl
	2.	Apartment	6. Slum
	3.	Row House	
Rent	House on Rent		

Employment Type (to drive auto):

Service	Full-Time	Part-Time
Metered Auto		
Shared Auto		
Ola/Uber/Rapido		
School Verdhi		

Business Reason	
Since how many years have you been in this business	

3. Vehicle Details	
Auto Manufacturer (eg: ATUL, Bajaj, Mahindra)	
New Vehicle or Used Vehicle (New/Second/Third Hand)	
Auto Maker Year	
Fuel Type (CNG, Diesel, Petrol, Electric)	
Engine Type (2-stroke / 4-stroke)	
Km Reading of the Auto	
Auto Ownership – Owned	
Auto Purchase Year	
Auto Purchase Price	
Loan Provider (Bank/ Private Lenders)	
Loan Amount (in Rs)	
Down Payment (in Rs)	
Total Number of EMI	
EMI amount per month (in Rs)	
Loan Repayment (completed/ ongoing)	
Rented Vehicle	
Daily Rent (in Rs)	
Fuel Management:	1. Returning empty 2. Refueling before return 3. Keeping Receipts
Owner's Name & Contact No.	

Number of Autos with Owner					
Other Details					
Insurance Amount (last yr.)					
Permit Registration No.		Duration (years)		Cost (in Rs)	
Fuel Cost per day (in Rs)					
Vehicle Servicing Cost per month (in Rs)		Location	Service Centre / Personal	Servicing Interval (in months)	
Maintenance Cost per months (in Rs)		Type of repair		Maintenance Interval (in months)	
Expected Vehicle Resale Value (current year)					
4. Trip Information					
From where you start operation (location of the auto stand)?					
Predominant Routes and Via Stops 1 2 3 4					
Number of trips in a day (Up + Down)					
Number of Passengers (in a day)					
Working hours / day (time range)	1. Morning time range 2. Evening time range				
Average Income (INR per day):	1. Weekday 2. Weekend				
Average km operated per day:	1. Weekday 2. Weekend				
Where do you operate?	1. Within Old City 2. Outside Old City				
Do you use Auto for Goods Transport? No / Yes	When? How much do you earn daily?				
Do you also operate as a school auto? No / Yes	If yes, Earning/ month:				
5. Electric Three-wheeler Awareness Details					
Are you aware of e-Auto or e-Rickshaw?	No / Yes				
Do you know about the subsidy amount? No / Yes	If yes, then Subsidy amount (in Rs.):				
Are you aware of the Total Cost of e-Auto or e-Rickshaw? No / Yes	If yes, then price:				
Are you interested in buying an e-Auto or e-Rickshaw? No / Yes	If no, reason:				

APPENDIX I: FREIGHT OPERATOR SURVEY FORM

CRDF CEPT RESEARCH AND DEVELOPMENT FOUNDATION | CEPT UNIVERSITY

Walled City Freight Operator Survey

By CoE-UT, CRDF, CEPT University

Low Emission Zone - Walled City of Ahmedabad

HIGH VOLUME TRANSPORT APPLIED RESEARCH

Interviewer Name:		Date	_ _ / _ _ / 2024
Location of Survey		Time:	

1. Personal Information

Respondent Name:		Mobile No.	
Residential Location:		Age:	
Address:		Personal Accident Insurance:	1. Yes 2. No

2. Choice of Occupation

Household Members	Male:	Female:	No. of Earning Members:

Household Income:

1.	Below 20,000
2.	20,001-30,000
3.	30,001-40,000
4.	40,001-50,000
5.	Above 50,000

Personal Earning:

1.	Below 20,000
2.	20,001-30,000
3.	30,001-40,000
4.	40,001-50,000
5.	Above 50,000

Education Level:

1.	Illiterate
2.	Up to Class V
3.	Class VI to IX
4.	Class X pass
5.	Class XII pass
6.	Graduate

Household Vehicle Ownership:

Type	Yes/ No	Number
Car		
Eco		
Auto		
2W		
Cycle		

Type of House:

Owned	1. Bungalow	5. Chawl
	2. Apartment	6. Slum
	3. Row House	
Rent	House on Rent	

Employment Type (to drive freight):

Weekday	Weekend
1. Full time	1. Full time
2. Part time	2. Part time

Average Income (INR per day):		Average km operated per day:	
Weekday		Weekday	
Weekend		Weekend	
Business Reason			
Since how many years have you been in this business			

3. Vehicle Details

Vehicle Type (3W Auto, 3W Goods, LCV, MCV)		
Vehicle Manufacturer & Model (eg: ATUL Shakti, Ashok Leyland Dost+, Bajaj Maxima C, Eicher Pro2050, Mahindra Jayo, TATA Gold SFC)		
New Vehicle or Used Vehicle (Second/ Third Hand)		
Vehicle Maker Year		
Fuel Type (CNG, Diesel, Petrol, Electric)		
Vehicle Capacity (tonne)		
Engine Type (2-stroke / 4-stroke)		
Km Reading of the Vehicle		
Mileage of Vehicle (in km/l)	Empty:	Fully Loaded:
Vehicle Ownership – Owned		
Vehicle Purchase Year		
Vehicle Purchase Price (in Rs)		
Loan Provider (Bank/ Private Lenders)		
Loan Amount (in Rs)		
Down Payment (in Rs)		
Total Number of EMI		

EMI amount per month (in Rs)						
Loan Repayment (completed/ ongoing)						
Rented Vehicle						
Daily Rent (in Rs)						
Fuel Management:	1. Returning empty		2. Refueling before return		3. Keeping Receipts	
Owner's Name & Contact No.						
Number of Vehicles with Owner						
Other Details						
Insurance Amount (last yr.)						
Permit Registration No.		Duration (years)		Cost (in Rs)		
Helper appointed (Yes/ No)		Cost per day (in Rs)				
Fuel Cost per day (in Rs)						
Cost of Vehicle Servicing (Rs - Monthly)		Location	Service Centre / Personal	Interval (in Months)		
Maintenance Cost (Rs - Monthly)		Type of repair		Interval (in Months)		
Expected Vehicle Resale Value (current year)						

4. Trip Information

S No	Commodity Type	Origin (Landmark & Area Name)	Start Time	Destination (Landmark & Area Name)	End Time	Trip Length (km)	Weight Received (in tons)	Location of Loading/ Unloading & Time Duration	Location of Parking, Cost & Time Duration
0 (Eg)	Textile, Grey Cloth	CEPT University, Navrangpura	10 am	Zaveriward, Relief road	10:30 am	5 km	1 ton	Roadside, 20 mins	Kalupur, Rs 20, 15 mins
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

5. Electric Freight Vehicle Awareness Details

Are you aware of electric freight vehicles?	No / Yes
Do you know about the subsidy amount? No / Yes	If yes, then Subsidy amount (in Rs.):
Are you aware of the Total Cost of Electric Vehicle? No / Yes	If yes, then price:
Are you interested in buying an electric vehicle? No / Yes	If no, reason:

APPENDIX J: QUESTIONNAIRE OF FOCUS GROUP DISCUSSION WITH RESIDENCE

- Travel Characteristics
  - Which modes of transport do you use most often for getting around the city? Are they convenient?
  - How often women travel independently and are there specific times of the day when they feel safe to travel?
  - How far is the nearest school from your home? How long does it typically take for children to reach the school? Which mode do they use?
  - What are the main transportation challenges you face living in the walled city while using PT, walking and IPT?
  - How often do you experience traffic congestion and how does it affect your daily routine?
  - Is parking a significant issue in your area? How do you typically manage it?
  - Have there been any incidents that made you or others in your household feel unsafe while travelling? How did you respond?
- Air Quality Issues
  - How concerned are you about air quality in the walled city? Do you notice it affecting your health or daily life?
  - What do you think are the main contributors to air pollution in your locality?
  - Have you or your family experienced health issues that you believe are related to poor air quality?
- Awareness of Electric Vehicles
  - How familiar are you with electric vehicles? Do you understand their benefits for air quality and the environment?
  - Would you consider purchasing an electric vehicle? What would influence your decision to do so?
  - What do you see as the biggest obstacles to adopting electric vehicles?
- What improvements do you suggest making transportation and air quality better in the walled city?
- How do you think residents can work together to address these challenges?

APPENDIX K: PROFILE OF THE NEIGHBOURHOODS

Mahurat Pol

It is one of the oldest residential neighbourhoods located in the walled city, consisting of around 30 households, mostly second and third generation families. The neighbourhood is located near Manek Chowk, which is a famous market for jewellery and utensils during the day and a popular food hub at night. Men are involved in work at different parts of the city and women are engaged in care giving. Male working population leaves for work at 8 am in 2Ws and returns by 8 pm as traffic is manageable during these hours. Women depend on men for longer commutes, while those employed prefer two-wheelers. Children's schooling takes place nearby with private transportation available during pick up and requires parents to be involved in after school pick-up. Public transportation is largely underutilised due to poor last-mile connectivity.

Jugaldas Nu Dhelu

The neighbourhood located near Raipur Darwaja is in a high traffic area surrounded by commercial establishments and it is home to low-income communities. The residents work in labour market, sales and factories, where women particularly are involved in informal labour roles. The community heavily relies on public and intermediate public transport, which is readily available and used for both work and non-work trips. Many women work in Manek Chowk, primarily in informal labour roles, who prefer walking to work. Children travel about 500 metres to school, with private vehicles used for pick-up and drop-off.

Shahpur Pol

A 150-year-old neighbourhood located is home to a mixed-income community. The pol is located within the Shahpur market but remains secluded from the main road. Many residents are employed in privately-owned businesses or the service industry. Residents use both 2Ws and 4Ws for commuting, with about 60% favouring two-wheelers, which are popular among both men and women. Women also prefer shared autorickshaw due to their shorter wait times and flexible stops. Children attend the school nearby and many now prefer to be dropped off by private vehicles. The proximity to the metro is considered a significant advantage. Residents report using both the metro and AMTS buses, with the metro being preferred for non-work trips.

Mahalakshmi Pol

The neighbourhood located near Delhi Darwaja consists of around 60 low-income households. Men are typically employed as salesman or security guards, while 50% of the women work as domestic helpers. Shared autorickshaw is the preferred mode of transportation in this neighbourhood and only a few residents own two-wheelers. Shahpur metro station, located 700 m away, is seldom used by the residents, except occasionally for leisure trips. Children typically commute to school by walk or are dropped off by two-wheelers, as the schools are within a 500 m radius.

Ranchod Khadi

It is one of the oldest residential neighbourhoods, consisting of 30 to 50 households and located near Kalupur Swaminarayan Temple. The residents belong to high-income groups, with most men engaged in privately owned businesses, while women are primarily caregivers working within the vicinity of the settlement. The most commonly used modes of transport are 2Ws and walking, due to the close proximity of workplaces. Children commute to school via private pick-up and drop-off services, with travel times ranging from 20 to 30 minutes.

Jagganath Ni Chhali

The neighbourhood is located near Jamalpur market, housing around 120 to 150 low-income households. The majority of men work as autorickshaw drivers or in loading and delivery services, while some are employed informally in the vegetable market. Less than 10% of women are employed, primarily in sales roles. Despite easy access to public transport, it is not a preferred option for most residents. Women tend to use shared autorickshaw or walk, while men favour 2Ws and 3Ws for commuting. Few children attend school due to the lack of nearby facilities, while those who do rely on private transport for a 10 to 15 minutes commute

Location of FGDs

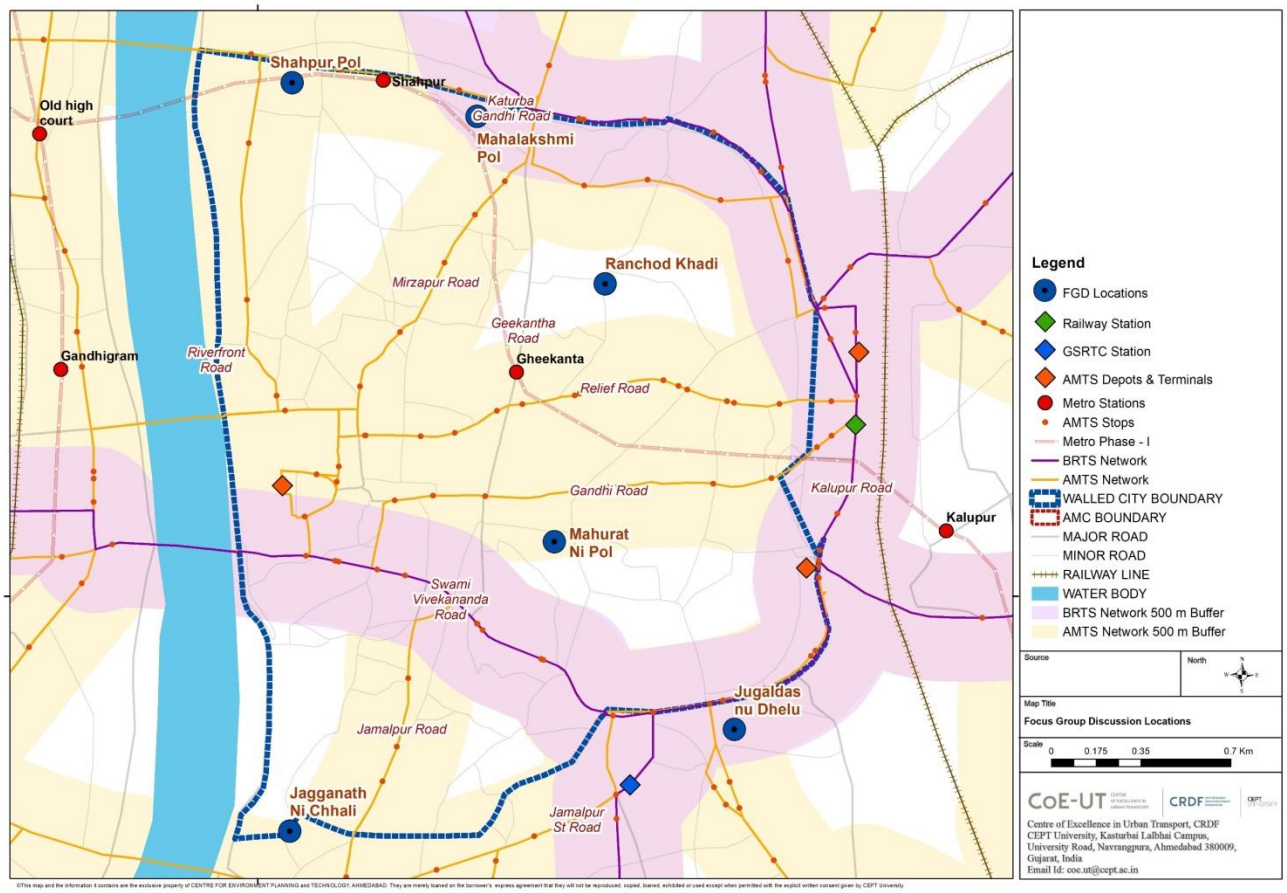


Figure 6-18 Locations of Focus Group Discussion with Residents

Source: CoE-UT, CRDF

APPENDIX L: SCENARIO COMPARISON IN REDUCTION OF POLLUTANTS

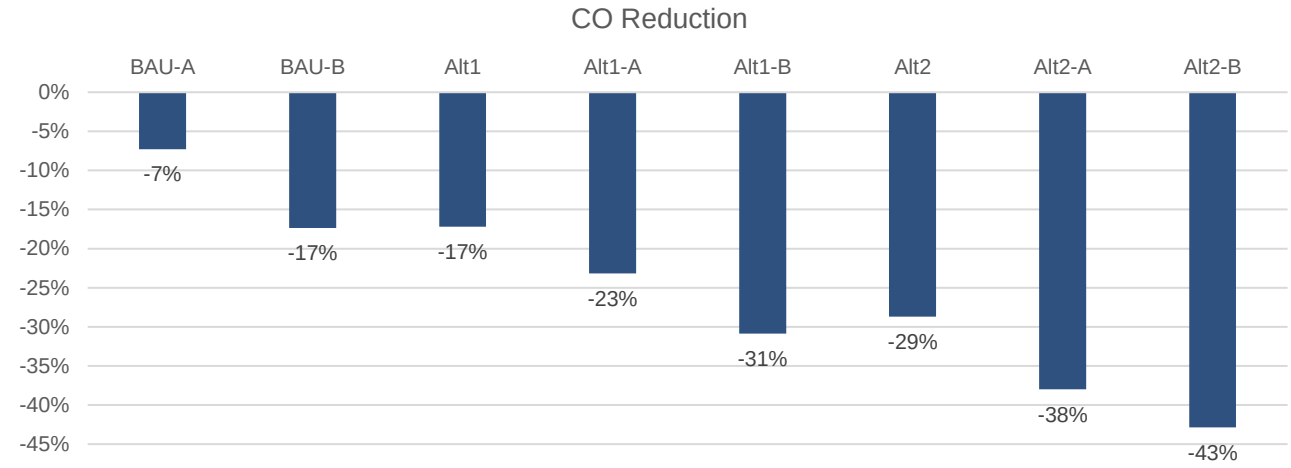


Figure 6-19 Reduction in CO compared to BAU scenario

Source: CoE-UT, CRDF

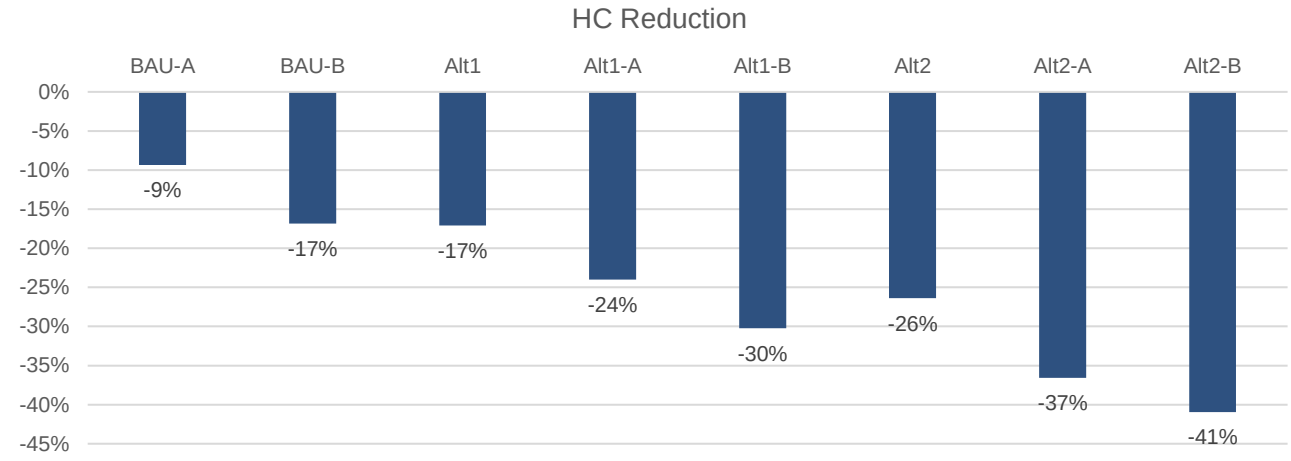


Figure 6-20 Reduction in HC compared to BAU scenario

Source: CoE-UT, CRDF

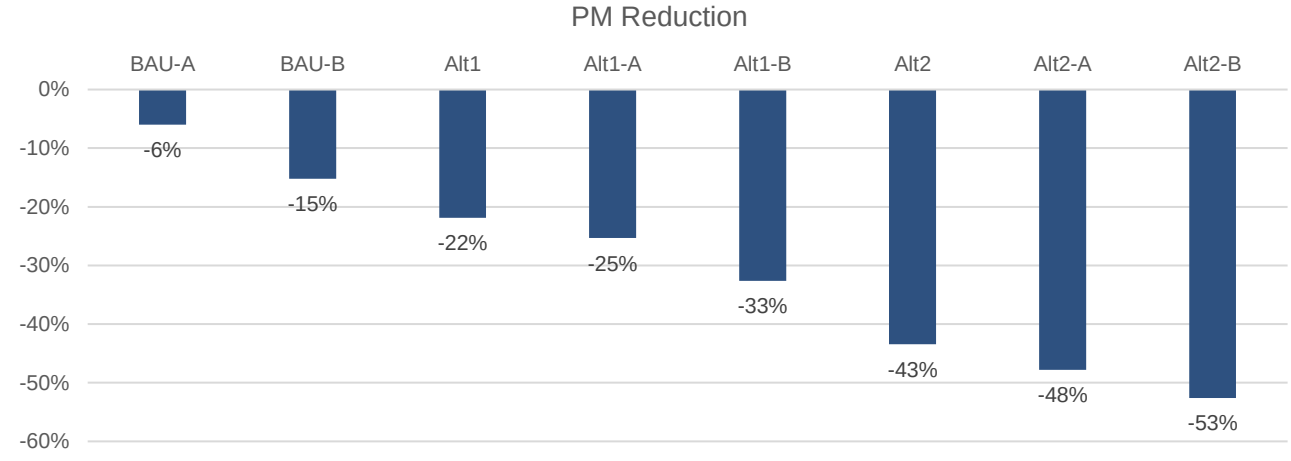


Figure 6-21 Reduction in PM compared to BAU scenario

Source: CoE-UT, CRDF

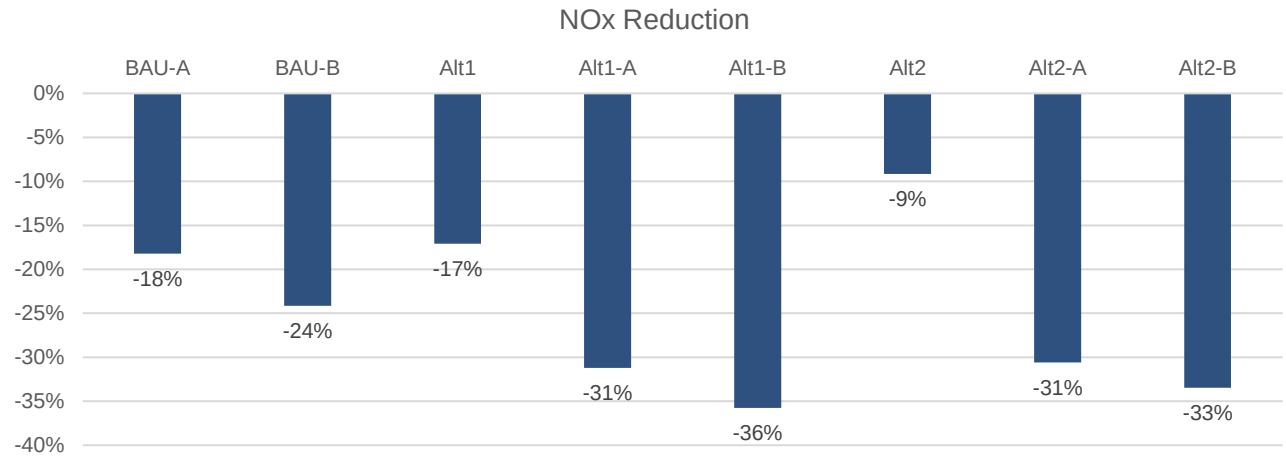


Figure 6-22 Reduction in NOx compared to BAU scenario

Source: CoE-UT, CRDF

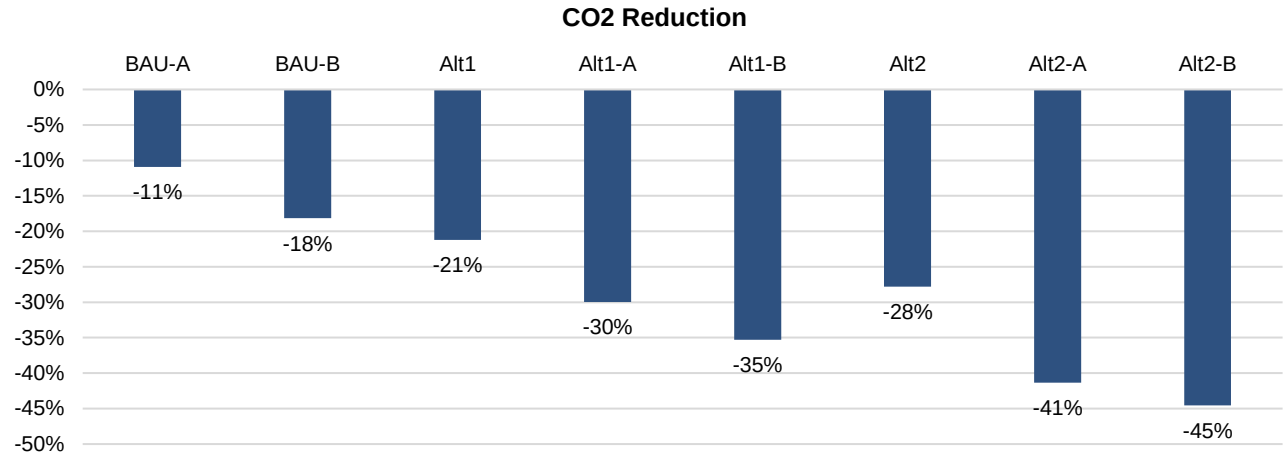


Figure 6-23 Reduction in CO2 compared to BAU scenario

Source: CoE-UT, CRDF

APPENDIX M: COMPARISON OF EMISSION FACTORS ACROSS VEHICLE TYPE, FUEL AND TECHNOLOGY

Table 6-9 Comparison of Emission Factors of Vehicles w.r.t. fuel type and technology

Vehicle Type	Fuel Type	Vehicle Technology	Times of BS VI Technology			
			CO	HC	NOx	PM
2W	P	BS I	8	20	13	38
		BS II	4	11	9	28
		BS III	3	7	6	23
		BS IV	2	2	5	5
3W	CNG	BS I	10	5	7	12
		BS II	3	16	5	2
		BS III	2	11	3	2
		BS IV	2	2	2	1
	D	BS I	23	14	11	15
		BS II	5	12	8	4
		BS III	2	7	6	2
		BS IV	2	2	2	2
	P	BS I	6	27	5	2
		BS II	3	16	5	2
		BS III	2	11	3	2
		BS IV	2	2	2	1
4W	CNG	BS I	3	3	4	4
		BS II	3	3	4	4
		BS III	2	2	2	2
		BS IV	1	1	1	1
	D	BS I	4	9	16	68
		BS II	4	9	16	48
		BS III	1	4	6	10
		BS IV	1	2	3	6
	P	BS I	3	3	4	4
		BS II	3	3	4	4
		BS III	2	2	2	2
		BS IV	1	1	1	1
LCV	CNG	BS I	4	4	4	29

Vehicle Type	Fuel Type	Vehicle Technology	Times of BS VI Technology			
			CO	HC	NOx	PM
		BS II	4	4	4	29
		BS III	4	4	4	29
		BS IV	1	1	1	5
	D	BS I	2	2	4	33
		BS II	2	2	4	33
		BS III	2	2	4	33
		BS IV	1	1	3	6

Source: CoE-UT, CRDF

APPENDIX N: MARKET ASSESSMENT OF ELECTRIC LIGHT COMMERCIAL VEHICLES AND THREE-WHEELERS

Table 6-10 LCVs Model in Indian Market

Manufacturer	Mahindra	Tata	Switch	EKA	Euler	Jupiter
Model	Zeo	Ace EV	IeV4	K1.5	T1250	JEM TEZ
						
Certified Range (km)	160	154	120	180	140	100
Battery Capacity (kWh)	21.3	21.3	32.2	32	30	14
Gross Vehicle Weight (kg)	1,675	1,840	3,490	2,510	2,600	2,200
Payload (kg)	765	600	1700	700	1250	1000

Source: OEMs Website

Table 6-11 Goods E-3W Models In Indian Market

Manufacturer	Kinetic Green	Bajaj	Mahindra	Piaggio	Euler
Model	Safar Jumbo	Maxima XL E-TEC	Treo Zor Grand	Ape E Xtra Fx	HiLoad EV
					
Certified Range (km)	140	149	153	110	130
Battery Capacity (kWh)	10.7	8.9	10.24	8	13
Gross Vehicle Weight (kg)	990	805	998	975	1,413
Payload (kg)	500	377	400	480	688

Source: OEMs Website

Table 6-12 Passenger E-3W Models in Indian Market

Manufacturer	Piaggio	Mahindra	eBlu	Bajaj
Model	Ape E-City FX	Treo	Rozee	RE E-TEC 9.0
				
Certified Range (km)	145	130	140	178
Battery Capacity (kWh)	8	7.37	10	8.9
Top Speed (kmph)	45	55	50	45
Seating Capacity	D+3	D+3	D+3	D+3

Source: OEMs Website

APPENDIX O: POTENTIAL LOCATIONS OF LIGHT COMMERCIAL VEHICLE AND THREE-WHEELER

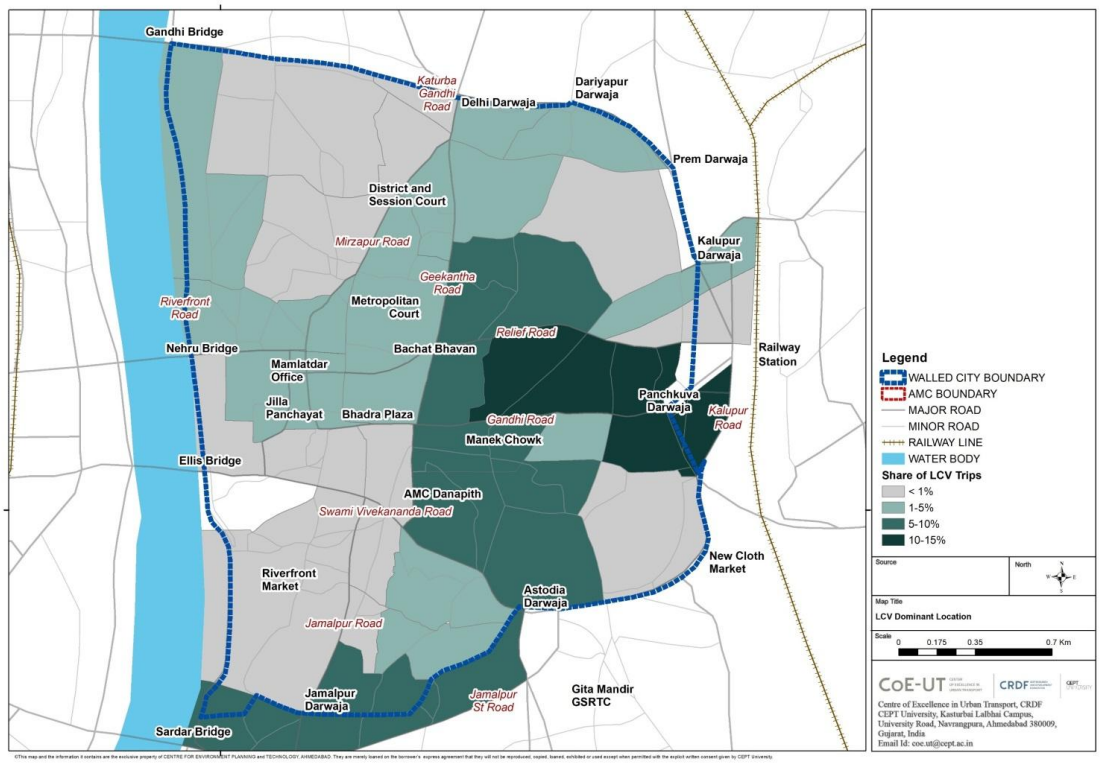


Figure 6-24 TAZ wise share of LCVs incoming trips

Source: Activity Survey Data 2024, CoE-UT, CRDF

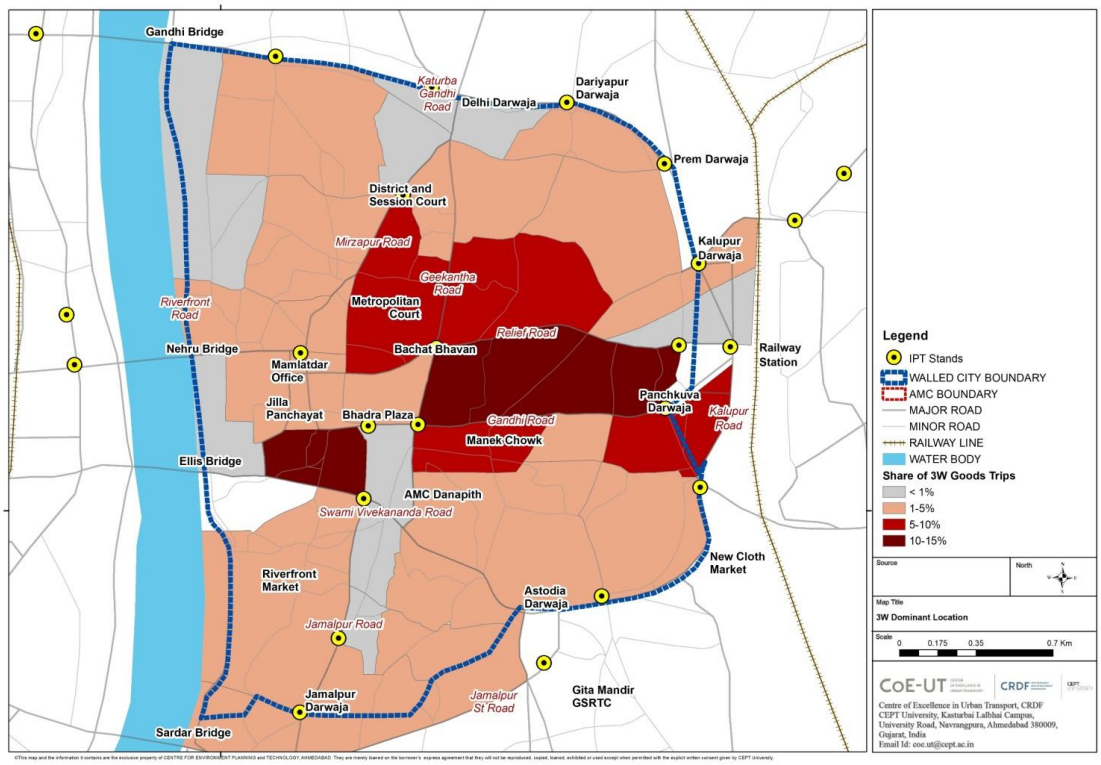


Figure 6-25 TAZ wise share of 3W goods incoming trips and IPT stands

Source: Activity Survey Data 2024, CoE-UT, CRDF

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