REIMAGINING URBAN MOBILITY IN INDIAN SMART CITIES: AN INTEGRATED APPROACH USING SMART MOBILITY SOLUTIONS IN VADODARA

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ABSTRACT

Urban growth is neither accidental nor entirely organic; it is continuously shaped by human activities, socio-economic dynamics, and the physical infrastructure that frames daily movement. Yet, contemporary urban expansion across the globe is increasingly marked by dispersed, low-density sprawl that results in inefficient land consumption, environmental stress, and weakened social cohesion. Such fragmented development patterns limit opportunities for interaction, constrain innovation, and compromise the efficiency of cities. For urban centres to function productively, accessibility—to goods, services, and opportunities—must be prioritized. This calls for a shift from transport systems focused solely on vehicular movement to mobility paradigms that emphasize sustainable, multimodal, and human-centric travel options. Modern and Sustainable mobility is fundamentally about connecting people and places, not merely expanding transport infrastructure. Urban planning and design must therefore focus on enhancing accessibility, promoting optimal urban densities, and supporting active modes of travel such as walking and cycling. These approaches help create inclusive, resilient, and energy-efficient cities. Aligned with these principles, this research develops a comprehensive urban mobility framework grounded in the Smart City Mission of India, under which Vadodara was selected as one of the 100 smart cities in 2015. The study proposes an integrated strategy that combines sustainable transport solutions, technological advancements, and urban design interventions to create a smart, connected, and people-friendly mobility system. Key initiatives include restructuring larger urban blocks into walkable, human-scale networks, advancing Non-Motorized Transport (NMT) infrastructure, and incorporating intelligent mobility systems. The overarching aim is to enable holistic urban innovation and promote a sustainable, equitable mobility future for the city.

KEYWORDS: Urban centres, Sustainable mobility, Smart City Mission, sustainable transport solutions, Non-motorized Transport (NMT)

INTRODUCTION

Urbanization has emerged as one of the most defining processes of the 21st century, particularly in developing nations such as India. Cities continue to grow rapidly in both population and spatial extent, driven by economic opportunities, migration and infrastructural development. However, this growth has often occurred in an unplanned and fragmented manner, resulting in urban sprawl, inefficient land use and increasing dependence on private motorized transport. These patterns weaken social interaction, limit innovation and reduce overall urban efficiency.

Traditionally, urban mobility planning has prioritized vehicular movement and road expansion as solutions to congestion and accessibility issues. Such approaches have proven unsustainable, leading to increased traffic congestion, environmental degradation, road safety concerns and the marginalization of pedestrians and cyclists. In contrast, contemporary planning paradigms emphasize accessibility over mobility—focusing on how people reach destinations rather than how vehicles move. Contemporary urban discourse increasingly emphasizes accessibility over mobility, advocating for cities that enable people to reach destinations through shorter distances, mixed land uses and multiple transport options. This shift aligns with global principles of sustainable urban mobility, which promote walking, cycling, public transport and technology-enabled systems as integral components of urban infrastructure.

In this context, sustainable urban mobility has emerged as a crucial framework that integrates land use planning, transport systems and urban design to create efficient, inclusive and environmentally responsible cities. The Smart City Mission initiated by the Government of India in 2015 seeks to operationalize these principles through Area-Based Development (ABD), technological interventions and citizen-centric planning.

Vadodara, a mid-sized city in Gujarat, presents a compelling case for examining the integration of sustainable mobility principles within the Smart City framework. With relatively short trip lengths, a compact urban form and a growing demand for efficient transport solutions, the city offers significant potential for reimagining mobility through active transport, multimodal systems and intelligent infrastructure.

Study Area: Vadodara City

Vadodara is the third-largest city in Gujarat and a major administrative, educational, and cultural center. The city exhibits a compact urban structure, with a high concentration of institutional, commercial, and recreational land uses in its central areas. Despite having a well-developed road network, Vadodara faces significant mobility challenges, including low public transport share, increasing private vehicle ownership, congestion, and poor pedestrian infrastructure.

The ABD zone identified under the Smart City Mission spans approximately 1,698 acres and includes the railway station, central and city bus terminals, Maharaja Sayajirao University campus, major commercial districts, and key recreational spaces such as Sayaji Baug. This area represents the city's highest travel demand zone and is

therefore ideal for testing integrated mobility interventions.

Figure 1: Location of Vadodara in Gujarat and India.

AIM AND PURPOSE

The primary aim of this research is to develop a comprehensive and integrated urban mobility framework for Vadodara City that promotes sustainable, accessible and human-centric mobility within the Smart City Mission context. The purpose of the study is to explore how Area-Based Development (ABD), Non-Motorized Transport (NMT) and Intelligent Transport Systems (ITS) can collectively address existing mobility challenges in a mid-sized Indian city. The focus of the study is to examine the role of smart mobility solutions in addressing challenges arising from urban sprawl, inefficient land use and fragmented transport networks. The research seeks to:

- Promote accessibility-based planning over vehicle-oriented mobility
- Encourage active travel through walkability and cycling infrastructure
- Integrate Non-Motorized Transport (NMT) with public transport systems
- Leverage intelligent mobility technologies for efficient transport management
- Create a model that is adaptable to other mid-sized Indian cities

RESEARCH METHODOLOGY

Study Approach

This study adopts a qualitative, exploratory and case-study–based research methodology to examine urban mobility challenges and propose an integrated smart mobility framework for Vadodara city. The methodology is derived from the author's thesis research and aligns with principles of sustainable urban mobility, Area-Based Development (ABD) and smart city planning. The approach combines policy review, spatial analysis, mobility assessment and design-based evaluation to ensure a comprehensive understanding of the urban mobility system. Vadodara city was selected as the case study due to its classification as a mid-sized Indian city under the Smart City Mission, its compact urban structure, relatively short trip lengths and the presence of a defined Area-Based Development (ABD) zone. These characteristics make Vadodara an appropriate context for evaluating sustainable and technology-enabled mobility strategies that can be replicated in similar Indian cities.

Data Sources and Analysis

The methodology involved: Review of Smart City Mission guidelines and Vadodara Smart City proposals

- Analysis of existing land use patterns, road hierarchy and transport infrastructure
- Study of travel characteristics, including trip length distribution and modal share
- Identification of key activity nodes such as railway stations, bus terminals, institutional campuses and commercial areas
- Evaluation of proposed mobility interventions including Public Bicycle Systems, walkability improvements and intelligent transport systems

The ABD zone was selected as the primary focus due to its high concentration of transport demand and its role as a demonstrative area for city-wide replication. The Area-Based Development (ABD) zone was selected as the primary study area due to its dense concentration of transport hubs, institutional campuses, commercial areas and public spaces (Fig. 3). Secondary data from Smart City proposals, mobility plans, and urban studies were analyzed to identify existing mobility conditions and gaps.

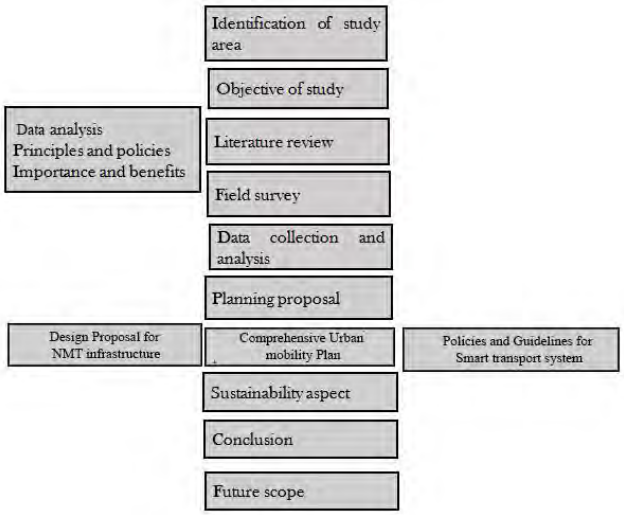
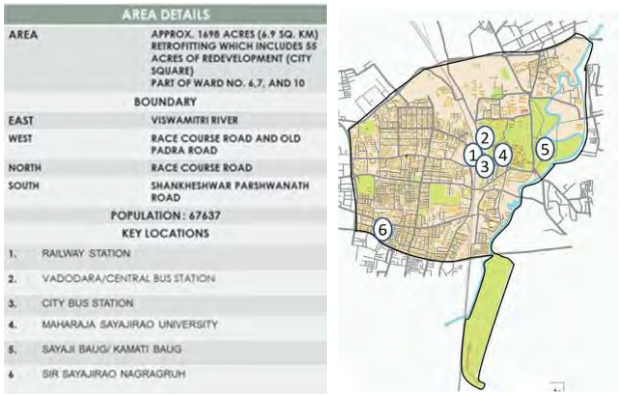


Figure 2: Research methodology framework integrating spatial analysis and mobility assessment



AREA DETAILS	
AREA	APPROX. 1698 ACRES (6.9 SQ. KM) RETROFITTING WHICH INCLUDES 55 ACRES OF REDEVELOPMENT (CITY SQUARE) PART OF WARD NO. 6,7, AND 10
BOUNDARY	
EAST	VISWAMITRI RIVER
WEST	RACE COURSE ROAD AND OLD PADRA ROAD
NORTH	RACE COURSE ROAD
SOUTH	SHANKHESHWAR PARSHWANATH ROAD
POPULATION : 67637	
KEY LOCATIONS	
1.	RAILWAY STATION
2.	VADODARA/CENTRAL BUS STATION
3.	CITY BUS STATION
4.	MAHARAJA SAYAJIRAO UNIVERSITY
5.	SAYAJI BAUG/ KAMATI BAUG
6	SIR SAYAJIRAO NAGRAGRUH

Figure 3: Area-Based Development (ABD) zone and major activity nodes in Vadodara

FINDINGS, ANALYSIS AND INFERENCE

- **Urban Structure and Spatial Distribution of Activities**

Findings

The urban structure map of Vadodara as shown in the fig illustrates a **compact city core** with high concentration of residential, commercial, institutional and public activity

nodes within short distances of each other. Major employment centres, educational institutions, transit nodes, and recreational spaces are distributed primarily along arterial and sub-arterial corridors within the central city and the Area-Based Development (ABD) zone.

The land-use pattern reveals a **mixed-use character**, particularly within the ABD area, where residential neighbourhoods coexist with commercial streets, public institutions, and social infrastructure.

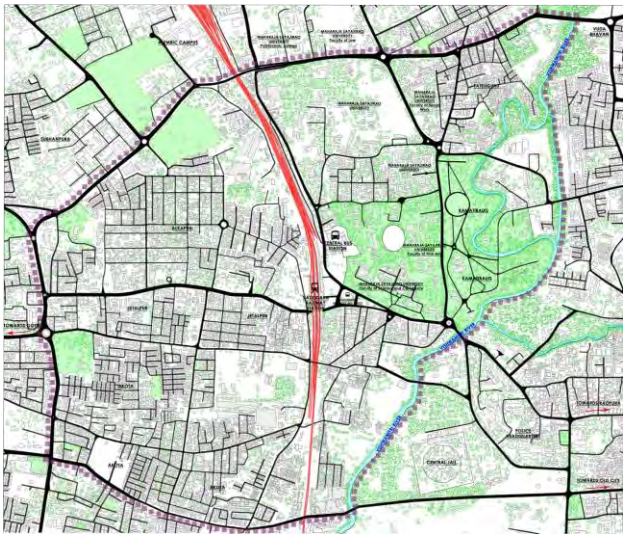


Figure 4: Urban structure of ABD area, Vadodara city. Source: Primary survey.

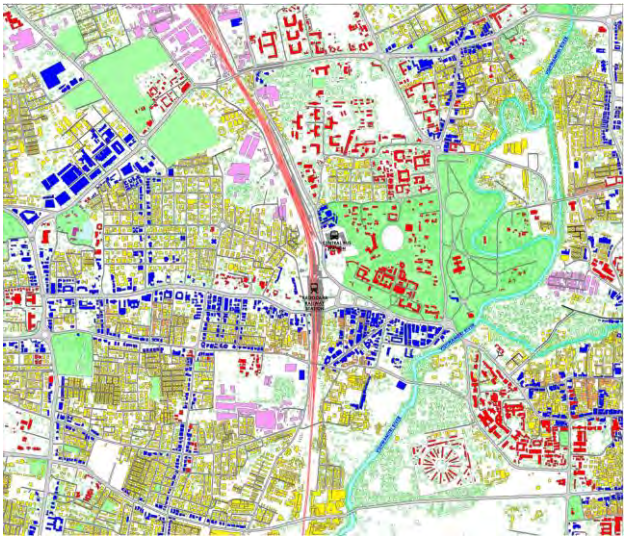


Figure 5: Land-use distribution of ABD area, Vadodara city Source: Primary Survey.

Analysis

The compact nature of the city and the mixed-use urban fabric significantly reduce travel distances and increase the feasibility of walking, cycling and short-duration public transport trips. Unlike sprawled metropolitan regions, Vadodara's spatial configuration supports a proximity-based mobility system rather than long-distance commuting. However, despite this inherent spatial advantage, the urban structure has not been leveraged to promote sustainable modes. Transport infrastructure development has remained vehicle-oriented, failing to respond to the city's walkable scale.

- **Area-Based Development (ABD) Zone Characteristics**

Findings

The ABD map in the thesis identifies a strategically selected zone comprising:

- Railway station and city bus terminal
- Educational campuses
- Commercial corridors
- Public and recreational spaces
- Dense residential neighborhoods

The map shows that the ABD zone functions as a high-intensity mobility catchment, generating significant pedestrian and vehicular movement throughout the day

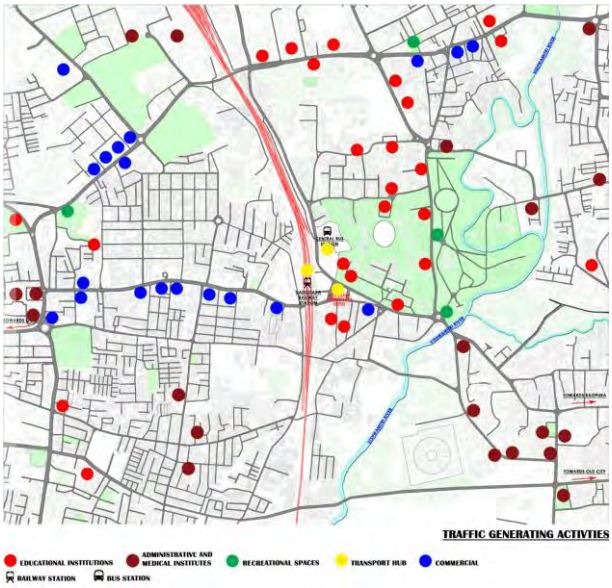


Figure 6: Area Based Development zone with key activity generators. Source: Primary Survey.

Analysis

The concentration of trip origins and destinations within the ABD area creates overlapping movement patterns that are currently inefficiently served by fragmented transport modes. The absence of integrated mobility infrastructure results in congestion, unsafe pedestrian conditions and poor last-mile connectivity.

Given its functional density, the ABD zone offers the maximum potential impact for pilot mobility interventions, which can later be scaled citywide.

- **Existing Road Network and Mobility Hierarchy**

Findings

The road network analysis map illustrates a clear hierarchy of arterial, sub-arterial, collector, and local streets. While arterial roads are wide and traffic-dominated, internal neighborhood streets remain underutilized as pedestrian connectors.

The map highlights:

- Overdependence on arterial corridors
- Limited permeability within large urban blocks

Absence of dedicated NMT corridors

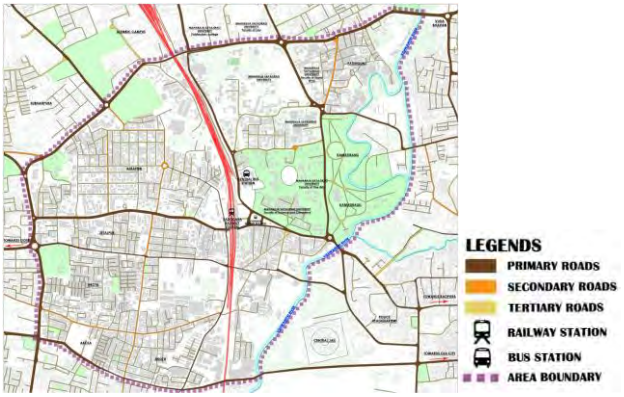


Figure 7: Existing road hierarchy and mobility network

Analysis

The prioritization of vehicular movement on major corridors has resulted in congestion and unsafe conditions for pedestrians and cyclists. Meanwhile, internal streets remain disconnected, forcing short-distance travellers onto high-speed roads. This disconnect between the road hierarchy and human-scale mobility exposes a fundamental mismatch between urban form and transport planning.

- **Trip Length and Modal Share Characteristics**

Findings

Trip length analysis presented in the report indicates that a significant proportion of daily trips fall within the 0–5 km range. Despite this, two-wheelers dominate the modal share, while walking and cycling remain underrepresented. The average trip length of the city is not more than 4.8 km. The average trip rate of the city is around 1.3 km, which includes walking trips.

Details regarding the various means of transit separately are given below

- NMT forms 40% of all trips. One-fifth of all trips in the city (19%) are already been made on bicycles.
- 68% trips are of less than 5km trip length and the share of IPT, bicycle, two-wheeler and walk takes over 90% mode share.
- The mode share of public transport is very low (only 6% share). The bus service, VTCOS (Vallabhaipur Transportation Co. Op. Society Pvt Ltd), suffers low ridership due to low frequency and poor service.
- Auto rickshaws have a mode share of 14%. They fill the gap created by the inefficient bus service and their share is on the rise catering to the demand unmet by public transit.
- Two wheelers are the dominant private mode for transit in Vadodara. They represent 36% of all commuting trips while cars account for only 5% of the modal share.

Analysis

Short travel distances are ideal for active mobility modes; however, inadequate pedestrian infrastructure, unsafe cycling conditions and lack of continuity discourage their use. This has resulted in avoidable reliance on motorized vehicles even for short trips.

- **Walkability and Urban Block Structure**

Findings

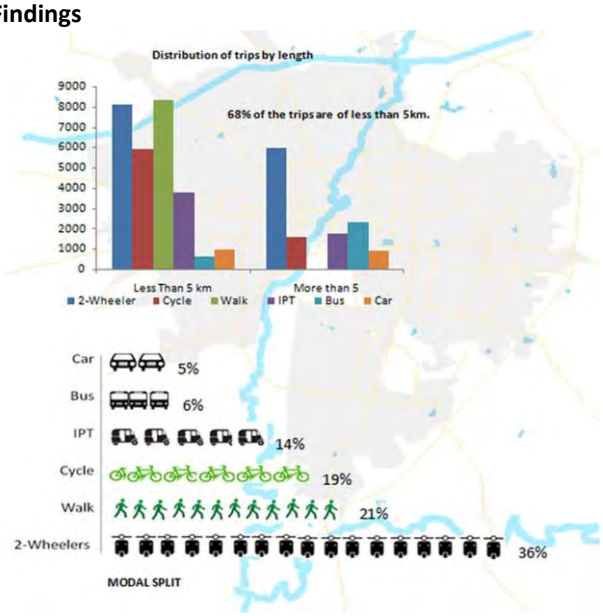


Figure 8: Travel distance and existing modal share in Vadodara, Source: CMP Vadodara, 2012

The block analysis diagram demonstrates that many urban blocks within the ABD zone are excessively large with limited internal permeability. Pedestrian movement is forced along long, indirect routes, discouraging walking.

Figure 8: Urban block restructuring to enhance walkability. Source: Authors thesis

Analysis

Large block sizes reduce pedestrian choice and increase walking distances. Breaking these into smaller, connected blocks enhances permeability, safety and accessibility, while also activating public life at the street level.

- **Non-Motorized Transport (NMT) Network**

The NMT network map proposes continuous pedestrian and cycling corridors connecting major activity nodes, public spaces and transit hubs within the ABD zone.

Figure 9: Proposed pedestrian and cycling network within the ABD zone, Source: Primary Survey

FINDINGS

Analysis

The proposed network addresses gaps in continuity, safety and legibility. By prioritizing NMT on selected corridors, the network establishes walking and cycling as primary modes rather than residual ones.

- **Public Bicycle System (PBS) Integration**

Findings

The Public Bicycle System (PBS) proposed in the ABD area is structured as a **shared, station-based, short-distance Mobility system** designed to strengthen first- and last-mile connectivity within the Area-Based Development (ABD) zone of Vadodara. The PBS station location map presented (Fig 11) identifies docking stations at key urban nodes such as:

- Railway station and bus terminals
- Educational and institutional campuses
- Commercial and mixed-use corridors
- Public open spaces and recreational areas
- High-density residential neighborhoods

The spatial distribution of stations indicates a uniform coverage pattern, with stations placed at walkable intervals to ensure accessibility and convenience for users.

Analysis

The PBS proposal (Fig 10) is strategically aligned with the city's compact urban structure and short trip lengths. Since a significant proportion of daily trips in Vadodara fall within the 0–5 km range, bicycles emerge as an efficient, non-polluting, and space-efficient mode of transport.

The station placement strategy demonstrates a clear understanding of:

- Catchment areas within walking distance
- Trip generators and attractors
- Integration with public transport nodes

By situating PBS stations near bus stops and railway terminals, the system facilitates seamless modal transitions, thereby addressing one of the key limitations of public transport—last-mile connectivity.

The system also responds to the lack of continuous cycling infrastructure by identifying preferred cycling corridors that align with proposed Non-Motorized Transport (NMT) networks. This integration ensures that bicycles are not treated as isolated elements but as part of a broader multimodal mobility framework.

Technological Integration and Smart Infrastructure

The PBS is supported by Intelligent Transport Systems (ITS) to improve operational efficiency and user experience. Key smart features proposed include:

- GPS-enabled bicycles for real-time tracking
- Automated docking and locking mechanisms
- Smart cards and mobile applications for access and payment
- Centralized monitoring and data management systems

These technological components enable data-driven decision-making related to bicycle redistribution, demand patterns, and system optimization.

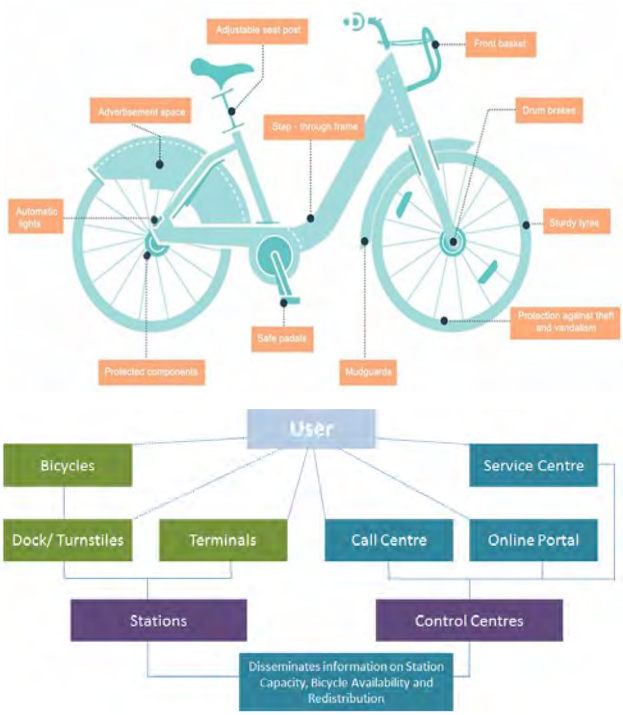


Figure 10:Components of the Proposed PBS system. Source: adapted from Guidance Document, IBI Group.

Social, Environmental and Urban Impact Analysis*From a social perspective, the PBS enhances mobility equity by* providing affordable transport options accessible to a wide range of users, including students, daily commuters and tourists. Environmentally, the system contributes to reduced carbon emissions and improved air quality by replacing short motorized trips. At an urban design level, PBS stations act as micro-mobility hubs, activating public spaces and reinforcing street-level activity. Their presence encourages increased pedestrian movement and supports the transition towards people-centric streets.

- **Inference**

The analysis of urban structure, mobility patterns and proposed interventions in Vadodara indicates that the city's mobility challenges are not primarily the result of insufficient infrastructure capacity, but rather of weak integration between land use planning, street design and transport systems. Vadodara's compact urban form, mixed land-use configuration and short average trip lengths provide favorable conditions for sustainable urban mobility; however, these spatial advantages have remained underutilized due to long-standing vehicle-centric planning practices.

The Area-Based Development (ABD) zone emerges as a critical spatial unit where mobility inefficiencies are most evident. High concentrations of activity nodes within close proximity generate intense short-distance travel demand, suggesting that focused, people-oriented interventions within this zone can deliver significant and scalable impacts at the city level. The study further identifies that large, impermeable urban blocks and arterial-dominated road hierarchies force short trips onto high-speed corridors, increasing conflicts between users and

compromising pedestrian safety. Restructuring these blocks into finer, more permeable networks enhances walkability and distributes movement more evenly across the street system. Despite the predominance of trips under 5 km, motorized two-wheelers dominate modal share, indicating that infrastructure quality, continuity and safety are more influential on mode choice than travel distance. The proposed Non-Motorized Transport (NMT) network and Public Bicycle System (PBS) address these gaps by strengthening pedestrian and cycling connectivity and improving first- and last-mile access. The integration of Intelligent Transport Systems (ITS) further enhances operational efficiency and adaptability of sustainable modes. Overall, the study infers that sustainable urban mobility in Indian Smart Cities must be approached as an integrated urban planning and design challenge, rather than a transport engineering exercise alone. The Vadodara case demonstrates that aligning ABD, NMT, PBS and ITS within a unified framework can create an accessible, inclusive and resilient urban mobility system.

CONCLUSION

This research highlights that urban mobility challenges in Indian cities arise not only from increasing travel demand but also from fragmented urban growth and vehicle-centric planning approaches. Through the case study of Vadodara, the study demonstrates that compact urban form, mixed land-use patterns and short trip lengths provide strong potential for sustainable urban mobility, yet remain underutilized due to weak integration between urban design and transport planning. The findings emphasize the effectiveness of Area-Based Development (ABD) as a focused framework for initiating mobility transformation. Targeted interventions within the ABD zone—such as enhanced walkability, Non-Motorized Transport (NMT) networks, and improved public spaces—demonstrate how accessibility and human-scale design can significantly influence travel behavior. The integration of Public Bicycle Systems (PBS) and multimodal connectivity strengthens first- and last-mile access while reducing dependence on private motorized vehicles. Furthermore, the incorporation of Intelligent Transport Systems (ITS) enhances operational efficiency and supports data-driven mobility management when applied to people-centric transport modes. In conclusion, the study establishes that sustainable urban mobility must be approached as an integrated urban planning and design challenge rather than a standalone transport issue. The proposed framework for Vadodara offers a replicable model for mid-sized Indian Smart Cities, demonstrating that aligning spatial planning, active mobility, shared systems and smart infrastructure can create accessible, inclusive and resilient urban mobility systems.

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