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Unveiling Travel Patterns and Challenges Considering Mixed Land Use and User Behavior in an Indian City

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Abstract: Transportation and land use are inextricably linked. Travel patterns are influenced by the location, design of new developments, and users' behavior. In many Tier II cities in India where rapid transit systems are unavailable, such as Vadodara, spatial and transportation planning lack integration with land use. This disconnect neglects user behavior and travel needs, resulting in congestion and pollution as ongoing, reactive challenges rather than being addressed through sustainable and proactive solutions. This research used a triangulation approach incorporating literature analysis, questionnaire surveys, and field observations to enhance the robustness of the results. After a comprehensive analysis, findings were derived from the user behavior, traffic patterns, and field observations for mixed land use. The study revealed a heavy reliance on private vehicles for work trips (53%) despite low satisfaction with sustainable transport options (average rating of 2.8 out of 5). Infrastructure issues, such as disorganized parking and pedestrian safety concerns, exacerbate congestion and pollution. This study recommends a Comprehensive Mobility Plan (C.M.P.) and a land use and transport integration (LUTI) cell to address these issues and promote sustainability. Future research should explore comparative studies, socioeconomic factors, and legal frameworks for sustainable development.

Keywords: mixed land use; transport integration; travel behavior; transport infrastructure; sustainable mobility

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1. Introduction

India, especially in Tier II cities where rapid transit systems are not available, is now facing a transportation crisis characterized by severe congestion, pollution, and insufficient infrastructure. This issue is worsened by fast urban expansion, increasing automobile ownership, and a lack of integrated land planning [1]. While it helps millions of people get around, provides jobs, and promotes the economy, India's rapid motor vehicle ownership and use causes damage to people's health, the environment, society, and resource consumption [2].

Sustainable urban transportation is a critical aspect of sustainable urban development, significantly influenced by land use patterns and user behavior [3]. In rapidly urbanizing regions like India, understanding travel patterns and addressing challenges related to mixed land use and user behavior are essential for fostering efficient and sustainable transportation systems [4]. This research paper delves into the intricate dynamics of transportation in an Indian city, focusing on the interaction between mixed land use and user behavior. Transportation and land use are inherently linked, with land use decisions shaping transportation demand and infrastructure [5]. Mixed land use, which integrates diverse activities within specific areas, offers opportunities for promoting sustainable transportation modes and reducing reliance on private vehicles [4,6]. Understanding

how mixed land use influences travel patterns and user behavior is crucial for designing transportation systems that cater to the needs of diverse urban populations [7,8].

Urban transportation and land use have been extensively studied, particularly in larger metropolitan areas, where the interplay between these two elements is often highlighted. For instance, Cervero discusses the critical link between urban transport and land use in developing countries, emphasizing the need for integrated planning [5]. Similarly, Bahadure and Kotharkar assess the sustainability of mixed-use neighborhoods, providing insights into travel behavior in urban settings [4]. However, much of the existing literature tends to focus on major cities, leaving a significant gap in understanding the dynamics in Tier II cities, such as Vadodara, India.

The relationship between land use and transport planning is a critical area of study, particularly in the context of urban sustainability. Previous research, such as the studies conducted in Bhopal and Nagpur, has highlighted the importance of integrating land use and transport planning to influence travel behavior and promote sustainable transportation modes. The Bhopal study emphasizes how integrated planning can reduce reliance on motorized transport by encouraging the use of public transport, walking, and cycling through strategic land use distribution and transport network planning [9]. Similarly, the Nagpur study assesses the sustainability of mixed-use neighborhoods by examining residents' travel behavior and perceptions, revealing that neighborhoods with a moderate mix of land uses are more sustainable [4].

User behavior plays a significant role in shaping transportation choices and preferences. Individual preferences, socioeconomic status, and accessibility to transportation options influence travel behavior [9,10]. By uncovering the underlying factors driving user behavior, policymakers and urban planners can devise targeted interventions to promote sustainable transportation modes and enhance urban mobility.

This research paper focuses on unveiling travel patterns and challenges in an Indian city, specifically emphasizing mixed land use and user behavior. Vadodara, a bustling city in Gujarat, faces significant transportation challenges, including traffic congestion and inadequate public transport [11]. According to *The Times of India* [12], the city's roads are frequently congested, leading to longer travel times. Public transport, primarily buses, struggles to meet demand, resulting in overcrowding and unreliable service.

Additionally, poor pedestrian infrastructure poses safety risks, hindering efforts to promote sustainable transportation [13,14]. Addressing these issues requires coordinated efforts to improve infrastructure and enhance urban mobility. This study aims to provide insights into how mixed land use influences travel patterns and user behavior in the context of urban transportation in Tier II cities through a comprehensive literature analysis, questionnaire surveys, and field observations. The findings of this research paper will contribute to the existing body of knowledge on transportation dynamics in Indian cities and provide valuable insights for policymakers, urban planners, and researchers. By understanding the complexities of mixed land use and user behavior, cities can develop strategies to address transportation challenges effectively and move towards more sustainable and livable urban environments.

Research on integrating land use and transportation has shown success in major cities like Mumbai and Delhi, demonstrating reduced car dependency and improved public transport use [15,16]. Internationally, integrated planning in cities like Copenhagen, Singapore, and Curitiba has enhanced urban accessibility and reduced congestion [17–19]. However, most studies have focused on Tier I cities, leaving a significant gap regarding Tier II cities like Vadodara. These cities face rapid urbanization, congestion, and inadequate infrastructure but lack comprehensive studies that link mixed land use, travel behavior, and existing transport systems [20]. This research addresses this gap, providing insights relevant to urban planners in similar developing regions globally.

2. Literature Review

The relationship between land use characteristics and transportation is critical to urban planning and sustainability. Transportation and land use are interconnected elements that influence cities, towns, and human settlements' physical, social, and economic structures [21]. Residential, commercial, recreational, and office activities are integrated within a specific area in mixed land use. Instead of segregating these activities, as was commonly carried out after the Industrial Revolution, mixed zoning promotes a balanced land use distribution [4]. Land use transport integration involves synchronizing land use and transportation systems designed to enhance urban efficiency, sustainability, and livability [22,23]. This approach ensures that building and infrastructure development aligns with transportation networks, improving accessibility and reducing travel distances. Integrated models T.O.D. (transit-oriented development) and T.N.D. (transit node development) for comprehensive planning, and B.R.T. (bus rapid transit) and complete streets, combine socioeconomic data, travel patterns, and infrastructure. Transit node development (T.N.D.), similar to transit-oriented development (T.O.D.), integrates residential, commercial, and recreational areas around public transit hubs to encourage sustainable land use. T.O.D. increases density and mixed-use development near transit stations, decreasing automobile usage and improving urban livability. T.O.D. regions encourage development and reduce urban sprawl, promoting sustainable growth. T.O.D. promises sustainable urban development despite policy and infrastructural issues [24,25].

Bus rapid transit (B.R.T.) systems significantly affect land use and travel behaviors. Bus rapid transit (B.R.T.) increases usage by attracting people away from cars and onto public transportation, which is both efficient and dependable [26]. Increased density and the creation of mixed-use areas are two outcomes of the increased accessibility that encourages commercial and residential growth [27]. Reducing urban sprawl, B.R.T. promotes the development of compact, transit-oriented neighborhoods [28]. Policy backing, strategic planning, and community involvement are essential for a successful B.R.T. rollout. The model of complete streets in urban planning aims to enhance the safety of all users by accommodating various modes of transportation. The two primary advantages of this concept are increased density and mixed land use, which contribute to improved land use and walkability [29]. Complete streets were implemented to promote public transit and active transportation to increase the number of people using these modes of transportation and reduce traffic congestion. Collaboration among diverse stakeholders is necessary to implement complete streets, which may improve property values, public health, and sustainability [30]. These models predict policy impacts and support better urban development decisions by considering population distribution, travel time, and transport infrastructure [31]. Mixed land use development is linked to sustainable travel behavior and positive resident perceptions, particularly in neighborhoods with a moderate land use mix [4]. Similarly, the positive correlation between mixed land use and sustainable transportation behavior, emphasizing the importance of proximity to diverse land uses in facilitating transportation choices and mitigating congestion and pollution, is highlighted [3].

The integration of land use and transportation is a significant problem for India. Inefficient land use and terrible traffic congestion are outcomes of rapid urbanization's uncontrolled, spreading expansion [32]. When public transportation systems cannot keep up with the needs of an expanding metropolitan population, more and more individuals turn to private vehicles, which worsens traffic and air pollution [33]. A lack of infrastructure for non-motorized transport users, such as bicycles and pedestrians, is a danger [34]. Inefficient urbanization directly results from the lack of coordination between land use and transportation policies and plans [35]. Without considering the long-term effects on transportation preferences, pedestrian access, and other related factors, the urban transport policy only focuses on expanding the road network [36]. To create sustainable and habitable cities in India, it is essential to address these concerns via thorough planning. In India, the responsibility of land use planning is within the jurisdiction of the city's municipality council or development authority.

On the other hand, separate planning components are overseen by different municipal, state, and national authorities [37]. The lack of integration between transportation and land use planning in India has resulted in traffic congestion and inadequate urban growth. The absence of coordination has resulted in an infrastructure that does not align or correspond effectively [5,38]. The travel behaviors of individuals are greatly influenced by how land use and transportation systems are planned and organized. By adequately integrating these elements, one may decrease the reliance on motorized transportation and encourage using alternatives such as public transit and non-motorized modes. Effectively tackling essential issues is vital for achieving effective integration [9].

Tier I cities are major metropolitan areas with high population density and substantial economic activity. Conversely, Tier II cities are smaller urban centers rapidly expanding in industrial sectors and have relatively lower living costs. These cities typically feature good infrastructure and frequently participate in government programs such as the Smart City Mission [39,40]. This categorization helps policymakers and resource allocation by showing India's cities' urbanization and development demands. Tier I cities in India, characterized by a high prevalence of transit-oriented development (T.O.D.), have been the primary focus of research on integrating land use and transportation with user behavior. For cities, effective and efficient land use patterns must be explored in depth by traffic and transportation planning in conjunction with land use plans [41]. With fast urbanization and despite intensive research and policy efforts, deep knowledge gaps persist in India's land use and transportation integration. Most of the studies and research are focused on Tier I cities like Mumbai and Delhi, where T.O.D. and transportation infrastructure are well developed.

Sustainable urban development ideas have focused on more significant metropolitan areas of cities, not neighborhoods, especially in developing nations [42]. In particular, Tier II and smaller urban areas have not been thoroughly explored in India. Insufficient data impede the process of formulating policies and allocating resources. This lack of study and research focused on Tier II cities hinders effective policymaking and resource allocation. Inefficient urban development results from the absence of coordinated land use and transportation strategies, often caused by fragmented coordination among planning bodies [33]. Despite the established benefits of mixed-use development in promoting sustainable travel behaviors, there is a lack of empirical data from various cities in India to support these conclusions. To promote sustainable and livable urban settings in India, it is essential to address these gaps by conducting localized studies, improving data collection, and conducting inclusive research considering all population groups' requirements.

3. Materials and Methods

Understanding travel patterns, user behavior, and mixed land use in urban neighborhoods is critical for devising sustainable transportation solutions and enhancing livability. In Vadodara's Karelibaug neighborhood, where rapid industrialization and urbanization have increased reliance on private vehicles, addressing transportation challenges requires a nuanced approach. The research aims to inform evidence-based policy interventions for sustainable urban development tailored to Karelibaug's unique needs by triangulating data from these phases. This methodology section outlines the systematic approach undertaken to analyze travel behavior, user preferences, and the impact of mixed land use on transportation dynamics within Karelibaug. This research is structured into three phases to analyze transportation dynamics in Vadodara's Karelibaug neighborhood comprehensively. Firstly, a literature review identifies knowledge gaps and frames the research within urban transportation planning. Secondly, a citizen survey captures firsthand insights into travel patterns and user preferences. Finally, field observations provide real-time context to enhance understanding.

3.1. Study Area

The study area as shown in Figure 1 is located in Vadodara, a city in western India that is part of the Vadodara district (7548.50 Sq km area) at coordinates 22.30° N and 73.19° E. It has an elevation of 39 m (123 feet). Vadodara, a city in Gujarat, has an area of 149 square kilometers, making it the 18th biggest city in India and the third biggest city in the state. Vadodara's temperature fluctuates from 7 °C in winter to 44 °C in summer, with an average annual rainfall of about 625 mm. The city has a simple and rolling landscape [43], a population of 1,741,791 according to the 2011 census [44]. Based on census statistics over the last three decades, it can be seen that the city of Vadodara is experiencing significant and fast growth. Based on the 2001 census data, the population of Vadodara was recorded at 1,491,045, showing a growth rate of 32.30% compared with the population in 1991. In 2011, the growth rate significantly increased by 6.2%, and the population 2011 reached 1,741,791 [44]. The combined length of arterial, sub-arterial, collector, and other roads in the VMC (Vadodara Municipal Corporation) area is roughly 1000 km. These roads cover approximately 11.5 square kilometers of land, constituting approximately 11% of the total area [11]. Vadodara is classified as a Tier II city due to its moderate economic growth, expanding industrial base, and improving infrastructure in sectors like education, healthcare, and transport. While it offers a lower cost of living and growing job opportunities, it lacks the international connectivity and financial prominence of Tier I cities, making it an appealing choice for businesses and professionals seeking a balance between development and quality of life [45,46]. As the city's population and land use change, all infrastructural development occurs quickly. The road's physical infrastructure has improved, allowing access to all new development areas. In urban areas, motorbikes and motorcycles usually account for about 50–60% of the overall traffic, while cars represent a smaller proportion, ranging from 6% to 15%. Autorickshaws, a kind of para-transit mode, make up between 5% and 20% of the overall transportation options, whereas buses account for roughly 1–4%. Over the years, the number of para-transit vehicles in the city has consistently increased, reaching over 35,000 automobiles and taxis. This number grows yearly at a rate of 2.85% [11]. The rise in private automobiles contrasts with the decline of sustainable modes like walking, cycling, and public transit. This shift leads to congestion, pollution, and accidents, deteriorating urban life. Mitigating these issues is crucial for sustainable urban development and residents' well-being, necessitating prioritization of sustainable transportation options. This research focuses on the Karelibaug neighborhood, a vital component of Vadodara's developing urban fabric. Selected to reflect the city's infrastructural advancements, Karelibaug is situated within ward No.8 (an administrative division within the city), nestled amidst the historic districts of Vadodara. This study delves into the dynamics of this specific area to assess its unique characteristics and contribute valuable insights into its infrastructural progress and urban development. While predominantly residential, the area also features mixed land use, adding diversity to its urban fabric. Despite rising private vehicle use challenges impacting congestion and pollution, Karelibaug requires a nuanced approach to address unique mobility and sustainability needs. Strategic measures emphasizing sustainable transportation modes could enhance livability in Karelibaug by addressing its distinct mixed land use dynamics.

Figure 1. Location of Karelibaug in Vadodara, city in India.

3.2. Research Approach

The study conceptual framework of the research is shown in Figure 2. In the initial phase of the research methodology, a systematic approach was employed to identify the relevant literature about the study's focus on travel patterns, user behavior, and mixed land use in urban environments. Leveraging digital platforms such as Google Scholar, comprehensive searches were conducted using a set of predefined keywords, including "travel pattern", "user behavior", "Tier II cities", and "mixed land use". This process yielded diverse journal articles, research papers, and relevant publications. Subsequently, the identified studies underwent a thorough review, wherein each was meticulously examined, summarized, and synthesized. Key concepts, trends, and gaps in understanding were extracted to discern the intricate relationship between mixed land use, user behavior, and transportation challenges. This synthesis generated common themes and patterns, offering valuable insights into urban transportation planning dynamics in Tier II cities like Vadodara. Identifying these themes informed the research objectives and provided a conceptual framework for subsequent data collection and analysis. This methodological approach ensured a comprehensive understanding of existing knowledge, facilitating the development of research questions and hypotheses to guide the remainder of the study.

To comprehensively understand neighborhood travel behavior in Vadodara's Karelibaug area, a purposive random pilot survey was conducted with a sample size of 95 individuals. The Karelibaug neighborhood comes under Ward Number 6. As per the 2011 census, the total population of this ward was 130,715 [44]. However, estimating the population of a particular neighborhood within the ward is challenging. To address this, the study by Bahadure and Kotharkar (2015) [4] on neighborhoods was considered. Their study suggested conducting 30 surveys per neighborhood, and for this research, 95 surveys were conducted, serving as a pilot study to ensure robust results at the neighborhood level. The Karelibaug survey included 95 respondents, selected to represent the local population. The

sample size ensured practical and meaningful insights, with data reliability strengthened through a structured questionnaire and thorough data cleaning for accuracy.

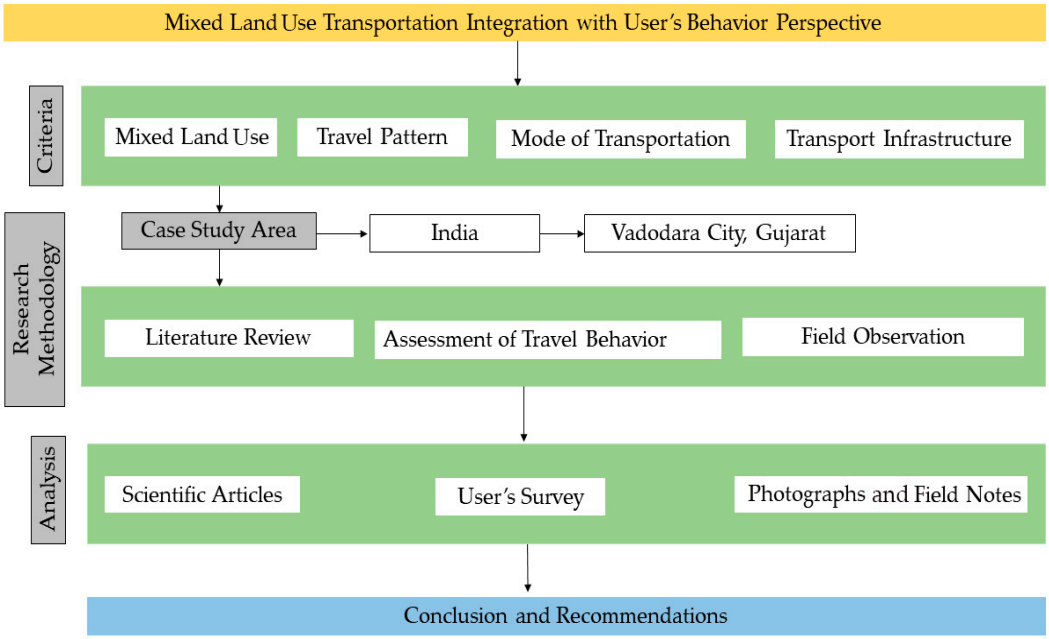


Figure 2. Study conceptual framework.

This survey considered diverse socioeconomic profiles, including gender, age, occupation, and income range, to ensure representation across demographic groups. The structured questionnaire, inspired by methodology from Bahadure and Kotharkar [4], focused on various trip purposes such as work, education, recreation, and shopping. It captured details on origin–destination pairs, both actual and preferred modes of transportation, reasons for mode selection, challenges faced, satisfaction levels, travel frequency, and destination infrastructure quality. The survey focused on both the actual mode and preferred mode of transportation. The actual mode refers to what people currently use, based on their preferences and available options. In contrast, the preferred mode represents what individuals would ideally choose under optimal conditions, prioritizing convenience, comfort, and environmental friendliness. Through this questionnaire, insights were gleaned into the factors influencing transportation choices, frequency of travel, and perceptions of transportation amenities within Karelibaug. The survey was conducted in March 2022 using a combination of Google Forms and in-person interactions. Survey responses underwent thorough scrutiny in the data cleaning and preparation phase to ensure accuracy and reliability. This involved detecting and rectifying missing or erroneous data entries and coding open-ended responses for systematic analysis. Following this, an analysis was employed to summarize the survey data effectively. Statistics such as frequencies, percentages, and means were computed to unveil patterns in travel behavior, mode preferences, and satisfaction levels among respondents. This methodological approach facilitated a comprehensive understanding of neighborhood travel dynamics, formulating targeted interventions and policy recommendations to enhance the transportation infrastructure and improve overall livability within the Karelibaug neighborhood in Vadodara city.

During on-site visits to the Karelibaug neighborhood, exhaustive field observations were made, including real-time visual documentation and extensive field notes. The observations were centered on many areas, such as transportation infrastructure, land use patterns, and the current problems in the vicinity. Afterward, a qualitative analysis was performed on the field observations to identify recurring themes, patterns, and issues related to transportation concerns and the interplay between different types of land use in Karelibaug. This qualitative analysis provided a detailed insight into the neighborhood's

distinct transportation environment, emphasizing the crucial aspects that affect travel behavior and the use of infrastructure. Integrating field observation results with survey data was pivotal in providing additional context and insight into the practical implications of transportation issues in the vicinity. Researchers enhanced their comprehension of the intricate nature of traffic dynamics in Karelibaug by combining qualitative field observations with quantitative survey data. This integration enhanced the study by allowing researchers to uncover connections and differences more thoroughly between observed occurrences and reported behaviors. As a result, it improved the accuracy and strength of this study's results, allowing for better decision-making and policy development to tackle transportation issues and boost the overall quality of life in the Karelibaug area.

4. Results

Land use patterns significantly influence travel behavior, affecting factors like commute distance, automobile ownership, and various transportation modes, including autorickshaws, public transit, and non-motorized options [47]. Mixed land use is linked to shorter commute lengths, fewer cars owned, and higher use of public transportation and non-motorized modes of transportation. This indicates that the proximity of various land uses may promote more sustainable travel patterns [4,48]. However, to the author's knowledge, few studies have explored the correlation between mixed land use, travel behavior, and the availability of existing transportation infrastructure. Furthermore, there is a predominant emphasis on Tier I cities like Ahmedabad in Gujarat, where well-established and integrated transportation infrastructure in transit-oriented development is in place. The research highlights the problem of insufficient integration between spatial and transportation planning in Tier II cities where T.O.D. does not exist, like Vadodara.

The Karelibaug survey had 95 respondents, 53% male and 47% female. Most participants were aged 24 to 40 (44%), followed by 41 to 60 (31%), 16–23 (14%), above 60 (7%), and 0 to 15 (4%). Regarding occupation, 36% were employed, 23% were self-employed or in business, 21% were students, 14% were homemakers, and 6% were retired. Income distribution showed 23% earning INR 10,000–30,000, 23% earning more than INR 60,000, 21% earning INR 30,000 to 60,000, 16% earning less than INR 10,000, and 17% marked as not applicable. Family size data revealed that 56% had four members, 22% had three members, 18% had more than four members, and 4% had two members.

As shown in Figure 3, in the survey result, people in the Karelibaug neighborhood predominantly choose private motorized vehicles (53%) for work trips due to personal preference and cost considerations. Despite facing challenges like insufficient footpaths and parking facilities, individuals are generally reluctant to switch their mode of transportation for work trips. This leads to low satisfaction with the existing transport infrastructure in Karelibaug. Individuals in the Karelibaug neighborhood commonly opt for private motorized vehicles (52%) and vans/rickshaws (27%) for educational excursions. Personal preference is the leading factor for choosing private motorized vehicles, but factors like the absence of public transportation and considerable distance also contribute. Despite facing challenges such as inadequate pathways, limited parking facilities, traffic congestion, and a lack of cycle tracks, many people are open to changing their mode of transportation for educational visits, expressing a preference for sustainable options. Private motorized vehicles (67%) are the primary mode of transportation for everyday shopping needs, driven mainly by personal preference. While most people are willing to switch to sustainable methods like walking for daily requirements, the Karelibaug neighborhood encounters challenges such as inadequate pathways, parking problems, safety concerns, and interference from local sellers. As shown in Table 1, the survey results indicate a low satisfaction level of 2 for such journeys in this area. Due to personal preferences and distance considerations, individuals prefer private motorized vehicles (81%) for shopping items rather than everyday necessities. However, as shown in Table 2, facing issues like traffic conflicts, insufficient parking, and congestion results in a moderate level of satisfaction, rated at 3. Many Karelibaug residents favor recreational trips outside the neighborhood, predominantly relying on private motor-

ized vehicles (76%) as their primary mode of transportation. This preference stems from an unwillingness to change due to issues such as vendor encroachment and a notable traffic conflict related to land use. Despite these challenges, satisfaction levels for recreational trips remain high, rated at 4.

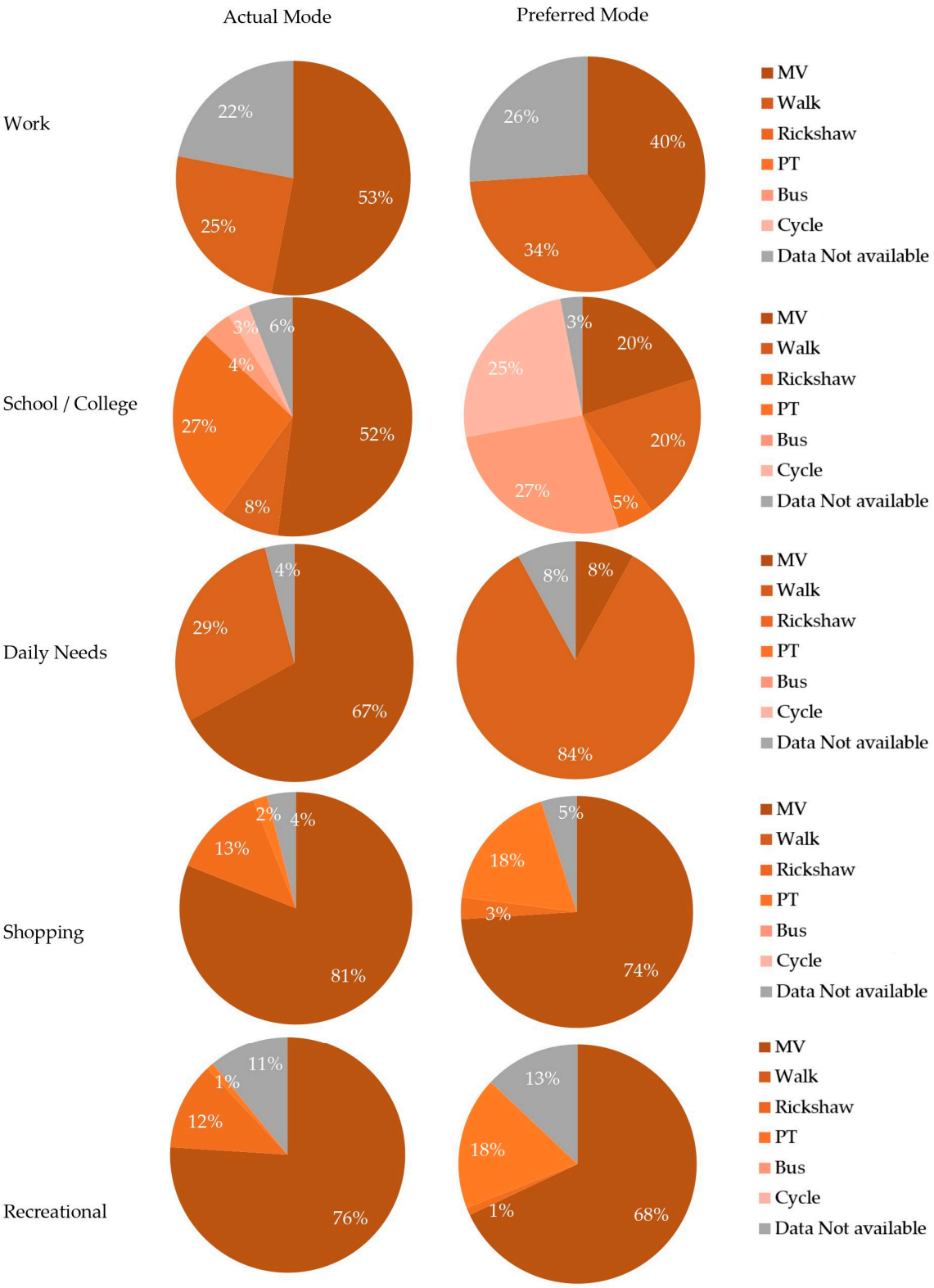


Figure 3. Actual and preferred modes in Karelibaug (MV—motor vehicle; PT—public transit).

Table 1. Users with satisfaction level on a scale of 1 to 5 for satisfaction level with infrastructure availability in Karelibaug.

Satisfaction Level	1	2	3	4	5
Work		✔			
School/College		✔			
Daily Needs		✔			
Shopping			✔		
Recreational				✔	

Table 2. Issues faced by users in Karelibaug (brown—prominent issues and green—no problems.

	Footpath	Parking	Safety	Congestion	Vendors	Encroachment of Vendors
Work						
School/College						
Daily Needs						
Shopping						
Recreational						

In Table 2, green indicates no significant issues during the trip, while brown highlights areas where respondents experience challenges. Work trips face issues with parking, safety, and congestion, likely due to limited parking spaces, high traffic during peak hours, and safety concerns in busy areas. However, vendor activity has less impact on these trips, as the land use for office areas typically does not involve vendors encroaching on spaces. School/college trips struggle with parking and safety, possibly due to overcrowded lots and safety concerns around educational institutions, but congestion and vendor-related factors are less problematic since these areas are generally structured for educational purposes rather than heavy commercial activity. Daily needs trips show challenges in parking, safety, and congestion, likely because of frequent, short trips to local stores where parking is limited and pedestrian safety is a concern. However, vendor presence is not a significant issue as the land use here is typically for smaller retail or service purposes. In contrast, shopping trips receive mostly positive ratings, particularly for parking and congestion, as shopping areas are often allocated specific land use with dedicated parking facilities, making it easier for users to park and reducing congestion around these locations. Recreational trips are also rated positively across all factors, likely due to occurring during off-peak hours and at locations with ample parking, which are designed for leisure activities.

The findings from the Karelibaug locality reveal a significant dependence on private motorized vehicles for diverse reasons, principally motivated by individual desire and economic factors. Although insufficient infrastructure and traffic congestion are recognized, there seems to be a reluctance to adopt other transportation modes, especially for commuting for work and daily shopping. Nevertheless, a more positive disposition exists towards embracing sustainable transportation alternatives for educational trips, emphasizing a possible openness to change under certain conditions. In general, satisfaction levels may vary depending on the kind of journey. Still, there is a pressing need to solve infrastructure shortcomings and promote sustainable transportation options. This will help improve overall satisfaction and reduce problems caused by excessive dependence on private automobiles.

Field observations conducted in the Karelibaug area were essential to understand the local transportation infrastructure and usage patterns comprehensively. The observations revealed several critical issues impacting pedestrian safety and overall traffic flow. At first, there was a significant decrease in the number of people using footpaths, primarily due to problems with people occupying the footpaths. Unlawful structures like billboards, benches, and street sellers hindered pedestrian access on sidewalks, forcing pedestrians

to move through vehicular traffic on the road and increasing the likelihood of accidents (Figure 4a,g,h).

(a) Encroachment by street vendors on the road

(b) Jaywalking due to lack of crosswalks

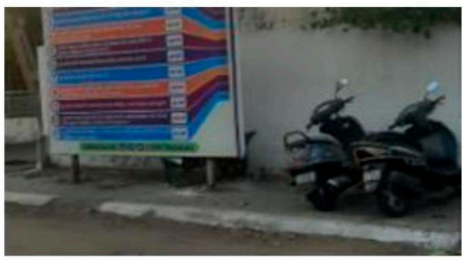
(c) No land separation, chaotic roadside parking

(d) No pathway separation

(e) No designated parking for autorickshaws

(f) No designated parking for vehicles

(g) Encroachment of seating on footpath



(h) Billaboards and parked vehicles on footpath

(i) Haphazard parking on road

(j) Haphazard parking on footpath

Figure 4. Field observation campaign at study site highlighting infrastructure availability issues in the study area.

Field observations revealed that approximately most of the available walkway space was occupied by parked motorcycles, significantly reducing pedestrian access and exacerbating safety concerns (Figure 4j). This encroachment limited the effective width of walkways and forced pedestrians to navigate through vehicular traffic, increasing the risk of accidents. An evident problem in the area was the disorganized parking situation. The lack of authorized parking areas for rickshaws and vehicles resulted in their being disorganized along the side of the road, causing disruptions to the flow of traffic and posing safety risks for both motorists and pedestrians (Figure 4e,i). The absence of structured parking options worsened the congestion problems in the area.

Moreover, the intense traffic flow compounded safety concerns for pedestrians crossing the road. With no designated crossings or traffic calming measures, pedestrians faced challenges navigating the chaotic traffic, increasing the likelihood of accidents and injuries (Figure 4b). Moreover, the absence of designated vendor areas resulted in the haphazard organization of businesses along the roadside (Figure 4a). This worsened congestion problems and disturbed the general appearance of the streets, affecting both the movement of vehicles and the safety of pedestrians. These findings highlighted Karelibaug's poor transport infrastructure and the need for strategic solutions. Land use transportation integration (LUTI) policies may improve transportation infrastructure development and administration, improving traffic management and pedestrian safety. Enforcing unwanted encroachments and parking offenses would also reduce congestion and improve transit.

5. Discussion

This study emphasizes the connection between land use patterns, transportation infrastructure, and travel conduct in Tier II cities, emphasizing the Karelibaug area in Vadodara. The findings from the survey and field observations in the Karelibaug neighborhood highlight a significant reliance on private motorized vehicles driven by personal preference and cost considerations. The survey results show that 53% of respondents use private vehicles for work trips despite dissatisfaction with the existing transport infrastructure. This reluctance to switch transportation modes is supported by field observations, where challenges like inadequate footpaths and parking facilities were prevalent. Encroachment by parked motorcycles, which occupied the majority of walkway space, severely limited pedestrian access and increased safety risks. For educational trips, private vehicles (52%) and vans/rickshaws (27%) are the most common modes of transport, with distance and lack of public transportation contributing to this preference. Field observations, however, reveal that despite the infrastructure issues, many are open to switching to sustainable transport options for education, indicating a potential for change under the right conditions. Shopping trips exhibit a similar pattern, with 67% relying on private vehicles due to personal preference but facing challenges such as traffic congestion, inadequate parking, and interference from local vendors. Satisfaction levels for these trips remained low, rated at 2 for daily shopping and 3 for other items. The field observations of disorganized parking and vendor encroachment further emphasize the need for better infrastructure and management. Recreational trips outside the neighborhood saw 76% of respondents using private vehicles, with high satisfaction levels (rated at 4), despite issues like traffic conflicts and vendor encroachment. The combination of survey results and field observations highlights those issues with destination land use, including the absence of sufficient transportation infrastructure and a functional land use transport integration (LUTI) system, are key contributors to the challenges faced by residents. The study identified traffic problems such as congestion, vendor encroachment, lack of parking, and inadequate walkways as significant barriers preventing the shift from private vehicles to more sustainable transportation options. Field observations confirmed these findings, showing that parked motorcycles occupied most walkway space, exacerbating pedestrian safety risks and traffic flow. The root cause of these challenges lies in the failure to implement a comprehensive LUTI system, which, along with poor transport infrastructure, continues to hinder the transition to sustainable mobility in Karelibaug.

The analysis highlights a substantial reliance on private motorized vehicles in Karelibaug, primarily due to individual preferences and inadequate public transportation. Despite acknowledging infrastructure challenges like insufficient footpaths and parking, there remains a resistance to adopting sustainable modes of transport. It is emphasized that overcoming these barriers requires targeted improvements in pedestrian infrastructure, parking management, and safety measures. Notably, the willingness to consider sustainable options for educational travel points to a potential gradual shift, suggesting that well-designed interventions could encourage more eco-friendly travel behaviors.

A transportation system that is affordable, sustainable, efficient, and inclusive in both the short and long term can be achieved by maintaining and enhancing existing non-motorized and public transport infrastructure, along with expanding it [49]. From the results, it is clear that improving infrastructure and encouraging sustainable mobility options are essential to increase general happiness and mitigate the adverse effects of over-dependence on private automobiles in the Karelibaug area. The observations within the study area underscored the insufficient and improper transport infrastructure in the Karelibaug area, highlighting the urgent need for strategic interventions to address these challenges. A comprehensive approach is necessary to address the transportation and pedestrian safety issues in Karelibaug. Designated parking spaces for vehicles and autorickshaws should be established to prevent disorderly parking and reduce congestion. Constructing proper footpaths free from encroachments by unlawful structures, vendors, and advertising boards is essential to ensure pedestrian safety. Vendors should be allocated specific areas that do not obstruct walkways, and communal seating should be relocated to designated public spaces away from pedestrian pathways. Installing crosswalks and dedicated lanes for vehicular traffic near schools and residential neighborhoods will enhance safety. Finally, the enforcement of parking regulations and removal of motorcycles parked on footpaths will help reduce congestion and improve overall accessibility. Ongoing monitoring of policy interventions is needed to assess effectiveness and inform improvements in transportation infrastructure and urban mobility. Implementing land use transportation integration (LUTI) policies through an institutional framework to organize LUTI systematically could help better plan and manage transportation infrastructure, ensuring efficient traffic management and pedestrian safety. Additionally, measures to enforce regulations regarding unauthorized encroachments and parking violations would be crucial in alleviating congestion and improving the overall transportation experience in the area. The evaluation also highlighted the importance of considering parameters like land use intensity, travel behavior, and user satisfaction levels in designing streets for successful LUTI implementation.

A multi-faceted approach is proposed to enhance urban sustainability, starting with establishing a land use transport integration (LUTI) planning cell at the macro level within the Department of Town Planning. This cell, led by a high-ranking transport manager, would oversee all aspects of LUTI, including planning, designing, funding, and maintenance. Streets are essential to daily life, offering access to homes, workplaces, and leisure activities. They shape urban areas, occupy a significant portion of city land, and support movement, connectivity, and utility services [50].

By adopting the 15 min community model, urban planning may transition from a "land-oriented" to a "human-oriented" perspective. The goal is to improve sustainability and quality of life by creating small, walkable communities where basic services are within a 15 min drive [51]. Equitable distribution of street space and a comprehensive street design handbook are recommended to harmonize street design aspects and cater to the diverse needs of road users. Introducing a bottom-up form-based coding strategy at the district/local area plan level is emphasized, promoting customized codes tailored to the local context for enhanced street livability and accessibility.

Additionally, the formation of a Comprehensive Mobility Plan (C.M.P.) for Vadodara is proposed, focusing on optimizing people and goods movement, integrating land use and transport systems, and providing legislative recommendations. Provisions are suggested

for regularizing macro-level planning and micro-level street design into guidelines, expressing land use intensity in terms of road width within the General Development Control Regulations (GDCRs). Prior permission from authorities and penalties for non-compliance are advised before changing land use to ensure parking capacity alignment. These strategic recommendations aim to address the complexities of urban planning, fostering sustainability and efficient mobility management. Practical implications suggest establishing a LUTI Planning Cell, adopting equitable street guidelines, and formulating Comprehensive Mobility Plans.

A limitation of this research is that the survey conducted was a pilot survey with a limited sample size, which may not fully capture the broader transportation patterns and user behavior. Future studies should aim for a larger sample size to provide more comprehensive insights into the issues. The study also focuses on Tier II cities in India that lack a bus rapid transit (B.R.T.) system. However, the methodology employed in this research can be replicated in other cities, making it adaptable to different urban contexts.

6. Conclusions

The research on travel patterns in Vadodara's Karelibaug area provides unique insights into the intricacies of urban mobility and the difficulties encountered by Tier II cities such as Vadodara. This research offers a detailed knowledge of travel patterns, user behavior, and the influence of mixed land use on traffic dynamics in Karelibaug. It does this through a thorough approach by employing triangulation, including analyzing the literature, conducting questionnaire surveys, and making field observations. Integrating survey data with field observations enhances the validity of findings, offering a holistic understanding of transportation issues in Karelibaug and facilitating informed policy interventions. One of the key strengths of this research is its consideration of user behavior, which enriches the analysis by offering insights into how individuals interact with transportation systems in their daily lives. Its specificity to Tier II cities like Vadodara provides valuable insights into transportation challenges and solutions relevant to similar urban contexts. Focusing on Karelibaug as a representative urban neighborhood, the study provides context-specific recommendations that can inform evidence-based policy interventions for sustainable urban development tailored to the unique needs of similar urban contexts.

The results highlight the substantial reliance on private motorized vehicles in Karelibaug, principally influenced by individual choices and economic considerations. Although the issues of inadequate infrastructure and traffic congestion are acknowledged, there seems to be a reluctance to embrace sustainable mobility options for commuting and everyday tasks. Nevertheless, there is a greater inclination to use sustainable methods for educational excursions, suggesting a willingness to accept change under certain circumstances. Field observations reveal significant problems afflicting the transportation infrastructure in the area, such as encroachments on footpaths, chaotic parking, and traffic congestion. These observations emphasize the pressing need for strategic interventions to tackle these concerns. Suggestions for thoroughly integrating land use and transport include creating a planning cell focused on land use and transport integration (LUTI) and developing a Comprehensive Mobility Plan to enhance transportation infrastructure and promote urban sustainability in Karelibaug. Ultimately, this research improves the current discussion on sustainable urban development by providing practical observations and suggestions for tackling mobility obstacles in Tier II cities such as Vadodara. This study establishes a foundation for making well-informed decisions and implementing policy interventions to enhance transportation infrastructure and improve the quality of life in urban neighborhoods. It achieves this by integrating data from various sources and considering the viewpoints of users, policymakers, and urban planners.

A notable limitation of this study is the relatively small sample size of 95 respondents, which may not fully represent broader travel patterns and user behavior in Tier II cities. Future research should include larger sample sizes and comparative analyses across different cities to provide more comprehensive data and inform policy development effectively.

The focus on Tier II cities in India is due to their unique characteristics, such as rapid urbanization, moderate economic growth, expanding infrastructure, and specific transportation challenges that differ from those in larger Tier I cities. These cities typically feature growing industrial bases, improving infrastructure in education and transport, and a balance between development and cost of living. Although this study centers on Indian Tier II cities, the findings extend beyond this specific context. The challenges identified, such as inadequate transport infrastructure, heavy reliance on private vehicles, and the influence of mixed land use on travel behavior, are relevant to other developing urban centers worldwide experiencing similar growth and urbanization. By emphasizing these shared characteristics, the study provides insights that can inform strategies in similar cities across the globe.

This study focused on mixed land use and its impact on travel patterns and user behavior. Future research could explore how different levels of mixed land use affect travel behavior and traffic safety, offering deeper insights and helping create targeted urban planning strategies for sustainable mobility. Further studies could provide a balanced perspective by including longitudinal research and exploring success stories. Comparative studies across Tier II cities could offer tailored solutions for different urban settings. Investigating socioeconomic factors would add a nuanced understanding of user behavior. Future studies could explore how land use, transport planning, and road factors impact automated vehicles (AVs), including Advanced Driver Assistance Systems (ADASs) and Automated Driving Systems (ADSs), as technological advancements reshape transportation. This research could provide critical insights into enhancing safety, efficiency, and the integration of AVs within diverse urban settings [52]. The future scope also includes implementing a Comprehensive Mobility Plan based on research findings, conducting in-depth studies on existing legal provisions for GDCR modifications, exploring form-based codes for LUTI, and researching legislative requirements for practical guideline regularizations during the design phase.

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