Satya Swaroop Sahoo

Enhancing Public Bicycle Sharing (PBS) Adoption in Bhubaneswar

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Master of Planning
(Transport Planning and Logistics Management)

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Thesis submitted in partial fulfillment of the requirements for the award of the degree of

Master of Planning
(Transport Planning and Logistics Management)

By
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Declaration

I **Satya Swaroop Sahoo**, Scholar No. **2022MPTPLM004** hereby declare that the thesis titled **"Enhancing Public Bicycle Sharing (PBS) Adoption in Bhubaneswar"** submitted by me in partial fulfilment for the award of **Master of Planning**, at School of Planning and Architecture, Bhopal, India, is a record of bonafide work carried out by me. The matter/result embodied in this thesis has not been submitted to any other University or Institute for the award of any degree or diploma.

Signature of the Student

Date: _____

Certificate

This is to certify that the declaration of **Satya Swaroop Sahoo** is true to the best of my knowledge and that the student has worked under my guidance in preparing this thesis.

RECOMMENDED

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Signature of the Guide
Dr. Mayank Dubey

ACCEPTED

_____

Prof. Saurabh Popli
Head, Department of Transport Planning

May 2024

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Abstract

In today's dynamic urban cities, Public Bicycle Sharing (PBS) has emerged as a key element for promoting environmentally conscious urban transportation, alleviating traffic congestion, and cultivating improved air quality. PBS embodies a pragmatic and cost-efficient alternative, catering to the evolving commuting needs of urban populations. Despite its promise, numerous cities that have embraced PBS initiatives are encountering formidable challenges, witnessing a decline in effectiveness. This thesis underscores the imperative for a comprehensive approach aimed at remedying these challenges and revitalizing PBS systems. The proposed multifaceted strategy encompasses four core dimensions: firstly, the expansion and enhancement of PBS infrastructure through strategic augmentation of stations and bicycles across urban domains, bolstering accessibility and usability. Secondly, advocating for adaptable and financially feasible pricing models, designed to cater to a diverse spectrum of users and encourage broader adoption. Thirdly, integrating seamless mobile technology into the PBS framework, facilitating user-friendly applications for bike locating, reservations, payments, and real-time updates, thereby enhancing user convenience and engagement. Lastly, the execution of meticulously targeted awareness campaigns to elucidate the multifarious advantages of PBS, cultivating community involvement and augmenting its appeal. Through the holistic implementation of these strategies, cities can invigorate their PBS systems, thereby harnessing the manifold benefits they bestow upon urban mobility and sustainability endeavors. This thesis seeks to provide a comprehensive roadmap for overcoming the current challenges plaguing PBS initiatives, ultimately contributing to the resurgence of effective and impactful PBS systems in contemporary urban landscapes.

Keywords: Non-motorised transport, public bicycle sharing, Shared use, Urban transportation, Pricing model.

सारांश

आज के गतिशील शहरी शहरों में, सार्वजनिक साइकिल शेयरिंग (पीबीएस) पर्यावरण के प्रति जागरूक शहरी परिवहन को बढ़ावा देने, यातायात की भीड़ को कम करने और बेहतर वायु गुणवत्ता विकसित करने के लिए एक प्रमुख तत्व के रूप में उभरा है। पीबीएस एक व्यावहारिक और लागत-कुशल विकल्प का प्रतीक है, जो शहरी आबादी की बढ़ती आवागमन आवश्यकताओं को पूरा करता है। अपने वादे के बावजूद, पीबीएस पहल को अपनाने वाले कई शहर विकट चुनौतियों का सामना कर रहे हैं, प्रभावशीलता में गिरावट देखी जा रही है। यह थीसिस इन चुनौतियों का समाधान करने और पीबीएस सिस्टम को पुनर्जीवित करने के उद्देश्य से एक व्यापक दृष्टिकोण की अनिवार्यता को रेखांकित करती है। प्रस्तावित बहुआयामी रणनीति में चार मुख्य आयाम शामिल हैं: सबसे पहले, शहरी डोमेन में स्टेशनों और साइकिलों के रणनीतिक विस्तार के माध्यम से पीबीएस बुनियादी ढांचे का विस्तार और वृद्धि, पहुंच और उपयोगिता को बढ़ावा देना। दूसरे, अनुकूलनीय और वित्तीय रूप से व्यवहार्य मूल्य निर्धारण मॉडल की वकालत करना, जो उपयोगकर्ताओं के विविध स्पेक्ट्रम को पूरा करने और व्यापक अपनाने को प्रोत्साहित करने के लिए डिज़ाइन किया गया है। तीसरा, पीबीएस ढांचे में निर्बाध मोबाइल प्रौद्योगिकी को एकीकृत करना, बाइक का पता लगाने, आरक्षण, भुगतान और वास्तविक समय अपडेट के लिए उपयोगकर्ता के अनुकूल अनुप्रयोगों की सुविधा प्रदान करना, जिससे उपयोगकर्ता की सुविधा और जुड़ाव में वृद्धि होती है। अंत में, पीबीएस के विविध लाभों को स्पष्ट करने, सामुदायिक भागीदारी बढ़ाने और इसकी अपील को बढ़ाने के लिए सावधानीपूर्वक लक्षित जागरूकता अभियानों का कार्यान्वयन। इन रणनीतियों के समग्र कार्यान्वयन के माध्यम से, शहर अपने पीबीएस सिस्टम को मजबूत कर सकते हैं, जिससे शहरी गतिशीलता और स्थिरता प्रयासों को मिलने वाले कई गुना लाभों का उपयोग किया जा सकता है। यह थीसिस पीबीएस पहलों को परेशान करने वाली वर्तमान चुनौतियों पर काबू पाने के लिए एक व्यापक रोडमैप प्रदान करना चाहती है, जो अंततः समकालीन शहरी परिदृश्य में प्रभावी और प्रभावशाली पीबीएस सिस्टम के पुनरुत्थान में योगदान देती है।

कीवर्ड: गैर-मोटर चालित परिवहन, सार्वजनिक साइकिल शेयरिंग, साझा उपयोग, शहरी परिवहन, मूल्य निर्धारण मॉडल।

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Abbreviations

NMT Non Motorised Transport

PBS Public Bicycle Sharing

PT Public Transport

LCCA Life Cyle Cost Analysis

ROW Right of Way

CHAPTER 1: INTRODUCTION

1.0 Background

Non-motorized transport (NMT) refers to modes of transportation that are powered by human muscle, such as walking, cycling, and using wheelchairs and other small-wheeled vehicles. As shown in figure 1 it includes various components:

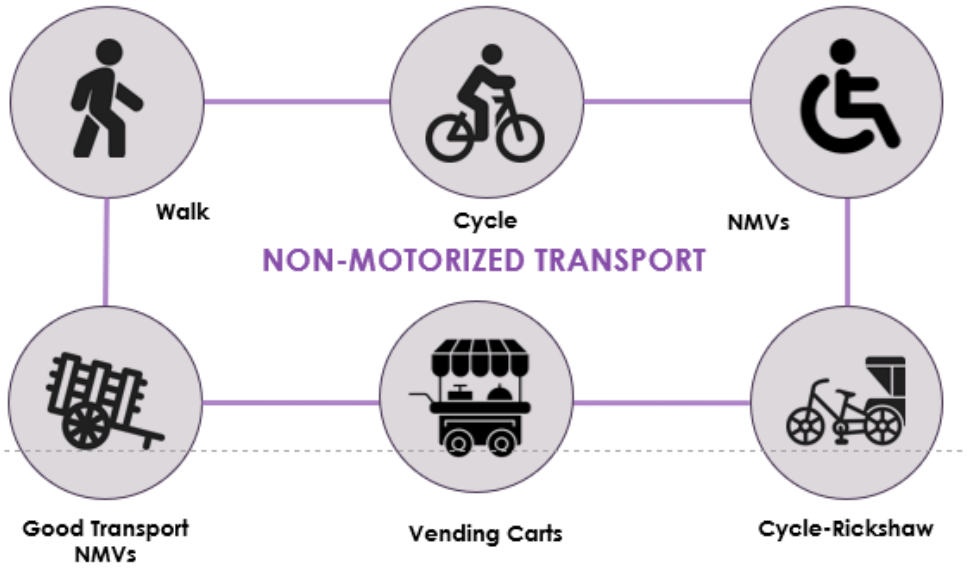


Figure 1 Showing the components of NMT.
Source: Author Generated

Pedestrians: People walking or moving on foot, forming the fundamental component of NMT. Sidewalks and pedestrian-friendly infrastructure support safe and efficient walking.

Cyclists: Individuals using bicycles for transportation or recreation. Cycling promotes eco-friendly mobility, offering health benefits and reducing traffic congestion.

Animal-Drawn Carts: Carts pulled by animals (such as horses, donkeys, or oxen) for transporting goods or people. Although traditional, they are still used in some areas for their practicality in carrying heavy loads.

Cycle Rickshaws: Human-powered vehicles with a driver pedalling and passengers seated in a carriage. They serve as a popular mode of transport in many cities, particularly for short trips.

E-rickshaws: Electrically powered rickshaws used for short-distance travel. They provide a sustainable alternative to fuel-powered vehicles and offer a cost-effective means of transport in some urban areas.

From the components of NMT by focusing on the mode of transport as bicycle it is found that there are two types of bicycle users

- Own Cycle users
- PBS users

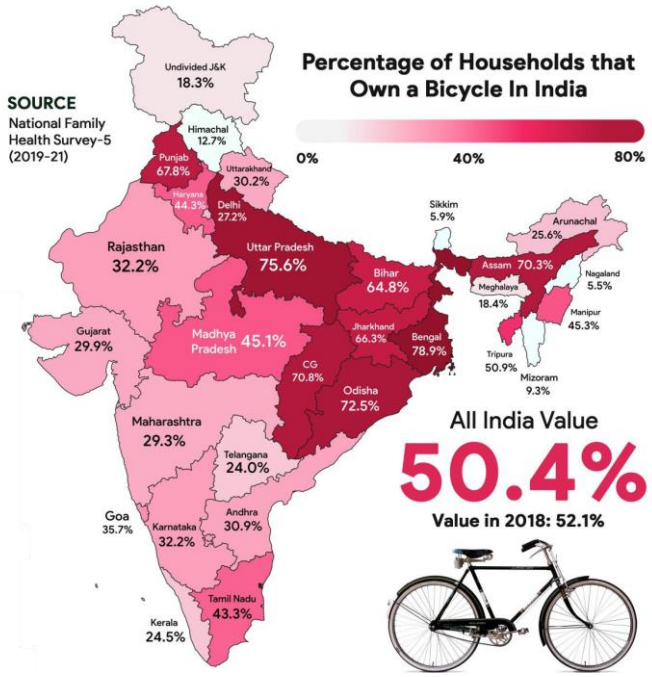


Figure 2 Showing the cycle ownership in India.
Source: National Family Health Survey-5 (2019-21)

The ownership of bicycle in India is decrease by 1.7% from year 2018 to 2021 shown in figure 2. In medium-sized cities across India, the proportion of trips made using motorized modes of transportation, such as cars, buses, and motorcycles, accounts for approximately 60%, while bicycles are used for just 15% of trips. This trend is observed despite an average trip length of 7 kilometers, which is not significantly long.

Public bike sharing is a short-term access method that offers customers an eco-friendly way to go around town(Shaheen et al., 2010). Additionally, it allows for short-distance active point-to-point mobility without the need for a bicycle. In addition, there are a lot of social, economic, and environmental advantages to implementing bike sharing in cities, including less traffic, lower emissions, better

health outcomes, and cheaper capital investment costs for transportation(Shaheen et al., 2010). Public Bike Sharing (PBS) is a system where bicycles are made available for shared use to individuals on a short-term basis. These bicycles are typically stationed at docking stations located throughout the city. Users can rent a bike from one station and return it to another, providing a convenient and eco-friendly mode of urban transportation. PBS promotes sustainable mobility and reduces the reliance on motorized vehicles for short trips within a city.

The Public Bicycle sharing focuses on the three main characteristics:

- Shared Use- PBS allows multiple individuals to use the same pool of bicycles, making it a collective and efficient mode of transportation.
- Availability of bicycles at multiple locations- Bicycles in a PBS system is distributed across various docking stations throughout a city, ensuring accessibility for users in different areas.
- Human powered fleet- PBS relies entirely on human effort for propulsion, emphasizing eco-friendliness and promoting physical activity.

Public Bicycle Sharing (PBS) serves as an excellent solution for the last-mile leg of a journey, offering a convenient and eco-friendly way to reach one's destination from a transportation hub. Additionally, it provides an independent mode of transportation for individuals who value the freedom to move around a city at their own pace and on their own terms, without the constraints of fixed schedules or the need for personal motorized vehicles.

PBS was introduced in Amsterdam in 1965 by Councilman Luud Schimmelpennink, the concept of Public Bicycle Sharing System (PBSS) has witnessed rapid global expansion in the past decade and continues to gain momentum worldwide. Globally around 600 cities have operational bicycle share systems, and still more programs are starting every year. The largest systems are in China, Paris, London, and Washington D.C. As of May 2018, the global landscape saw the growth of more than 1,600 bike-sharing initiatives, representing a significant expansion in urban transportation options. These programs collectively provided access to a staggering inventory of over 18 million bicycles available for public use. This marked proliferation underscores a growing trend towards the adoption of alternative and sustainable modes of urban mobility worldwide. The emergence of these bike-sharing programs reflects a concerted

effort by cities to address pressing challenges such as congestion, pollution, and limited access to transportation. By leveraging the popularity and accessibility of bicycles, municipalities aim to reduce reliance on traditional car-centric transportation systems and promote more environmentally friendly modes of travel. The widespread availability of bike-sharing schemes has transformed the urban transportation landscape, offering residents and visitors alike a convenient and eco-friendly means of navigating city streets. With bicycles stationed at strategically located docking stations throughout urban centres, users can easily access these shared resources for short-distance trips, errands, or leisure activities. As international cities continue to invest in and expand bike-sharing initiatives, the momentum towards creating bike-friendly urban environments is poised to accelerate. These programs not only offer practical transportation solutions but also embody a broader shift towards prioritizing sustainable, people-centric modes of mobility in urban planning and development strategies.

Initially in India, cycling has been a traditional mode of transportation, utilized by school children and even local milk vendors. Very constantly it was seen the bicycle mode share decreased from 35% in 1980 to 13% in 2016. In 2017, three cities—Mysuru (formerly Mysore), Bhopal, and Pune—introduced the country's first PBS systems, which were relatively more successful than the previous attempts. Major methods used in PBS implementation in Indian cities are Hub & Spoke method which includes Location-allocation method, Gis-based method, and Steady-speed power equation. And in the city of Surat the maximum coverage area method and minimum impedance method was given focus to provide the service to major chunk of the people.

1.1 Need of the Study

In various global metropolises, the implementation of public bicycle sharing systems has emerged as a transformative solution to address pressing mobility challenges while complementing existing public transportation infrastructure. These innovative schemes have introduced a new mode of transportation that seamlessly integrates with traditional transit options, offering residents and visitors enhanced flexibility and accessibility in navigating urban environments. Public bicycle sharing systems have proven instrumental in alleviating congestion

and mitigating the environmental impact of urban mobility. By incentivizing the use of bicycles for short-distance trips, these initiatives help minimize traffic congestion on overcrowded roads, thereby enhancing overall traffic flow and reducing emissions from motorized vehicles. Public bicycle sharing systems serve as a catalyst for urban revitalization and community engagement. By providing residents with convenient access to bicycles for both leisure and practical purposes, these initiatives foster a sense of ownership and pride in local neighbourhoods. Moreover, the presence of bicycle-friendly infrastructure, such as dedicated lanes and parking facilities, enhances the overall liveability and attractiveness of urban areas, contributing to their long-term sustainability and appeal. Moreover, public bicycle sharing initiatives have emerged as a powerful tool for promoting social equity and inclusion. By providing affordable and accessible transportation options to a diverse range of users, including low-income communities and marginalized groups, these programs help bridge socioeconomic divides and promote equal access to essential services and opportunities.

The rapid downfall of Public Bike Sharing (PBS) systems has garnered significant attention in recent years according to a study by (Kader P & Ghosh, 2022), and also highlighted by numerous newspaper articles detailing their struggles and failures. These articles often depict a narrative of optimism followed by disillusionment as PBS initiatives fail to gain traction or sustain themselves in urban environments. Despite initial enthusiasm and investment, many PBS schemes have faced challenges in achieving widespread adoption and long-term viability in a research by (Khan et al., 2023). Underrepresented communities, including low-income groups, people of colour, and women, face numerous barriers to adopting bike share systems. Safety concerns regarding riding in traffic and the lack of quality cycling infrastructure deter many from using bike share services. Additionally, immigrants may lack knowledge of biking rules and rights, further hindering adoption. Negative perceptions about biking, such as associations with drug dealers or gentrification, also discourage usage among these communities. Limited access to docking stations near essential destinations like employment centres exacerbates the issue, along with confusion about usage and payment methods. Language barriers and lack of internet access pose additional challenges, particularly for non-English speakers.

Moreover, requiring credit or debit cards for registration excludes unbanked individuals, who are disproportionately from low-income backgrounds. Concerns about the inability to transport children or cargo and worries about rental costs and liability further contribute to the reluctance to use bike share services (Grasso et al., 2020). Addressing these barriers is crucial to promote equitable access to bike share systems and ensuring that they serve all members of the community effectively. In Indian cities resulted in short-lived PBS initiatives due to factors such as limited coverage, inadequate infrastructure, and financial difficulties. So many of the Indian cities adopted shared funding and operational responsibilities between private and government entities, enabling the implementation of comparatively large-scale PBS systems. These systems initially experienced high ridership but faced challenges in sustaining momentum beyond the first year. While operational, they encounter issues such as declining ridership in subsequent years.

Learning from these experiences, it's crucial for cities to address past pitfalls and develop robust models that cater to specific needs while ensuring high-quality standards and customer service (Khan et al., 2023). Understanding the perspectives of PBS operators and manufacturers, along with selecting appropriate bicycling technology and infrastructure planning, are key components for successful PBS implementation in India.

1.2 Aim

To assess the factors affecting the use of Public Bicycle System (PBS) and suggesting strategies for improving efficiency in the system.

1.3 Objective

- To identify the unique factors affecting PBS and justifying its user groups.
  The first objective was to recognise the distinct factors impacting PBS. The factors identified included age, gender, trip duration, travel time, insufficient additional funds, lack of awareness, complex app aggregation, and minimal profits from subscription and rental revenue. In justifying the user group of the PBS, the focus was on the male population under the

age of 15-30 with low income, typically undertaking trips spanning less than 3 kilometers for recreational purpose.

- Identify specific challenges and barriers faced by users of the PBS system.

  As the aim of this study to enhance the PBS system so it is important to understand the challenges and barriers faced by the user group of the PBS system. This objective was achieved by the data collected primarily about the issues faced by the users and various analysis methods like demand route analysis and walkshed analysis.

- Investigate the effectiveness of existing pricing models and infrastructure in encouraging PBS usage.

  To know how the pricing model of PBS to be encouraged, its important to know the price of owning a cycle and owning a subscription of the PBS model. This objective was achieved by the LCCA that is Life cycle cost analysis and showed the user preference of the PBS and cycle.

- To develop a new model which will attract both the cycling crowd and non-cycling crowd to PBS.

  A new model would be proposed through the findings of the above analysis which will attract both the cycling and PBS user to use the PBS system.

1.4 Scope and Limitation

- The study is done only for the PBS system in Bhubaneswar.
- Data constraint as most of the PBS operators currently left the operational service.

1.5 Methodology

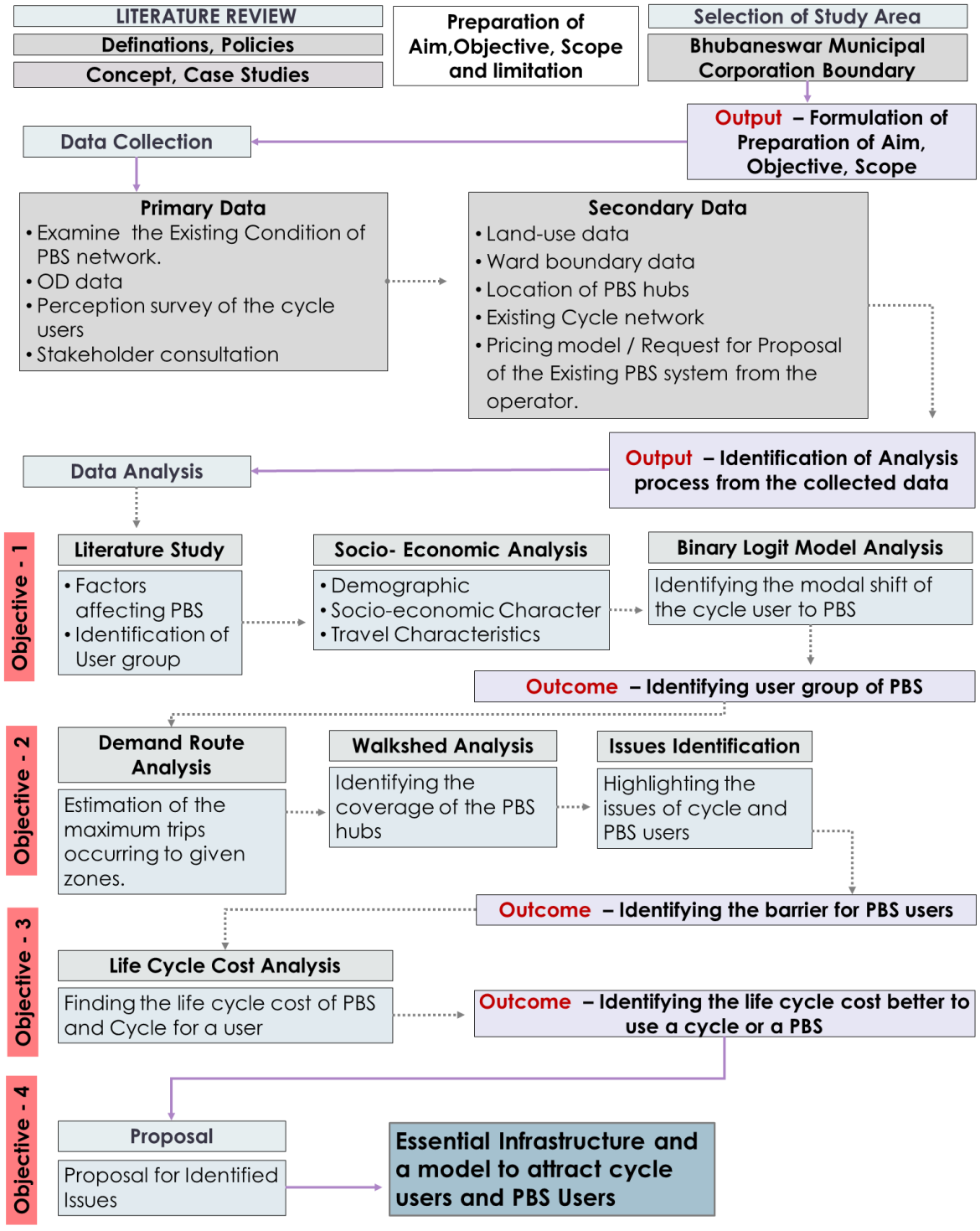


Figure 3 Showing the detailed methodology.

The methodology employed for the study depicted in Figure 3 above involves commencing with a literature review to establish the rationale and context for the study, focusing on the deterioration of the Public Bicycle Sharing (PBS) system in

Indian settings. This process led to the formulation of the study's aim, objectives, scope, and limitations. The study area chosen was the jurisdiction of the Bhubaneswar municipal corporation. Subsequently, both primary and secondary data were gathered. Primary data encompassed the current state of the PBS network, Origin and destination data, Perception survey data from cyclists, and consultations with stakeholders. Conversely, secondary data such as land use patterns, ward boundaries, PBS hub locations, existing cycling infrastructure, and pricing models sourced from government and private entities were collected. Following data collection, the next step involved identifying analytical methods that could address the study's objectives and enhance the PBS system. To ascertain the user demographics targeted in the initial objective, the analysis methods utilized included literature reviews, socio-economic assessments, and a binary logit model, resulting in the identification of the primary user group of the PBS system. Furthermore, issues and obstacles faced by PBS users were pinpointed through demand route analysis and walkshed assessments. Objective 3 entailed an investigation into the pricing model through a comparative Life Cycle Cost Analysis of the PBS and cycling systems, leading to the formulation of essential infrastructure requirements and a new model for PBS users based on the above-mentioned analysis fulfilling the final that is objective 4.

CHAPTER 2: LITERATURE STUDY

In the previous chapter we have discussed about the background, need of the study and the methodology of the study. The literature study has been divided into 5 sections. The first section focuses on the type of user of bicycle, PBS user and non-user of bicycle. The second section focuses on the factors affecting the public bicycle sharing system. The third section focuses on the benefits of public bicycle sharing system. The fourth section focuses on the identification of the targeted user group for the PBS system and the last section i.e. the fifth section is discussed about the international and Indian cities case study of public bicycle sharing system.

2.1 Comparing the Cycle users, PBS users and the Non-users.

Comparing users of bicycles, participants in Public Bicycle Sharing (PBS) system, and individuals who do not use bicycles yields valuable insights into transportation patterns and hurdles within urban environments. Each group exhibits distinct preferences, motivations, and challenges related to their transportation choices, contributing to the complexity of urban mobility dynamics. Individuals who engage in cycling, often with personal ownership of their bicycles, embrace cycling as a versatile mode of transportation that offers independence and adaptability. These cyclists utilize their bikes for various purposes, including commuting to work or school, leisurely rides, or engaging in physical activity. The ownership of a personal bicycle affords them the freedom to travel at their convenience, tailor their routes to specific destinations, and incorporate cycling into their daily routines seamlessly. Whereas the user group of Public Bicycle Sharing (PBS) system opt for shared bicycles for short-distance journeys, prioritizing convenience, and accessibility over ownership responsibilities. These individuals appreciate the ease of access to bicycles stationed at docking stations throughout the city, allowing them to initiate and conclude their trips without the burden of maintaining or storing a personal bike. PBS users value the flexibility and cost-effectiveness of this mode of transportation, making it an attractive option for spontaneous or occasional travel needs. Meanwhile, individuals who

do not use bicycles have yet to embrace cycling as a viable means of travel, citing various apprehensions and barriers that deter them from adopting this mode of transportation. Common concerns among non-cyclists include issues related to safety, perceived inadequacies in cycling infrastructure, and a preference for alternative modes of transportation perceived as more convenient or comfortable. A scholarly article (Fishman et al., 2012) emphasizes safety as a principal apprehension across all groups, with perceived inadequacies in bicycle infrastructure and negative perceptions from certain drivers as primary concerns. This discovery highlights the necessity of addressing safety apprehensions to encourage greater acceptance of cycling. Enhancing infrastructure, such as dedicated cycling paths and traffic designs that prioritize cyclist safety, can improve perceptions of safety, and motivate more individuals to cycle. Moreover, initiatives aimed at fostering positive interactions between cyclists and other road users through educational programs and awareness campaigns could help alleviate concerns related to road sharing.

Understanding the distinct requirements and inclinations of cyclists, PBS participants, and non-cyclists is imperative for formulating scenarios to identify the user categories of individuals utilizing bicycles, participating in PBS, and those who do not engage in cycling.

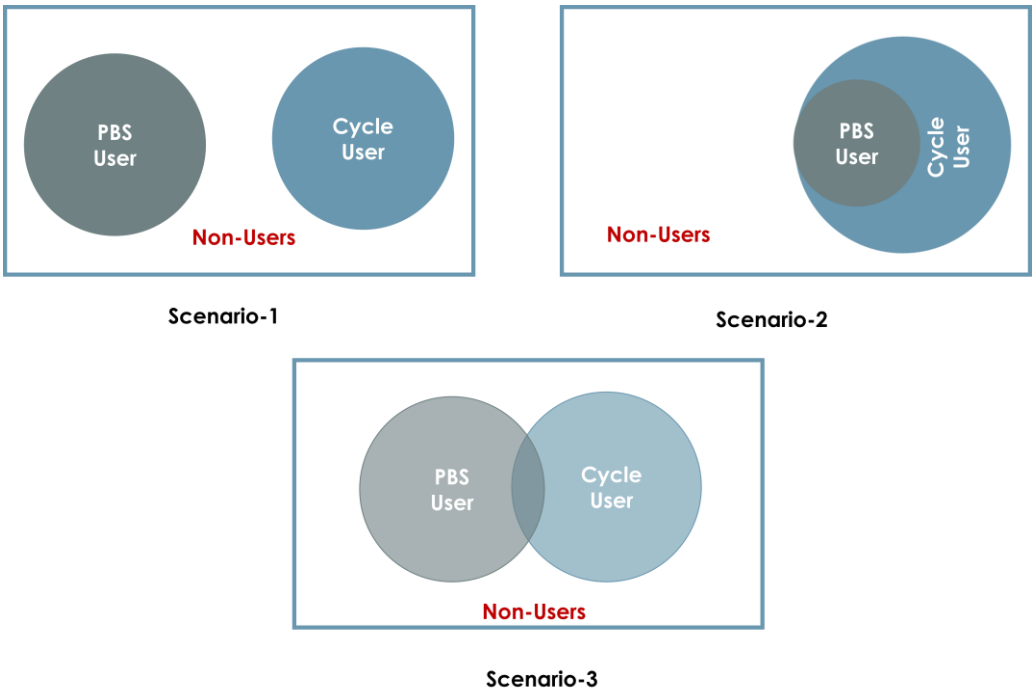


Figure 4 Showing the Scenarios for the cycle users, PBS users and non-user group.
Source: Author Generated

- Scenario - 1: In this scenario, the distinct user groups for the Public Bicycle System (PBS), bicycle users, and non-users are each carefully examined independently, reflecting their unique environments and characteristics as shown in figure 4. The PBS user group consists of individuals who opt for shared bicycles, benefiting from the convenience and accessibility of the system. They may include commuters seeking a cost-effective and environmentally friendly mode of transportation. The bicycle user group, in contrast, comprises individuals who own bicycles, utilizing them for various purposes such as commuting, recreation, or exercise. These users value the autonomy and flexibility that ownership provides, often preferring cycling for its health benefits and flexibility in navigating urban environments. On the other hand, non-users represent individuals who have yet to embrace cycling as a mode of transportation, citing concerns about safety, infrastructure, or simply preferring alternative modes of travel.
- Scenario – 2: In this scenario, it focuses primarily on two distinct environments: the bicycle user group and the non-user group. Within this framework, the Public Bicycle System (PBS) user group is subsumed within the bicycle user group as shown in figure 4. This perspective recognizes that individuals who regularly use bicycles, whether owned or shared through PBS, form a cohesive user group with shared characteristics and preferences. For those who own bicycles, cycling is an integral part of their transportation habits, driven by factors such as convenience, health benefits, and environmental consciousness. Similarly, PBS users, who utilize shared bicycles for their commuting and recreational needs, exhibit similar motivations and behaviours as cyclists. They value the accessibility and flexibility offered by cycling, irrespective of ownership status.
- Scenario – 3: In this scenario, the study reveals a significant intersection between PBS users and bicycle users, forming a distinct user group where individuals utilize both modes of transportation interchangeably as shown in figure 4. This hybrid user group encompasses individuals who may own

bicycles for personal use but also regularly utilize the Public Bicycle System (PBS) for specific trips or purposes. Likewise, PBS users may occasionally opt to use their own bicycles instead of shared ones, depending on factors such as availability, trip distance, or personal preference. This convergence of PBS users and bicycle users highlights a dynamic and adaptable approach to transportation, where individuals seamlessly transition between shared and personal modes of cycling based on their specific needs and circumstances. They value the flexibility and accessibility offered by both PBS and personal bicycles, utilizing each mode according to the demands of their daily routines and activities.

2.2 Factors Affecting Public Bicycle Sharing (PBS) System

The utilization of Public Bicycle Sharing (PBS) systems is influenced by a multitude of factors that encompass convenience, financial sustainability, and public awareness. Understanding these factors is essential for designing effective strategies to enhance the adoption and effectiveness of PBS systems within urban environments. Convenience plays a pivotal role in attracting users to PBS systems, particularly for short-distance travel. According to the paper (All India Cycle Manufacturers´ Association (AICMA), 2014). The quality of service provided by the Public Bicycle Sharing systems is a key determinant of their success and usage. The main factors that influence service quality are bicycle availability, the density and distribution of docking stations, and service to meet users' needs and expectations. In a well-designed and efficiently managed PBS, bicycles are available at the docking stations, accessible for use by a user whenever needed. Similarly, by strategically placing docking stations across the city, the entire coverage is attained, increasing the appeal of the system for the users. Other factors like ease of use, reliability, and customer support also help to identify high or low adoptions. A positive experience for the users enhances satisfaction and increases the use of the PBS systems over a long period. Moreover, poor experiences, like bicycle shortages, inadequate docking stations, and poor maintenance, decrease adoptions and lead to unfriendliness among users. Users prefer to use other available means of transportation rather than using the PBS system. In short, service quality plays a vital role in the success of

PBS systems, leading to widespread adoption. Factors such as bicycle availability, docking station distribution, and user experience should be considered by PBS operators. This will ensure that service is provided based on the needs and expectations of the users in cities.

In addition to low funding levels, the limited sources of funding are a major headache for the scaling and upgrading of Public Bicycle Sharing systems. In the absence of adequate funding, PBS operators cannot implement the necessary initiatives, such as those directed towards improving the system's infrastructure, accessibility, and user experience. Moreover, the non-availability of adequate funding adversely affects expansion of the PBS network to reach more users and ensure adequate network coverage across the urban environment. Another challenge is the lack of awareness among target PBS users. Many people may be unaware of the concept of PBS or may not know its benefits and availability in their city. Due to this lack of awareness, they may not even consider PBS as an available transportation option but may rather opt for some other mode of transportation familiar to them.

Another challenge is the development of complex app interfaces for PBS. If the mobile application is difficult to operate, it may scare away potential riders as they may find it difficult or confusing to access and use PBS through the app. The user experience problem can play a major role in affecting the adoption and utilization rate of the PBS systems, especially in technologically conscious urban commuters who heavily use mobile applications in transportation-related services (Halvadia et al., 2022). Towards addressing these challenges, a multi-dimensional approach is needed. For example, Public Bicycle Sharing operators can devise systems with greater focus on short-distance travel, ensuring that bikes are always available at the docking station within the city. In addition, service quality needs to be improved as it enhances the experience of the user and builds user satisfaction and loyalty. Increasing the number of revenue streams can also help the PBS operators to address the financial challenges to some extent, such as by reducing dependence on traditional funding. This can be done by exploring partner projects with corporate sponsors, advertisers, or local businesses to augment the revenue streams of the operators. Long-term financial sustainability also involves the fact that PBS systems need long-term financial support. PBS operators need to seek funding commitments from government

agencies, private investors, or other stakeholders to run, maintain, and scale the operations of PBS. Awareness creation through selective campaigns also helps to increase the utilization of PBS. Through the education of the public on the benefits of PBS and accessibility, as well as availability, PBS operators can attract new users and make current users utilize the service more often.

By looking into these factors, PBS systems can evolve into more efficient, financially viable, and user-friendly urban transportation options, enriching urban mobility landscapes and fostering sustainability.

2.3 Benefits of Public Bicycle Sharing (PBS)

Public bicycle sharing (PBS) systems represent a significant advancement in urban transportation, offering a range of direct and indirect benefits that contribute to enhanced mobility, sustainability, and overall quality of life in cities worldwide. Direct benefits of PBS systems are manifold, starting with their ability to maximize resources and efficiency. By facilitating more trips per bicycle per day, PBS systems ensure the optimal utilization of public bicycles, minimizing waste and maximizing the return on investment in bicycle infrastructure (Patel & Patel, 2019). This efficient use of resources is not only cost-effective but also environmentally sustainable, reducing the need for additional vehicles and associated emissions. Convenience is another key direct benefit of PBS systems for users. With PBS, individuals have the flexibility to access bicycles when needed, without the burden of ownership, maintenance, or storage. This on-demand availability of bicycles provides users with a convenient and hassle-free transportation option for short trips, effectively addressing the "last mile" problem commonly encountered in urban mobility (Shaheen et al., 2010). By easing entry into cycling, public bicycle sharing attracts new or latent users to bicycle use, fostering increased physical activity and promoting healthier lifestyles among citizens.

These indirect benefits, apart from contributing significantly to the usefulness of the public bicycle sharing systems for the urban community, include the encouragement of a healthy and active life on the part of citizens. They provide convenient, safe, and low-cost transport for short trips, and, therefore, PBS has the potential to help more people include physical activity in their daily routines, thus contributing to the improvement of public health by lowering the incidence of

sedentary behaviour and improving health rates. Additionally, PBS is an effective tool for environmental sustainability since it reduces tailpipe emissions and noise pollution. Consequently, PBS reduces the number of motorized vehicles on the road, hence contributing to reducing the environmental impact of transport and improving air quality, which results in more healthy and liveable urban environments. In addition, the adoption of PBS systems has potential positive impacts on social and economic aspects. These include increased social cohesion, reduced healthcare costs, and increased productivity due to reduced congestion and increased access to transport means. In essence, the indirect benefits of public bicycle sharing systems are complemented with direct benefits, making them an important tool for the realization of sustainable and healthy urban mobility.

Public bicycle sharing systems play a crucial role in overcoming the dilemma that often impedes the progress of cycling infrastructure in urban areas (Patel & Patel, 2019). By providing users with a convenient and accessible mode of transportation, PBS systems create a growing demand for cycling infrastructure, such as dedicated lanes and bike-friendly road designs. As more individuals opt to use public bicycles for their daily travel needs, there is a corresponding increase in awareness among motorists about the presence of cyclists on the road. This heightened awareness contributes to improved cycling safety, as motorists become more accustomed to sharing the road with cyclists and adjust their driving behaviour accordingly. Ultimately, the expansion of public bicycle sharing systems can help catalyse investments in cycling infrastructure, creating a positive feedback loop that benefits both cyclists and other road users. By fostering a safer and more supportive environment for cycling, PBS systems play a crucial role in promoting sustainable urban mobility and reducing reliance on motorized transportation modes. As more cyclists join the public bicycle sharing system, awareness among motorists increases, leading to improved cycling safety and reducing the risk of accidents on the roads.

Furthermore, PBS systems have broader socio-economic implications (Halvadia et al., 2022). They contribute to urban revitalization and increase property values, particularly through Transit-Oriented Development (TOD) initiatives. By fostering sustainable transportation options, PBS enhances the city's image in terms of "sustainability" and "liveability," attracting residents, businesses, and investment.

Overall, Public bicycle sharing systems offer a comprehensive suite of benefits that extend beyond individual convenience to encompass environmental sustainability, public health, economic vitality, and urban liveability. By promoting active transportation, minimizing environmental impact, and enhancing overall quality of life, PBS emerges as a vital component of modern urban transport systems.

2.4 Identification of Targeted User Group

Research from a number of papers and case studies all reflect a dominant demographic profile for bicycle users, coupled with an emphatic point towards males aged below 30, generally the low-income group by (Guo et al., 2017). Such a demographic trend points to the fact that cycling is a preferred mode of transport among young males, with likely reasons rooted in cost, convenience, and environment. The length of the trip for these bicycle users is often cited to be less than 5 kms (Majumdar & Mitra, 2015), papers (Majumdar & Mitra, 2018), and other studies tend to confirm this trend. This therefore indicates the fact that cycling is being used for short trips such as to work or school, doing errands, or exercising. The preference for cycling among the younger males can be attributed to both its affordability compared to other modes of transport and its flexibility in navigating the urban environment. Additionally, the environmental benefits of cycling, such as low carbon emissions and congestion, and consideration for environmental consciousness may have been another thing that contributes to its appeal. The convenience of riding bikes to short trips also integrates effectively with the issue of congestion and lack of parking in urban areas, making bikes a functional and efficient mode of transport. Finally, these demographic characteristics of bicycle users suggest that the cycling mode of transport may play a significant role in meeting transportation needs, especially among younger individuals and those with lower economic status. With bicycles being an affordable and accessible mode of transport, it adds to an increased list of options for mobility that has been otherwise difficult to access. Bicycles are also short in the lengths of the trip, and it may provide some degree of relief from congestion and rebalancing the overuse of motorized vehicles, creating in effect a more sustainable transport system in the cities.

A research paper by (Dill & McNeil, 2016) carried out some research and discovered an interesting trend with regard to the level of education of bicycle users; namely, a majority of bicycle users tend to have intermediate levels of education. This is an interesting demographic as it shows that bicyclists come from diverse backgrounds, ranging from elementary school education to higher levels. And regard to the diversity of education levels among bicycle users, there are several reasons that may explain this. First, cycling is considered a straightforward, readily available way to travel with little infrastructure and cost. As such, people with intermediate education levels are likely to find it an attractive and practical way of meeting their transportation needs. The appeal of cycling transcends education barriers, since it has some important benefits like cost-effectiveness, flexibility, and environmental sustainability. In comparison to other forms of transportation, such as cars and motorbikes that may require specialized training, the bicycle has no real specialization; it is relatively easy to operate and is, therefore, open to people from any level of education. Finally, because bicycles and cycling infrastructure are available in many cities makes the bicycle a very common form of transportation in any world city. For instance, bicycles are one of the common ways of getting to work or school, making errands, or just cycling for recreation, and people with intermediate education levels are likely to find this a convenient form of transportation.

Several papers and case studies have indicated that a significant number of bicycle users are students by (Molin et al., 2016; Thuany et al., 2020). There are many reasons why students prefer to use bikes. First, the habits of biking that students acquire for commuting to schools or colleges are very practical. Secondly, students find bike travel affordable and sustainable compared to other means of transportation. Among various reasons for the popularity of students as users of bikes, the most prominent reasons are the practicality of cycling for commuting to educational institutions and the affordability and sustainability of this mode of transportation. Bicycles can pass through traffic and roadblocks, unlike cars and buses, and that is what gives a safe, reliable, and flexible means of reaching school or college premises in time. Besides, bicycles are usually cheap compared to other means of transportation, and this appeals to students who might have limited money. The low cost of bike acquisition and maintenance, together with the absence of fuel and parking money, makes bike use an

economic alternative for budget-minded students. Moreover, the specific characteristics of this group of road users indicate that bicycles have the potential to be used to achieve sustainable mobility solutions in urban areas with high population density. Congestion and air pollution in densely populated cities can be considerably reduced when choosing to bike instead of using motorized forms of transportation. By doing so, students contribute to efforts for reducing traffic congestion and improving air quality, thus creating healthier and more liveable cities.

2.5 Case Study of Public Bicycle System

2.5.1 International Case Study

- London- Santander Cycles or Boris Bikes is the London public bicycle sharing system, which was launched in July 2010 as part of the cycling revolution in the city as shown in figure 5. It is operated by Transport for London and sponsored by Santander UK. This system was named after the former Mayor of London, Boris Johnson. The London bike-sharing system became one of the icons of London's urban landscape. One of the primary reasons behind the success of the London bike-sharing system

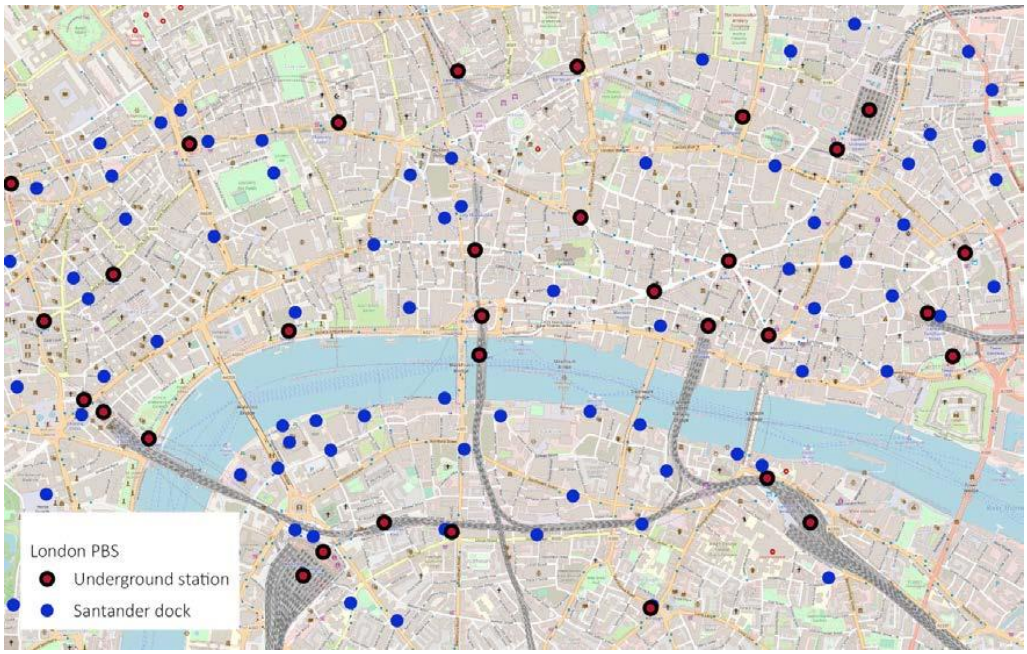


Figure 5 Showing bicycle stations in the city of London.
Source: www.tortacos.jp

was its incorporation with the city's public transport network. Bicycle docking stations were placed near transit stations to facilitate first and last-

mile connectivity for transit users. This integration promoted multimodal transport and offered commuters a smooth, efficient way to move around the city. The system started with an initial fleet of 6,000 bicycles in 2010 and increased to 11,700 bicycles by the end of 2019. This was part of a phased process of increasing the service area within inner London. The service remained available throughout inner London and spread across the city for users. This was a part of the strategy that played a pivotal role in the success of the system. More Londoners now had access to cost-effective and environmentally friendly transport means. The London bike-sharing system has significantly reduced congestion and emissions in the city. The system has encouraged cycling as a viable alternative to motorized transportation, which has helped relieve traffic congestion on the streets of London and, in general, reduced the overall carbon footprint of urban travel. The Santander Cycles have improved connectivity and offered residents and visitors with an easy-to-use and accessible means to explore the city. With regard to profitability and sustainability, the London-based bike-sharing system applied a Gross Cost Contract model, in which the operator receives a fixed sum of money through the government or the contracting authority for providing and running the service. This model has been created to ensure financial stability and motivate private operators to maintain and expand the system while providing a quality service to the users. Revenue was supplemented by subscriptions and user fees, in addition to sponsorship and municipal revenues, which in turn guarantees sustainability and success in the long run.

- New York- Citi Bike is a public transportation system launched in New York City in 2013. In its early days, the system began to morph rapidly into one of the largest and most successful bike-sharing systems in the United States. For this, the initial implementation had an initial supply of 6,000 bicycles and 330 stations as shown in figure 6. The plan of the company was to provide New Yorkers with an easy, affordable, and sustainable mode of transport for short journeys around the city. The stations of the Citi Bike system were strategically placed in many parts of Manhattan and Brooklyn so that the system reached huge regions and was accessible to

most New Yorkers. The Citi Bike system had differentiating characteristics in terms of its level of integration with the existing urban transportation infrastructure, such as subway stations and bus stops.

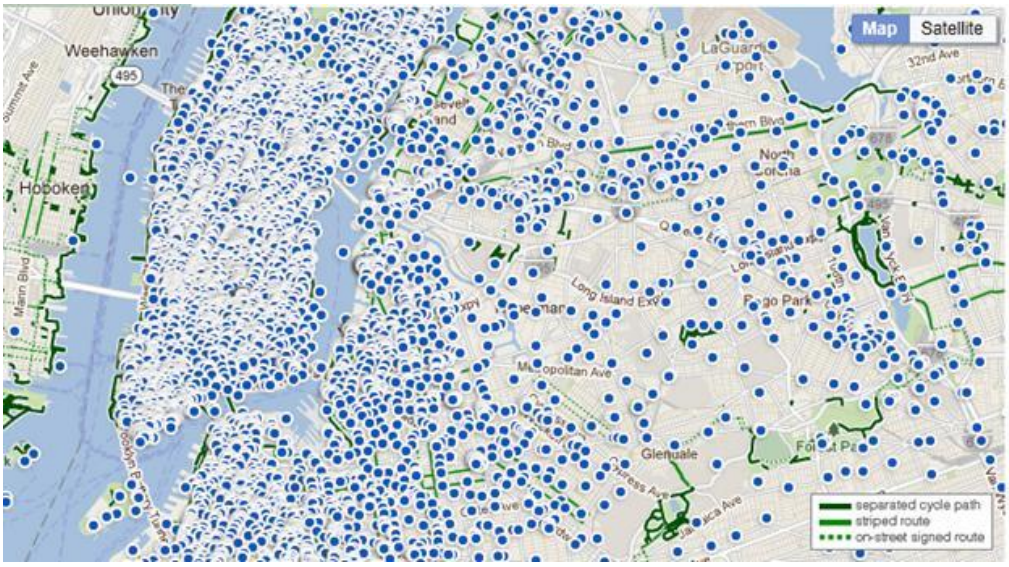


Figure 6 Showing the public bicycle sharing hubs in New York.
Source: huffspot.com

This gave commuters a smooth and practical way to complete their journeys, with first and last-mile connectivity and reduced use of private cars and taxis. Since its inception, Citi Bike has had a major role in serving the advancement of sustainable urban mobility and, therefore, reduction of congestion and emissions in New York City. With the promotion of cycling as an alternative to motorized transportation, the system has brought about a decrease in traffic congestion on the roads of the city and overall reduction of the carbon footprint of traveling in the city. The success of Citi Bike can also be attributed to its interface's convenience and ease of use. It had a friendly mobile application and flexible subscription options, and users can easily access and unlock bicycles at any station. This makes it an attractive and convenient option for short trips around the city. Regarding ridership and usage, Citi Bike has been steadily gaining traction from the start, becoming an integral part of New York City's transportation system with millions of trips made per year, shared by locals and tourists alike.

Over the years, it has expanded significantly, with over 12,000 bicycles and more than 750 stations across Manhattan, Brooklyn, Queens, and

Jersey City as of 2019. The system is designed to provide a convenient and eco-friendly transportation option for short trips within the city, serving as a complement to public transit. It successfully implemented a dense network of stations, integration with public transit, and the city's efforts to improve cycling infrastructure, such as the addition of dedicated bike lanes. The business model they chose was a privately owned and operated system sponsored by Citibank and Mastercard. In addition to Net Cost Contract (NCC) model, in which the government or contracting authority typically retains ownership of the bicycles, docking stations, and other infrastructure assets. The operator is responsible for managing day-to-day operations, such as bike maintenance, rebalancing of bikes across stations, customer service, and marketing. The primary revenue sources are the membership fee and the user fees of the public bicycle sharing system.

2.5.2 Indian Case Study

- Bhopal- The Chartered Bikes system was launched in Bhopal in 2017 as part of the participation of the city in the Smart Cities Mission by the Bhopal Smart City Development Corporation Limited. The project aimed to meet the growing need for sustainable urban transport solutions and provide convenient, low-carbon transport options within the city. The Chartered Bikes system was launched in Bhopal through a combination of public ownership and private operation under a Gross Cost Contract. The scheme received subsidy from BSCDCL at 50 percent of capital expenditure. This was supplemented by the provision of financial support given to the private operator emerging from a competitive bidding process. Another source of finance for BSCDCL in the operational phase came from providing viability gap funding that, after accounting for operating expenses, made the PBS system economically viable.

  The Chartered Bikes system in Bhopal came up against several challenges as it progressed in its operational phase. Among these challenges is the low density of the bikes. The density was only 0.7 bikes per square kilometer, far from the 53 bikes per square kilometer achieved in Copenhagen. The low density is why the average trips per bicycle per

day in Bhopal are low, at 0.5 trips. This underuse showed that the PBS system was not being served to its potential, being used in a much lesser number. Other issues that plagued the Bhopal PBS system included vandalism, encroachments around the docking stations, and viability concerns. The constraints limited the effectiveness of the PBS system as a tool to promote cycling and last-mile connectivity in the city. BSCDCL adopted measures to better integrate the PBS system with other public transport modes and build supportive cycling infrastructure across the city to overcome the drawbacks and achieve enhanced ridership. However, an important point here should be noted that the project, of course, was a standalone project without integration with a broader vision for urban mobility or policies to facilitate cycling. The project received funds from the Smart Cities Mission and capital subsidies by the Bhopal municipal Corporation, but the revenue was realized through advertising, membership fees, and user fees.

- Pune- The Pune Public Bicycle Sharing system represents the growing weightage on non-motorized transportation infrastructure as a sustainable mobility solution in India's urban centres. Being one of this national trend, the Pune PBS system represents a strategic initiative to popularize cycling as the easy and green mode of travel within the city. The Pune PBS system chose a medium-density system with about 3 bikes for every square kilometer. Although this is relatively low compared to the international benchmarks, much lower than Copenhagen, for example, it is still the investment that will go into making cycling popular within Pune. The docking stations are strategically located across significant sections of the city to make it widely available for use.

  A key characteristic of the Pune PBS system is the implementation of a dockless system. This facilitates the return and pickup of bicycles from anywhere at any time without being constrained by fixed docking stations. These features increase the convenience and user-friendliness of the PBS system and help cater to a large number of users, including students, office-goers, and tourists. In addition, the system also features user-friendly interfaces and payment mechanisms, making it accessible to a wide cross-section of the population. Regarding the operational regime,

the Pune PBS system adopted a privately owned and operated business model and leverages the Net Cost Contract (NCC) mechanism. Generally speaking, in the NCC model, ownership of bicycles, docking stations, and other infrastructural assets is typically held by the government or a contractual body, but its day-to-day management and operation are delivered by a private operator. The responsibilities of the operator include the maintenance of bikes, fleet management, customer service, and marketing efforts for encouraging PBS use. Financing of the Pune PBS system is mainly derived from venture capital investments; thus, it shows that private investors are increasingly taken up by sustainable solutions to urban mobility. Revenue is generated through user fees, which include subscription and usage fees, and thus form the platform for the system's operating sustainability.

- Bengaluru- The Bengaluru PBS system signifies a long stride forward in making the sustainable urban transportation part of the agenda. Government-led initiatives toward sustainable transportation infrastructure have made the Bengaluru PBS system the preferred choice for local people to commute within the city. The Bengaluru PBS system focuses on accessibility and user convenience. The city has a higher density of dockless public bicycle stations than many other cities, and the stations are spread across the city so that users can easily have access to bicycles whenever needed for daily commuting. This strategic presence of docking stations will help commuters travel seamlessly throughout the city, saving them valuable time on short trips. Studies have suggested that riders of PBS in Bengaluru have saved up to 10-20 minutes every day, saving them in commuting.

  The business model of the Bengaluru PBS system is built on the partnership of the government and private enterprise that is NCC model. Urban mobility leader Yulu runs the day-to-day operations of the PBS system, which works on a privately owned and run business model. Part of this deal will have Yulu pay the Directorate of Urban Land Transport, or DULT, a permit fee of INR 50 per bicycle per year, under whose authority the Bengaluru PBS system is operated. This type of model will ensure that all business risk related to the operation of the PBS system is transferred

onto the operator, which will highly motivate them to ensure that the system runs smoothly and efficiently, thus reaping profits that may be earned from the system. Besides, financial sustainability is an essential aspect of the Bengaluru PBS system's success. The system is financially supported by venture capital investments and user fees, and it is the primary source of revenue. Venture capital investments form the initial capital required for deployment and development of the system, while user fees in the form of subscriptions and usage fees contribute to working and maintenance costs. This revenue model ensures that the PBS system is financially stable and self-sustaining over the long term, thus eliminating the need for public funding and subsidies.

Beyond that, the implementation of the Bengaluru PBS system has implications for cities and the environment. Increasing cycling as an alternate mode of transport not only reduces congestion, lowers carbon footprints, and minimizes environmental impacts of the city but also promotes public health by increasing physical activity and minimizing sedentary habits.

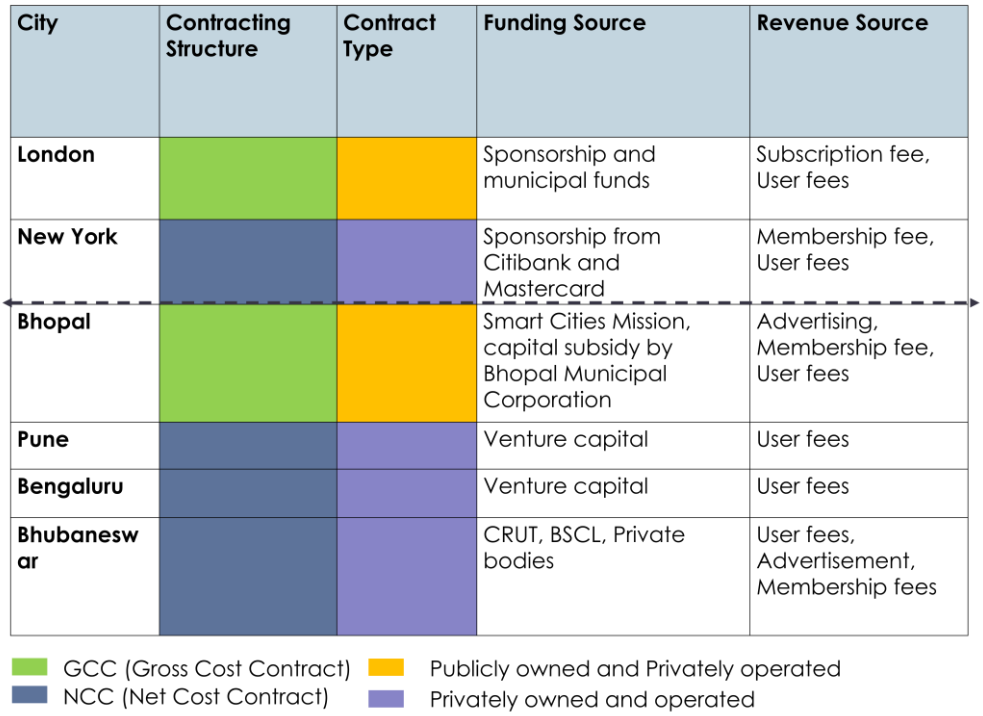


Figure 7 Sowing the business model of international and Indian cities. Source: Author Generated

CHAPTER 3: INTRODUCTION TO STUDY AREA AND DATA COLLECTION

3.0 Study Area

The study area chosen for this research is Bhubaneswar, the capital city of the state of Odisha, India. Bhubaneswar is located in the Khordha district and is one of the major urban centers in the local region as shown in figure 8. According to the latest available data in 2020, the municipal boundary has a population of approximately 11.07 lakh people where male polulation are 6.16 lakh and female population , which makes it one of the major cities in Odisha.

Bhubaneswar lies at the axis of the Eastern Ghats mountains in the Eastern coastal lowlands of India. The average elevation of the city is around 45 meters (148 feet) above sea level, which makes it an average city in terms of its topographical features. Bhubaneswar is strategically located southwest of the Mahanadi River, which acts as the northern boundary of the Bhubaneswar metropolitan area. The presence of the Mahanadi River plays a strong role in the

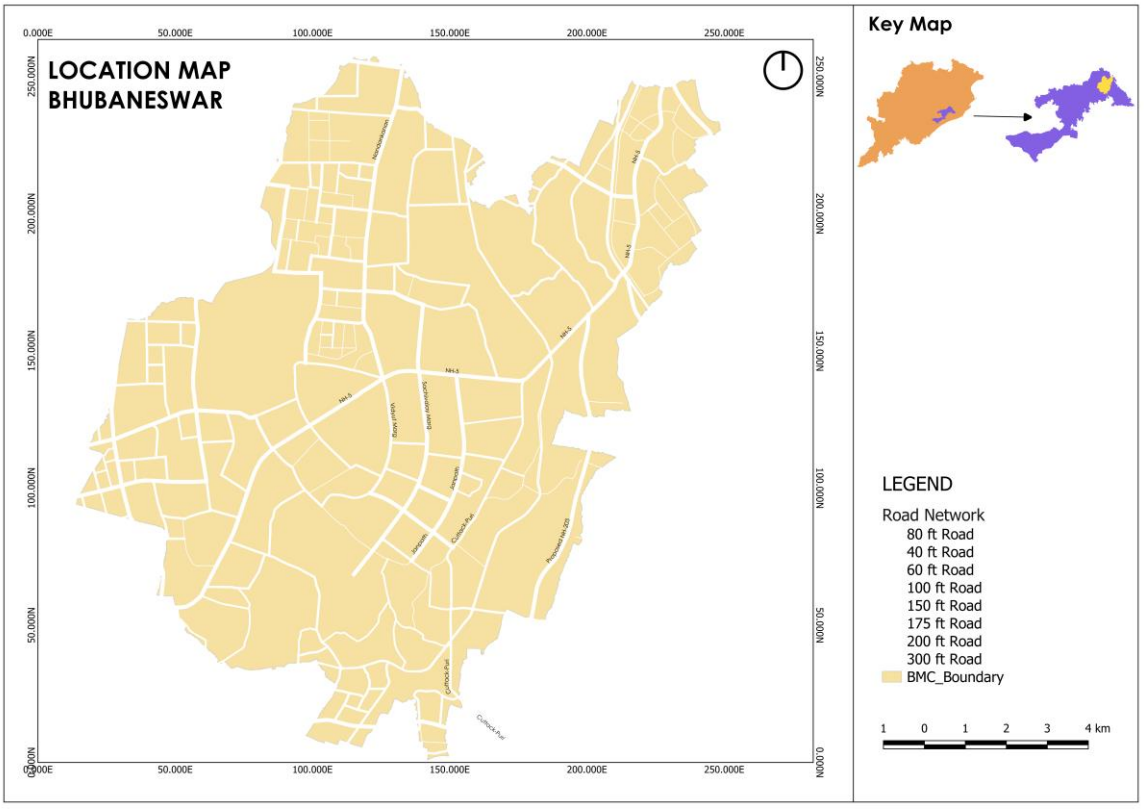


Figure 8 Showing the location of Bhubaneswar Municipal Boundary
Source: Author Generated

city's geography and hydrology, which influences its spatial organization and the patterns of development. To the south of the city, the boundaries are delineated by the Daya River; to the east, by the Kuakhai River. These rivers not only act as natural boundaries but contribute to the city's water resources and the environmental diversity as well. The presence of water bodies such as the Daya and Kuakhai rivers adds beauty to Bhubaneswar and provides opportunities for recreation and ecological conservation.

Apart from the river boundaries, Bhubaneswar is known for its proximity to natural reserves and wildlife sanctuaries. To the west of the city lies the Chandaka Wildlife Sanctuary, a protected area that is rich in biodiversity and diverse ecosystems. The sanctuary is a habitat for a variety of flora and fauna species, which enhances the ecological balance of the city and supports environmental conservation efforts. Nandankanan Zoological Park One of the most famous zoos in India lies beside Bhubaneswar. It is known to conduct conservation programs, research work, and initiatives to spread awareness and knowledge about wildlife among its visitors. Such natural reserves and wildlife sanctuaries give the city its identity. Bhubaneswar stands out, at once, as a city reflecting India's urban growth and pure natural beauty. Bhubaneswar is unique and popular because of its special location surrounded by rivers, wildlife sanctuaries, and natural reserves. This particularity in Bhubaneswar also gives it an identity as a tier 2 city of India. The population of Bhubaneswar, its geographical features, and environmental assets make it an excellent study area in which several facets of urban planning, transportation, and sustainable development could be studied.

In Bhubaneswar, the typical temperature ranges from 11 to 44 °C. Its five main seasons are as follows: winter (December to January), when lows as low as 11 °C are common; spring (February); summer (March to May), when highs as high as 44 °C are possible; monsoon (June to October); and post-monsoon (November). It is 27.4 °C on an annual mean basis. The residents of Bhubaneswar have a climate that is suited for them, with monthly mean temperatures between 22 °C and 32 °C.

Bhubaneswar highlights excellent connectivity to key transportation hubs such as airports, railway stations, and major national highways like NH-16, a vital segment of the Kolkata-Chennai corridor within the Golden Quadrilateral.

Additionally, the city is traversed by Asian Highway AH 45, further enhancing its accessibility and connectivity to regional and international destinations.

Bhubaneswar land use distribution within its municipal boundaries draw a picture of spatial organization and functional characteristics of the city. The largest land use category in the municipal boundary is transportation land, comprising

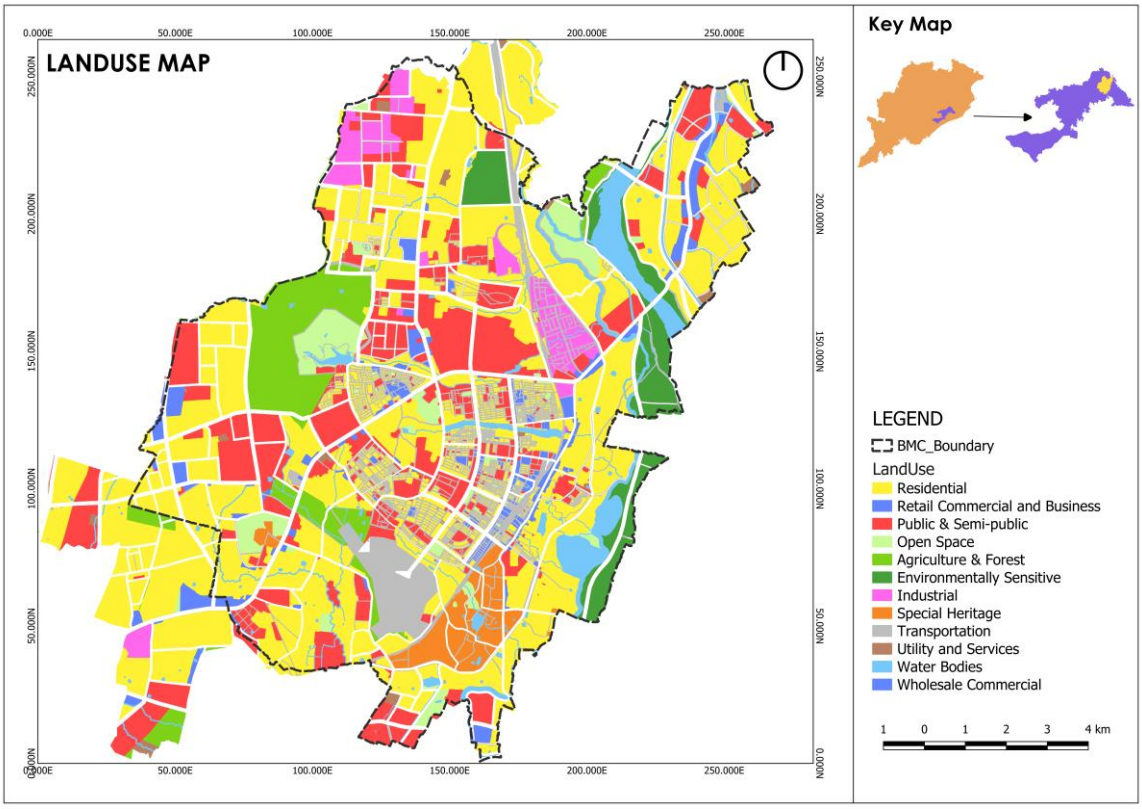


Figure 9 Showing the Land use pattern of Bhubaneswar.
Source: Author Generated

approximately 37.6% of the land. The residential areas occupy about 30.21% of the municipal boundary. The transportation land is divided into local roads, collector roads, sub-arterial roads, and arterial roads that run across the city's landscape as shown in figure 9. The road network is one of the vital components of the city's infrastructure. It facilitates the movement of people, goods, and services across the city or beyond. Most of the land allocated to transportation is used to highlight its emphasis on mobility and connectivity. Bhubaneswar's transport infrastructure has an extensive and developed road network across the city's landscape. These roads are both intra-city as well as regional and national transportation corridors. The road categories are different and reflect different

volumes of traffic, speed, and functional importance, according to the city's diverse mobility requirements.

Residential areas occupy the second largest amount of land, amounting to approximately 30.21% of the municipal boundary. Residential areas include residential typologies such as single-family homes, apartment complexes, gated communities, and informal settlements. These are the primary habitats of the people of Bhubaneswar. The residents live in these areas, derive housing, and support the construction of community spaces and other amenities to lead a good and quality life in the city. A huge amount of land is allocated to residential areas to accommodate the city's growing populace and satisfy demand. Bhubaneswar's residential areas are characterized by a variety of land uses, including commercial establishments, educational institutions, recreational facilities, and green areas.

Besides transport and residential land, a considerable percentage of the municipal limit is meant for agricultural and forest land, which constitutes almost 16.08% of the total area. This land comprises agricultural fields, orchards, plantations, and forested tracts and will contribute to the environmental sustainability, biodiversity, and ecological balance of the city. Bhubaneswar, being an urban centre, is linked to its rural hinterland in the form of agricultural and forest landscapes that are maintained in its municipal limit. Water bodies are another land-use category but are relatively small-covering nearly 4.1% of the city's area. These are lakes, ponds, rivers, and reservoirs that make vital contributions towards drainage, groundwater recharge, and recreational activities. The water bodies are great ecological assets for Bhubaneswar, supporting biodiversity, mitigating flood risks, and adding to the aesthetic appeal of the city.

The Bhubaneswar modal share in transportation reveals some interesting features. It is strongly dominated by private vehicles, with more than 60% of the total modality share. This reveals the fact that people are much dependent on private forms of transport, like cars and motor bikes. The use of private vehicles is convenient and flexible, and therefore the population could move according to their times and priorities. However, it also increases the level of traffic congestion and air pollution and creates problems regarding the parking of these vehicles.

Around 22% of the modality share in Bhubaneswar pertains to intermediate public transport (IPT). IPT comprises various modes such as auto-rickshaws and

bicycle rickshaws. Such means of transport play an essential role in providing last-mile connectivity and support the city's public transport network. These

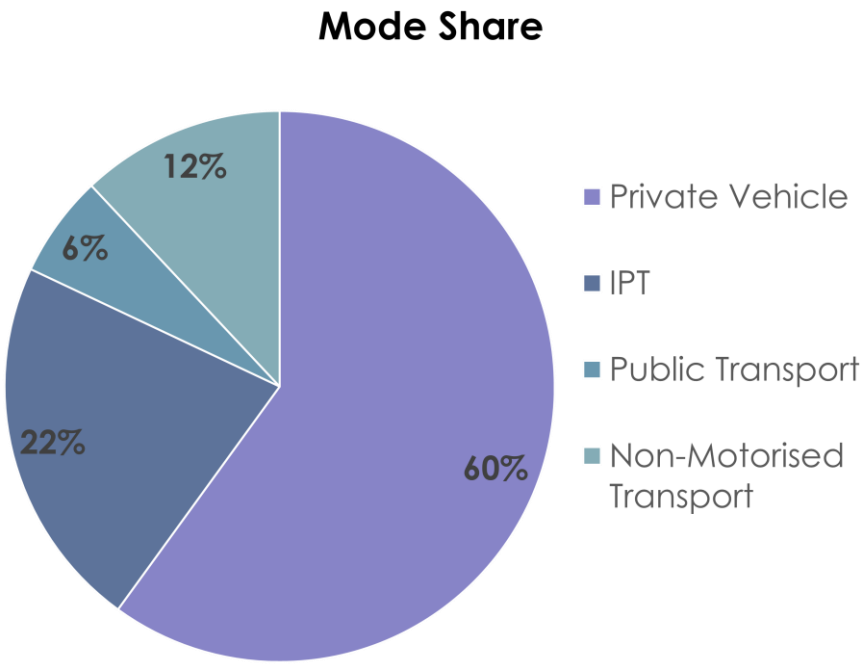


Figure 10 Showing the modal share of the city.
Source: Public Bicycle Plan, Bhubaneswar

transportation means provide affordable and flexible modes of transport for short trips and areas without good access to formal public transport systems. Another important element of the modal share of Bhubaneswar pertains to non-motorized transport (NMT) which is 12%. The transportation modes under NMT include walking and cycling. These are indispensable in making Bhubaneswar's goals of healthy and sustainable transport come true. Bhubaneswar has built dedicated infrastructure for NMT, such as the dedicated bicycle lanes, pathways for pedestrians, and the cycle-sharing programs. This ensures that the Transportation experience of pedestrians and cyclists is safe, accessible, and comfortable.

Public transport contributes to a small share of the mode split in Bhubaneswar, about 6% of total trips. However, the city has made remarkable steps in improving its public transport. The introduction of Mo Bus, a comprehensive and efficient urban bus service operated by the Capital Region Urban Transport (CRUT), has revolutionized public transport in Bhubaneswar. Mo Bus has kept the residents and visitors commuting in a reliable and affordable way. The

extensive network of routes covering significant destinations across the city is adding more value to commuters. The combination of technology, like real-time tracking and cashless payment options, is making the services more convenient and accessible, and more people are switching towards the Mo Bus services instead of driving their private vehicles. Mo Bus is just one of the many public transport initiatives in Bhubaneswar that try to offer better and most convenient access to commuters—where it really gets the push is the proposed Bhubaneswar metro system. With the introduction of the metro system, people can travel fast and efficiently in a sustainable mode. The introduction of a metro network could expand the coverage of public transport, making it possible for more travellers to shift away from private vehicles.

Bhubaneswar, with its growing population of 11.07 lakh residents spread across 161 square kilometers, faces typical metropolitan transportation challenges, including pollution and traffic congestion. To address these issues and provide efficient first and last-mile connectivity, municipal authorities have implemented a Public Bicycle Sharing (PBS) system, complementing the existing public bus service, MO BUS. By integrating cycling into the city's transportation network, the PBS system offers residents an alternative mode of transportation, reducing reliance on motorized vehicles and promoting sustainability.

The design of the PBS system was carefully planned to cover a distance of 120 kilometers in two phases, strategically spanning key areas of the city. Phase 1 of the project, spanning 40 kilometers, focused on establishing essential infrastructure and services to initiate the system's operations. This phase involved the installation of 175 stations and deployment of 2000 bicycles, strategically positioned to maximize accessibility and convenience for users. The primary objectives of Phase 1 were to establish a foundational network, attract early adopters, and demonstrate the viability and benefits of the PBS system to the residents of Bhubaneswar. During the initial phase, emphasis was placed on covering important regions within the city, including commercial hubs, residential neighbourhoods, educational institutions, and transit hubs. By strategically locating stations in high-demand areas and ensuring sufficient bicycle availability, the PBS system aimed to encourage usage and promote cycling as a viable mode of transportation for short trips.

Following the success of Phase 1 as shown in figure 11, the PBS network expansion entered Phase 2, aiming to extend the coverage area to 80 kilometers and further enhance connectivity and accessibility across Bhubaneswar. The second phase of the project focuses on strengthening the network's reach and

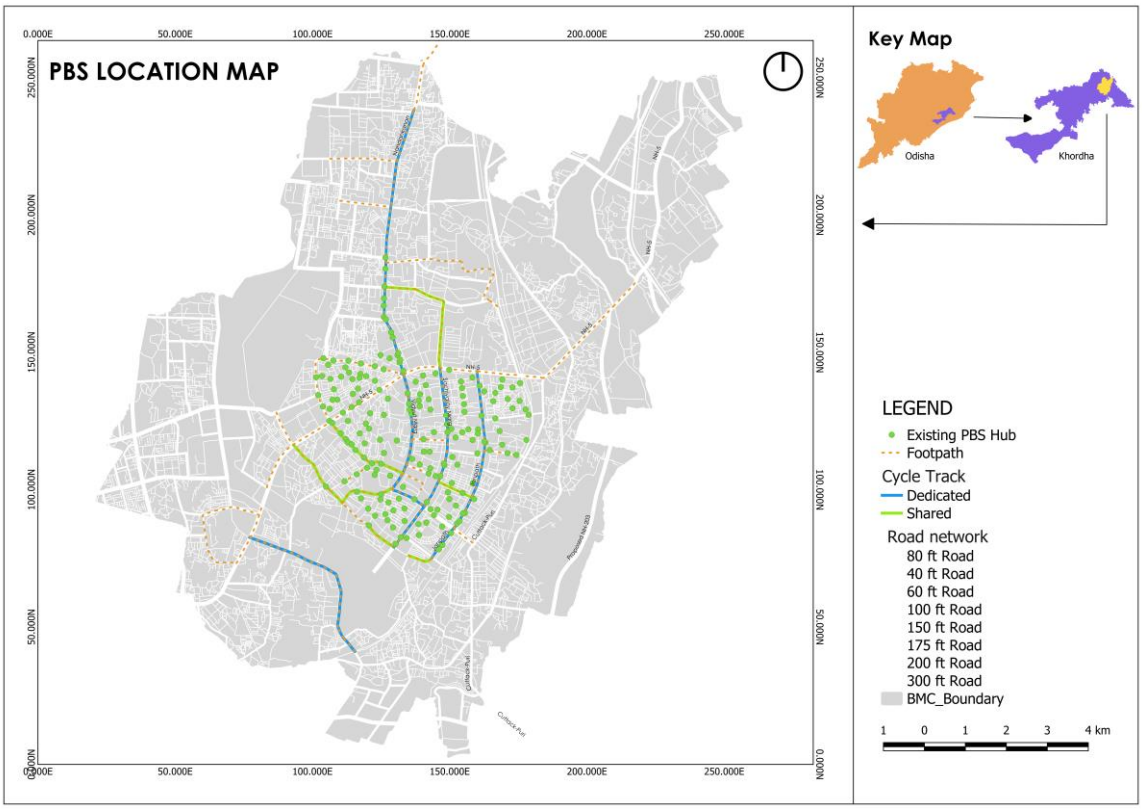


Figure 11 Showing the location of the PBS hubs.
Source: Author Generated

penetration, ensuring that more residents have access to the PBS system and can benefit from its services. The expansion project in Phase 2 will prioritize areas with high population density, transit corridors, and areas with limited access to other modes of transportation. By improving connection points and bridging gaps in the existing network, Phase 2 aims to create a seamless and integrated transportation system that offers residents a convenient and sustainable alternative for their daily travel needs.

Despite the city's significant road length of 1783.38 km, dedicated infrastructure for cycling was limited. Only 24.4 km of dedicated bicycle tracks and 11 km of shared bicycle tracks existed, along with 67.4 km of footpaths. This scarcity of cycling infrastructure highlighted the need for comprehensive urban planning to prioritize non-motorized transport options and create safer environments for cyclists and pedestrians. Integrating the PBS system with existing public transit

networks was a strategic move to encourage multimodal transportation and provide commuters with convenient options for short trips. By aligning PBS routes with MO BUS services, city planners aimed to complement existing transit options and reduce reliance on private vehicles for daily commuting.

3.1 Data Collection Framework

The initial phase of this research involved the identification and utilization of various data sources to comprehensively assess the status and dynamics of the Public Bicycle Sharing (PBS) system in Bhubaneswar. Primary data collection focused on multiple aspects, including the existing condition of the PBS network, origin and destination data pertaining to bicycle trips, perception surveys targeting cycle users, and consultations with key stakeholders involved in the planning and implementation of the PBS system. These primary data sources provided invaluable insights into the operational challenges, user preferences, and stakeholder perspectives shaping the current landscape of bicycle sharing in the city. Secondary data sources were also leveraged to enrich the analysis and contextualize the findings. These secondary data encompassed various facets, such as land use data, ward boundary data delineating administrative divisions, the geographical distribution of PBS hubs, the layout of existing cycle networks, and documentation related to the request for proposals (RFP) for the PBS system in Bhubaneswar. By integrating primary and secondary data sources, the research aimed to offer a holistic understanding of the PBS ecosystem, capturing both qualitative nuances and quantitative trends.

The data collection approach adopted for this study employed a combination of qualitative and quantitative methods to gather diverse insights and validate findings. Qualitative methods included perception surveys administered to cycle users, facilitating the exploration of subjective experiences, preferences, and challenges encountered in utilizing the PBS system. Stakeholder consultations, comprising meetings and group discussions, offered a platform for key actors to share their perspectives, experiences, and recommendations for enhancing the PBS system's effectiveness and sustainability. On the other hand, quantitative methods involved the analysis of origin and destination data to discern spatial patterns of bicycle usage, as well as the utilization of GIS tools to map the

existing non-motorized transport (NMT) network and assess its connectivity and accessibility.

The sampling Strategy followed to collect the primary data is Non-probability sampling in which I have moved forward with purposive sampling. In purposive sampling I have collected the data of a set of people of a same purpose. So the parameter of selection of samples are the People who are cycling inside the boundary of Bhubaneswar Municipal Corporation.

3.1.1 Primary Data Collection

The primary data collection process in Bhubaneswar was a multifaceted approach aimed at comprehensively understanding the dynamics of transportation usage and preferences within the city. This process primarily involved conducting perception surveys at various strategic locations within the Bhubaneswar Municipal Corporation boundary.

These perception survey questionaries were designed to gather a wide range of demographic information to capture the diverse profiles of the city's population. Key demographic variables included gender, age, education level, occupation, family monthly income, household size, and vehicle ownership status. By collecting this data, we sought to gain insights into the socio-economic characteristics of individuals and households influencing transportation choices. Then collecting the demographic data, the surveys also focused on capturing detailed trip characteristics. This included information on trip purpose, origin and destination of trips, trip length, and travel time. Understanding these trip characteristics was essential for discerning patterns of travel behaviour and identifying specific transportation needs and preferences. To know the behaviour and attitude of the bicycle users, the surveys delved into the behavioural attitudes of both bicycle users and Public Bicycle Sharing (PBS) users. For bicycle users, the questionnaire covered aspects such as the frequency of bicycle use, types of trips made using cycles, challenges encountered while cycling, frequency of use of bicycle tracks, and issues with existing bicycle track infrastructure. Similarly, for PBS users, data was collected on the challenges faced while using the public bicycle sharing system and potential interventions that could facilitate a transition from being a bicycle user to a PBS user.

This comprehensive approach to data collection, it was aimed to gather rich and nuanced insights into the transportation habits, preferences, and challenges faced by residents of Bhubaneswar. This data would serve as a foundation for informed decision-making and the development of targeted strategies to enhance sustainable transportation options, promote PBS as an active mobility option in the city, and improve overall urban mobility within the city.




Figure 12 Showing the perception survey done in site visit.
Source: Author Generated

3.1.2 Secondary Data Collection

The secondary data I gathered included the current road network, NMT network, and bicycle tracks from the Bhubaneswar Urban Knowledge Centre (BUKC). Next, I obtained the current land use data from the Bhubaneswar Development Authority (BDA), then the yearly ridership data from the Bhubaneswar Smart City Limited (BSCL), and finally, I obtained the Request for Proposal document of the Bhubaneswar Public Bicycle Sharing System from the Bhubaneswar Municipal Corporation(BMC).

Figure 13 Showing the organisations secondary data collected from.

CHAPTER 4: DATA ANALYSIS

4.1 Socio-Economic Characteristics of Bicycle Users

4.1.1 Gender

Figure 14 illustrates the distribution of bicycle riders by gender, revealing a notable gender disparity in bicycle usage. The data indicates that male users constitute the majority, accounting for 72.6% of bicycle riders, while female users comprise a significantly smaller proportion at 24.4%. This observation underscores the gender gap prevalent in cycling participation, with males far outnumbering females in terms of bicycle usage. The discrepancy between male and female users suggests potential barriers or challenges that may deter women from cycling, such as safety concerns, lack of infrastructure catering to their needs, cultural norms, or social perceptions surrounding cycling as a mode of transportation or leisure activity.

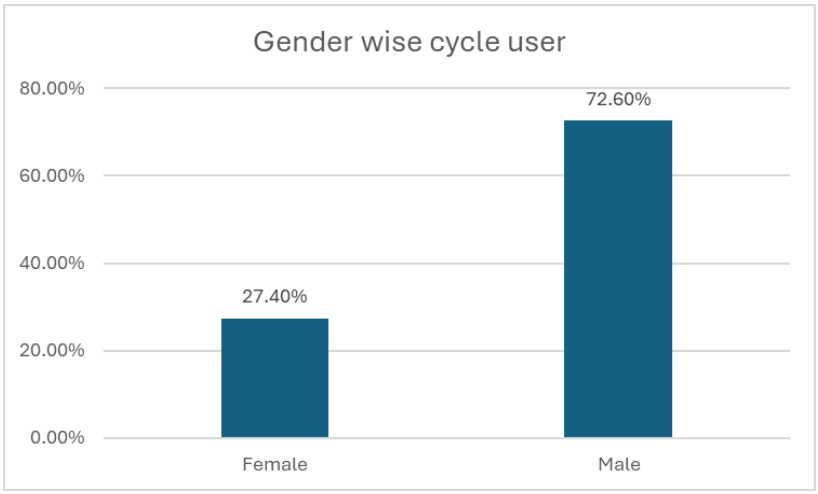


Figure 14 Graph showing the gender wise user of bicycle.

4.1.2 Age

Figure 15 presents the age-wise distribution of bicycle users, revealing insights into the demographics of cycling participation. The data indicates that individuals aged under 15 represent a considerable proportion of bicycle users, accounting for 19.18% of the total user base. Notably, the age group spanning from 15 to 30 years constitutes the largest segment of bicycle users, comprising 42.47% of the

user population. This finding suggests a strong affinity for cycling among young adults and adolescents, highlighting the popularity of bicycles as a mode of transportation or recreation within this demographic group. The data reveals a notable presence of bicycle users in the age bracket of 30 to 45 years, representing 28.77% of the total user base. While slightly lower than the 15-30 age group, this segment indicates continued interest and engagement in cycling among individuals in their thirties and forties. Conversely, individuals aged 45 to 60 years constitute a smaller proportion of bicycle users, accounting for 9.5% of the user population. This demographic trend underscores the prominence of cycling as a preferred mode of transportation or leisure activity among younger age groups, particularly those in their teens and twenties.

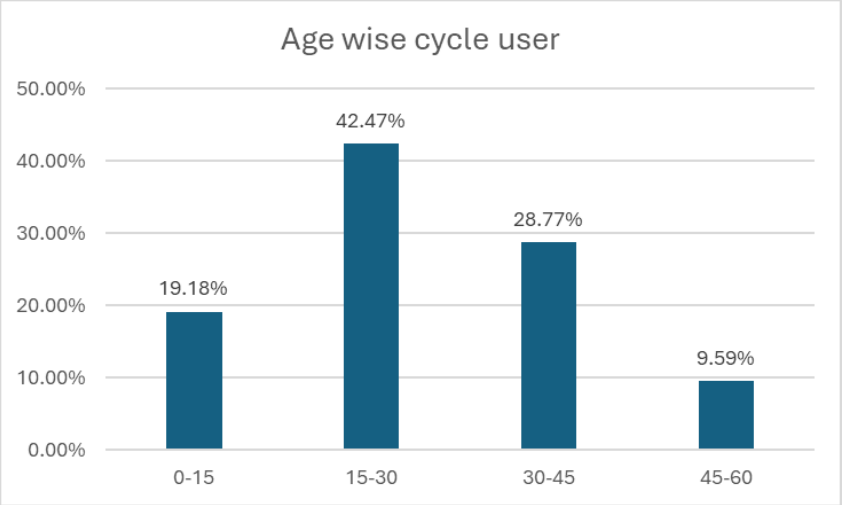


Figure 15 Graph showing the age wise user of bicycle.

4.1.3 Income

Figure 16 provides insights into the income distribution of bicycle users. The data reveals that a significant majority of bicycle users belong to the lower income brackets, with 50.68% of users reporting an income level of less than 10,000. This finding underscores the importance of bicycles as a cost-effective mode of transportation for individuals with limited financial resources, offering an affordable and accessible means of mobility for those in lower-income segments of the population.

The data indicates that a substantial proportion of bicycle users fall within the income range of 10,000 to 20,000, comprising 36.99% of the total user base. This

segment represents another economically disadvantaged group that relies on bicycles for their transportation needs, highlighting the role of cycling as a preferred mode of travel among individuals with moderate income levels. On the other hand, the data reveals a smaller presence of bicycle users in higher income brackets, with only 9.59% of users reporting an income level of 21,000 to 30,000, and a mere 2.74% reporting an income level of more than 30,000. While these higher income groups represent a minority of bicycle users, their inclusion underscores the diverse socioeconomic backgrounds of individuals who choose

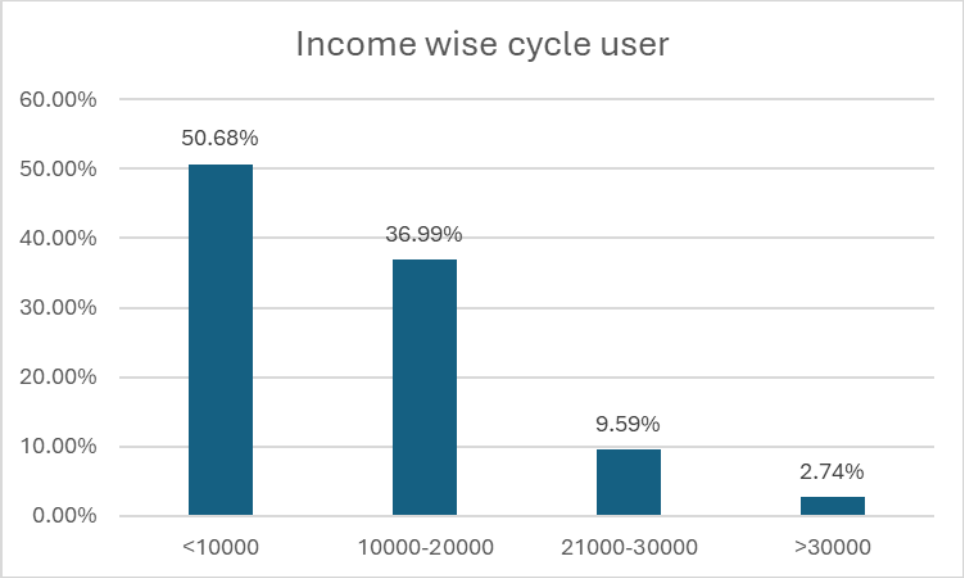


Figure 16 Graph Showing the income wise user of bicycle.

cycling as their mode of transportation.

4.1.4 Education

Figure 17 illustrates the distribution of educational qualifications among the users of bicycles, showcasing that individuals who have completed high school education or are currently pursuing it make up 45.21% of the total cycling population. Furthermore, those with an intermediate level of education or currently pursuing it constitute 20.55% of the cycling demographic. Similarly, individuals with a graduation degree or currently pursuing one represent 27.4% of the bicycle users, while those with post-graduation qualifications or currently pursuing them account for 6.85% of the cycling community. Based on the primary data analysis, it appears that individuals with a high school educational background are more inclined towards utilizing bicycles as a mode of transportation.

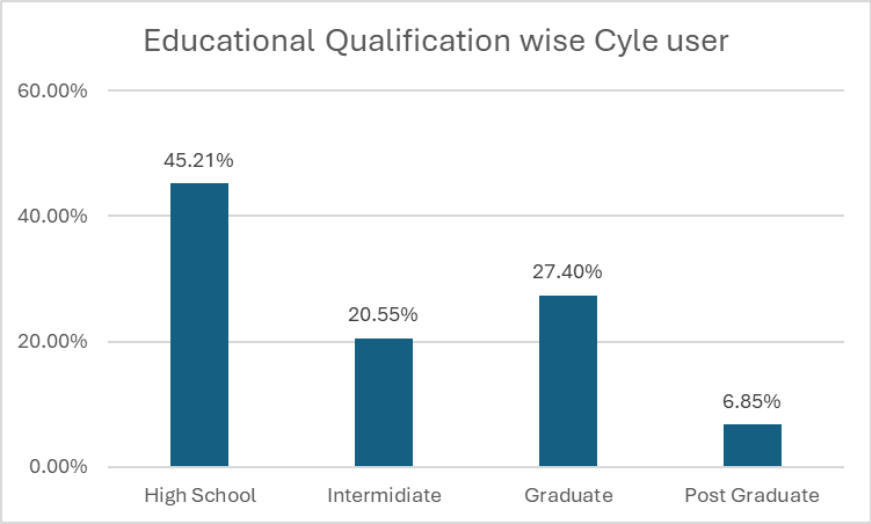


Figure 17 Graph showing the educational qualification wise user of bicycle.

4.1.5 Occupation

Figure 18 shows the distribution of occupation among the bicycle users, showcasing the individuals with occupation of business are 6.85%, individuals with occupation of self-employment are 19.18%, individual with occupation of service are 17.81% and individual who are in the category of students are 53.42%. Based on the primary data analysis it is found that the students are very likely to use bicycle as a mode of transportation.

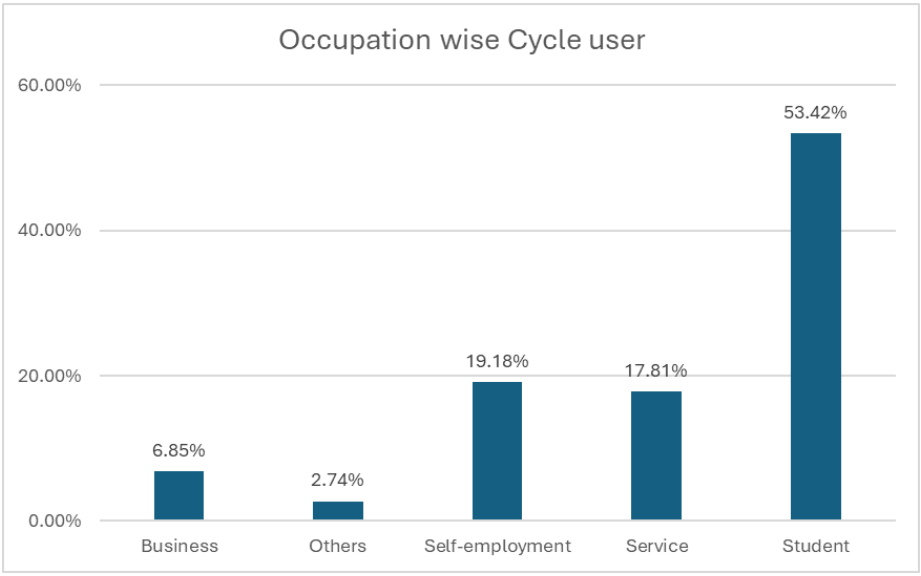


Figure 18 Graph showing the occupation wise user of bicycle.

4.2 Travel Characteristics of a Bicycle Users

4.2.1 Travel Time

Figure 19 illustrates the distribution of travel time among cycle users based on the primary data collected. It reveals that the majority of users, comprising 54%, ride bicycles for less than 15 minutes. Additionally, 31% of users ride for durations between 16 to 30 minutes, while 11% of users ride for durations ranging from 31 to 45 minutes. Only a small proportion, accounting for 4%, ride bicycles for more than 45 minutes. This data suggests that the predominant pattern among cycle users is shorter trips, with a significant portion opting for rides lasting less than 15 minutes.

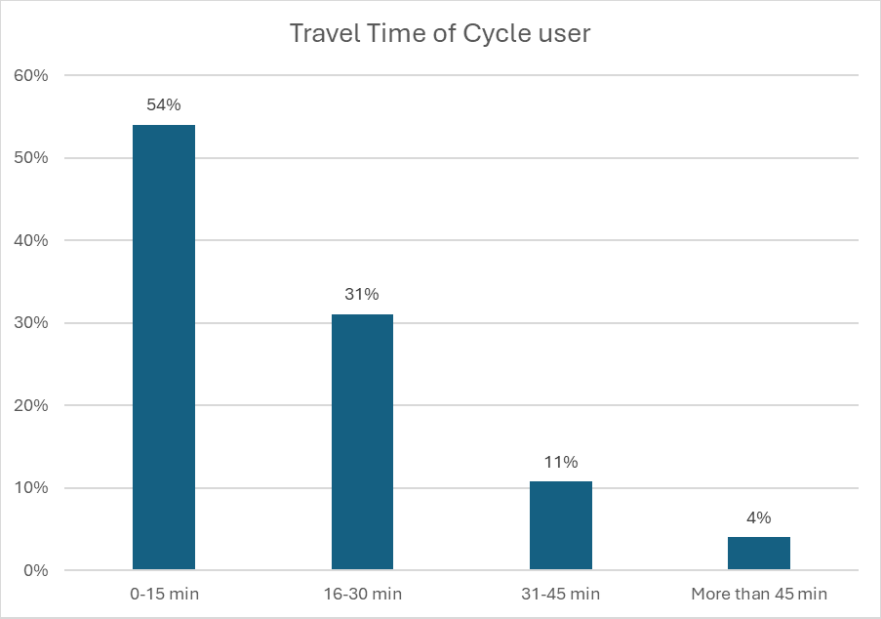


Figure 19 Graph showing the Travel time of the bicycle users.

4.2.2 Trip Length

Figure 20 provides insights into the duration of bicycle users' journeys, extracted from the primary dataset, categorizing them based on the distance covered. The data reveals that a significant majority, comprising 77% of all users, opt for trips spanning less than 5 km. Following this, 22% of users embark on slightly longer journeys, covering distances ranging from 6 to 10 km. A marginal fraction, accounting for only 1% of the total, consists of users who undertake trips exceeding the 10 km mark. This distribution underscores a prevalent trend where

a substantial proportion of individuals favour shorter distances for their routine commuting requirements, aligning with the practicality and convenience of cycling as a mode of transportation for shorter trips within urban settings.

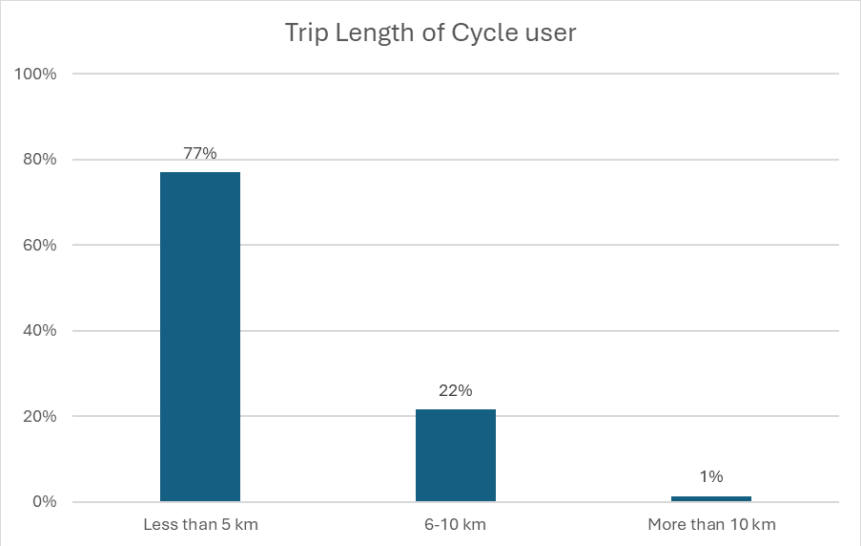


Figure 20 Graph showing the Trip length of the bicycle users.

4.2.3 Trip Purpose

Figure 21 provides a comprehensive overview of the various travel purposes among cyclists, delineating the percentages of cyclists engaging in different types of trips. It reveals that a notable segment, constituting 6.76% of cyclists, utilizes bicycles for business-related trips, emphasizing the practicality and versatility of cycling for professional purposes. Additionally, 6.7% of cyclists employ bicycles for commuting to colleges or educational institutions, highlighting the role of cycling as a convenient mode of transportation for students. Furthermore, a significant proportion of cyclists, comprising 27.03% of the total, utilize bicycles for recreational and social activities, indicating the widespread adoption of cycling as a leisurely pursuit and means of social engagement. Moreover, 21.6% of cyclists undertake journeys for school-related purposes, underscoring the importance of cycling in facilitating safe and sustainable transportation options for school-going children. Notably, the largest segment of cyclists, comprising 37.8% of the total, employs bicycles for work-related travels, reaffirming the significance of cycling as a practical and efficient mode of commuting to workplaces. This comprehensive breakdown of travel purposes among cyclists underscores the

diverse range of activities supported by cycling and highlights its multifaceted role in meeting various transportation needs within urban environments.

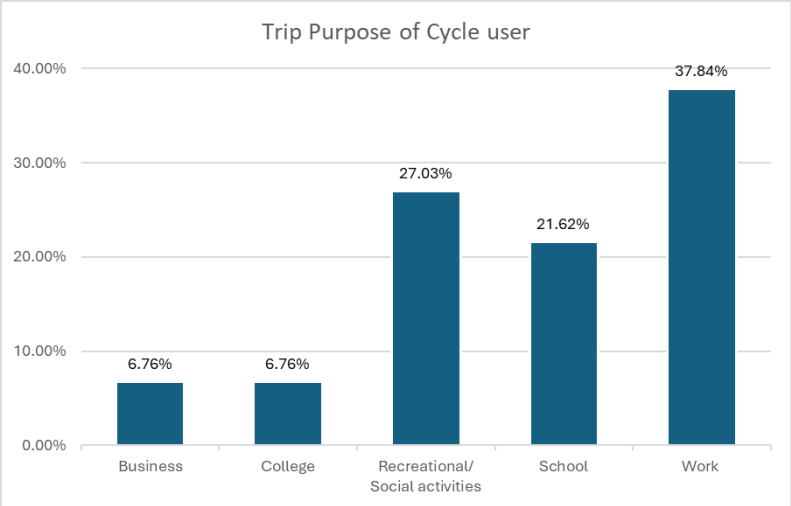


Figure 21 Graph showing the Trip purpose of the bicycle users.

4.3 Comparing the onsite scenario

The primary dataset collected for analysis encompasses a range of variables crucial for understanding the characteristics and preferences of cycle users within the study area. These variables include gender, age, income level, trip distance, education level, and occupation. By examining these factors, researchers aim to gain insights into the demographics and behaviour patterns of individuals utilizing bicycles for commuting and other purposes.

A comparison will be conducted between the primary data and findings from various research papers, including studies by (Acharjee & Sarkar, 2021; Ceyiz, 2019; Dill & McNeil, 2016; Guo et al., 2017; Kaplan et al., 2015; Majumdar & Mitra, 2015, 2018; Molin et al., 2016). These studies suggest that certain demographic characteristics are associated with a higher likelihood of bicycle usage. Specifically, males below the age of 30, belonging to lower-income brackets, traveling short distances of less than 5 km by cycle, possessing an intermediate level of education, and being students are identified as key user groups in previous research. The comparison between the collected primary data and the user profiles identified in existing literature aims to validate the findings and identify any alignment or deviation within the study area. If the primary data align closely with the identified user groups from previous studies, it would

reinforce the validity and generalizability of the existing research findings to the specific context of the study area. On the other hand, if significant disparities are observed, it could indicate unique characteristics or preferences among cycle users in the study area, warranting further investigation and analysis.

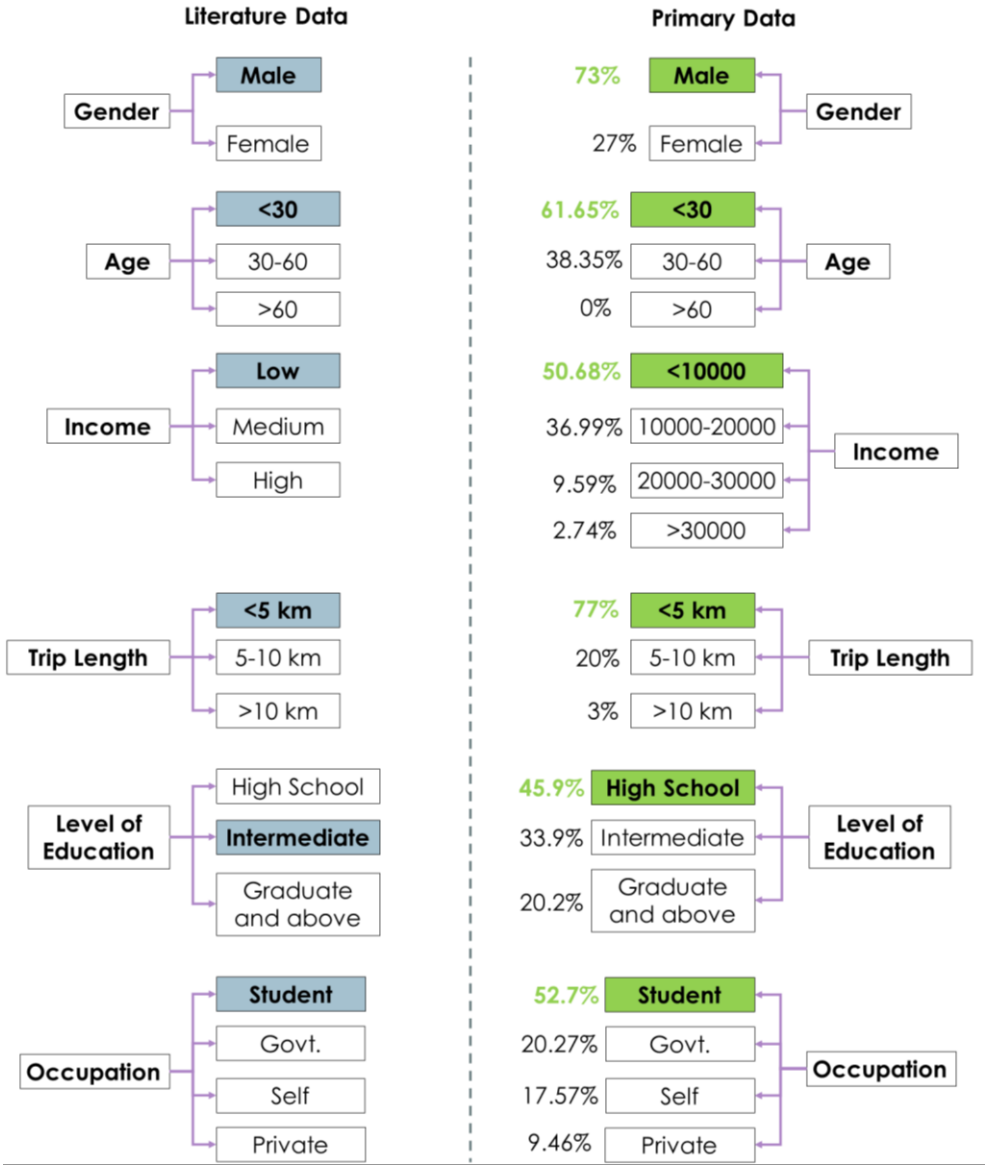


Figure 22 Showing the comparison between literature data and primary data.

The primary data analysis in Figure 22 reveals striking similarities between the characteristics of cycle users in Bhubaneswar and those identified in the literature. Across various demographic variables such as gender, age, income level, trip distance, and occupation, the patterns observed align closely with the findings reported in research papers. However, one notable difference emerges concerning the level of education among cycle users in Bhubaneswar, where a

higher proportion of individuals have attained a high school education. Socio-economic factors and cultural norms prevalent in Bhubaneswar may contribute to the educational profile of cycle users. In many Indian cities, including Bhubaneswar, access to higher education is often influenced by socio-economic status and family background. Individuals from lower-income households or marginalized communities may face barriers to accessing higher education beyond the high school level. Consequently, a larger proportion of cycle users in Bhubaneswar may have completed their education at the high school level, reflecting the socio-economic composition of the city's population.

The role of cycling as a mode of transportation for students cannot be overlooked. Many students rely on bicycles to commute to educational institutions due to factors such as affordability, convenience, and accessibility. As such, the high prevalence of students among cycle users may contribute to the observed distribution of educational attainment, with a significant portion having completed high school education.

4.4 Analysing Average Trip Length with different variables

The average trip length data available for 72 persons in Bhubaneswar provide the fundamental insights on the cycling dynamics of the city. Trip length is a measure to understand the behaviour of cyclists, which acts as a benchmark for comparing the trips with various demographic factors. Examining trip lengths and the various demographic factors, such as gender, age, income, education, occupation, and trip purpose, brings forth the essential insights to understand the factors that influence the cycling pattern in Bhubaneswar.

The trip lengths between various demographic groups uncover interesting patterns that highlight the motivations and preferences for the cycling activity of the people in the city. For instance, the trip length between the genders can reveal differences in the cycling behaviour of women and men. Age demographics suggest the generational differences in preferences and the mobility needs. Levels of income and education can indicate differing access and attitudes towards cycling. Occupation and trip purpose further enrich the analysis and reveal highly nuanced insights into the cycling behaviour of people in Bhubaneswar. An understanding of trip lengths based on occupations shows an

insight into the various commuting habits of people, while trip purpose gives an insight into both functional and recreational patterns of cycling.

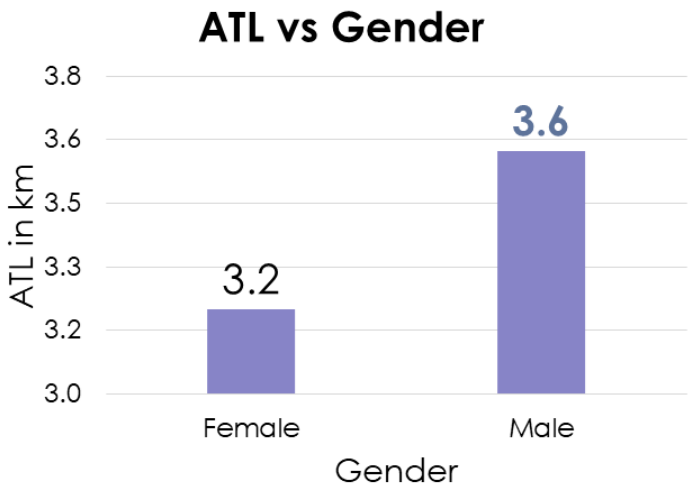


Figure 23 Showing the graphs of ATL vs Gender.

Figure 23 illustrates a notable disparity in the average trip lengths between male and female users, with male users averaging 3.6 kilometers per trip compared to 3.2 kilometers for female users. This discrepancy underscores potential differences in travel behavior and preferences between genders, highlighting the importance of gender-sensitive transportation planning and infrastructure development.

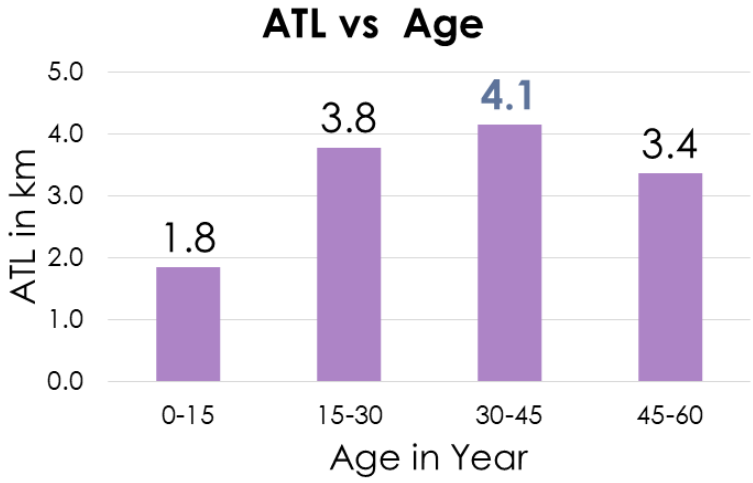


Figure 24 Showing the graphs of ATL vs Age.

Figure 24 shows the distribution of average trip lengths across different age categories, revealing that the age group covering the longest distances, at 4.1 kilometers, falls between 30 and 45 years. Following this, the age group spanning from 15 to 30 years covers an average distance of 3.8 kilometers, trailed by the 45-60 age bracket at 3.4 kilometers. Lastly, the age group comprising individuals aged 0-15 covers the shortest average distance, at 1.8 kilometers.

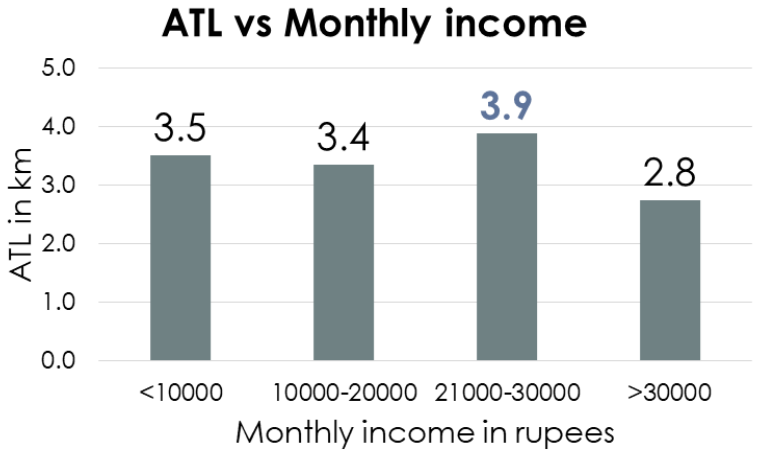


Figure 25 Showing the graphs of ATL vs Monthly income.

Figure 25 illustrates the relationship between average trip length and the monthly income of users. It reveals that the highest average trip length, at 3.9 kilometers, is observed among users with a monthly income ranging from 21000 to 30000 rupees. This is followed by an average trip length of 3.5 kilometers among users earning less than 10000 rupees per month, and 3.4 kilometers among those with a monthly income between 10000 and 20000 rupees. In contrast, users with a monthly income exceeding 30000 rupees have the shortest average trip length, at 2.8 kilometers.

Below is Figure 26, illustrating the relationship between the educational qualifications of users and their average trip lengths. Among the user groups, those with postgraduate qualifications cover the longest average trip distance, at 5.4 kilometers, followed by individuals with intermediate qualifications, who travel an average distance of 4.75 kilometers. Users with undergraduate qualifications come next, with an average trip length of 4.28 kilometers, while those with high school qualifications cover the shortest average distance, at 2.11 kilometers.

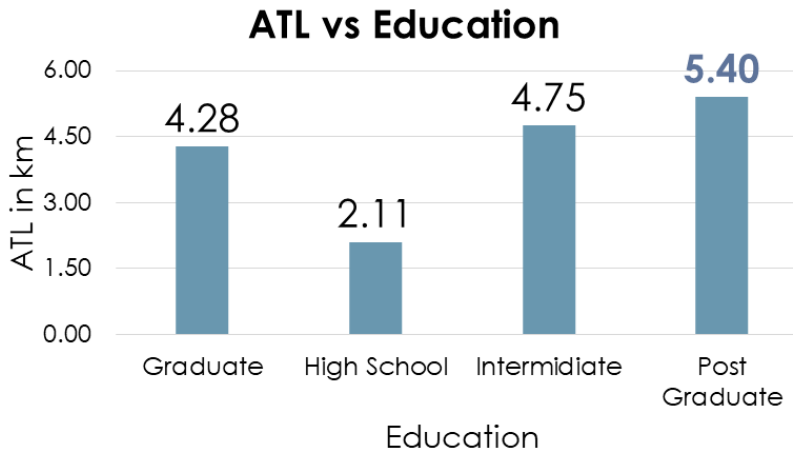


Figure 27 Showing the graphs of ATL vs Education.

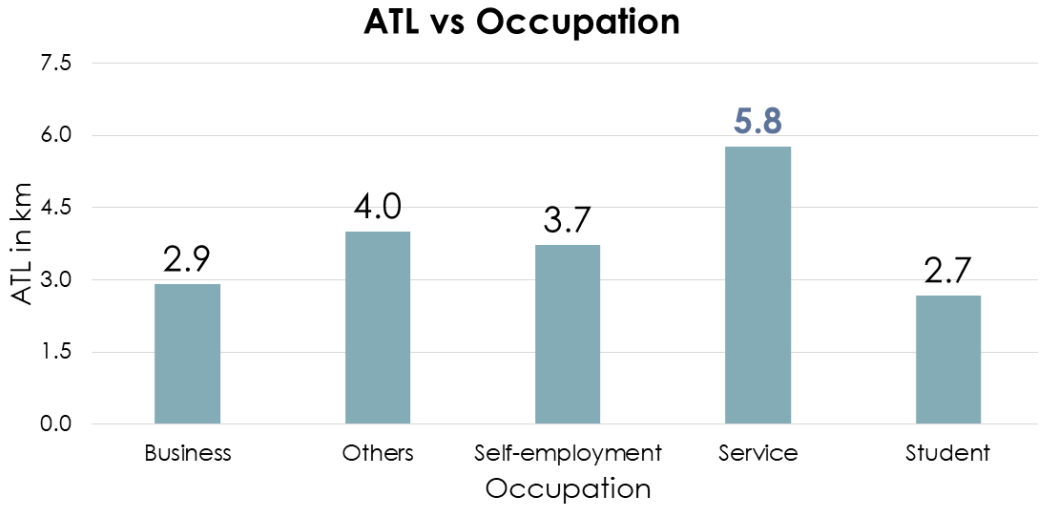


Figure 26 Showing the graphs of ATL vs Education.

In Figure 27, the occupations of users are correlated with their average trip lengths. Users employed in the service sector record the longest average trip length, at 5.8 kilometers, followed by those engaged in self-employment, who travel an average of 3.7 kilometers. Individuals in business occupations cover an average distance of 2.9 kilometers, while students have the shortest average trip length, at 2.7 kilometers.

In Figure 28 below, the average trip lengths of users are depicted according to different trip purposes. The longest trip length, at 4.4 kilometers, is recorded by individuals using bicycles for work-related trips. This is followed by a trip length of

4.3 kilometers for those commuting for recreational activities. Users traveling to college cover an average distance of 2.8 kilometers, while those traveling for business purposes travel 2.1 kilometers on average. The shortest trip length is observed among users commuting to schools.

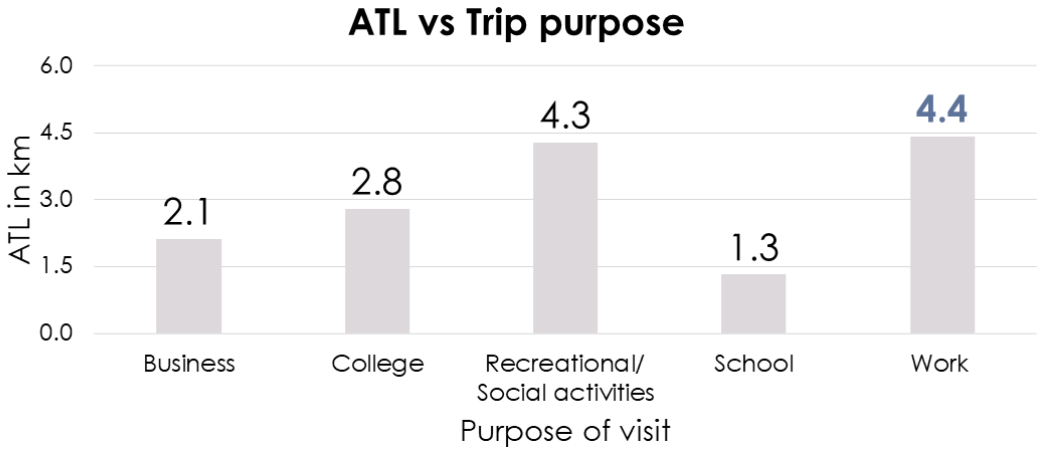


Figure 28 Showing the graphs of ATL vs Trip purpose.

With an average trip length of 3.47 km, it becomes evident that a significant segment of cyclists in Bhubaneswar prefers shorter commuting distances. However, a notable subset within this cycling community stands out for their longer average trip lengths. This subgroup primarily consists of males aged between 30 to 45 years, indicating a specific demographic preference for cycling. These individuals typically hold postgraduate qualifications and engage in service-oriented occupations, suggesting a certain level of stability and professional engagement. Their monthly income falls within the moderate range of 21000 to 30000, reflecting a level of financial comfort that enables them to afford cycling as a viable mode of transportation. Importantly, their trips predominantly serve work-related purposes, underscoring the role of cycling as a practical means of commuting to and from their workplaces. Understanding the characteristics and preferences of this user group is crucial for devising targeted strategies to promote cycling and enhance urban mobility in Bhubaneswar.

4.5 Analysing Trip length and Travel Time

The collected data on individual trip length and travel time of cycle users in Bhubaneswar offers valuable insights into the efficiency and effectiveness of cycling as a mode of transportation within the city. However, to comprehensively understand the transportation characteristics, it is imperative to contrast this data with corresponding information for walking, another prevalent mode of active transportation. Walking is a fundamental mode of travel, particularly for short distances, and is often perceived as a convenient and environmentally friendly option. In urban settings like Bhubaneswar, where infrastructure supports pedestrian mobility, walking serves as a viable mode of transportation for many residents. To evaluate the relative efficiency of cycling versus walking, it is essential to analyse the travel time for walking the same distance as cycling.

Utilizing Google Maps data, it is estimated that the travel time for walking for the same trip length as that of cycling. This approach allows for a direct comparison between the two modes of transportation in terms of their time efficiency. By identifying specific trip lengths covered by cyclists and determining the corresponding travel time for walking, we can assess the relative merits of each mode for covering similar distances within Bhubaneswar. Cycling offers several advantages over walking, especially for longer distances. It typically allows for faster travel times and covers greater distances within a similar timeframe. This can be particularly advantageous in urban areas where time is often a critical factor for commuters. Additionally, cycling may require less physical exertion compared to walking, making it a preferred choice for individuals seeking a balance between efficiency and comfort.

The comparison between cycling and walking efficiency offers several key insights into the mobility dynamics and preferences of city residents. Firstly, it allowed to evaluate the time savings associated with cycling compared to walking, considering factors such as road conditions, traffic congestion, and pedestrian infrastructure. Cycling, being a faster mode of transportation for covering medium to long distances, may offer significant time advantages over walking, particularly for commuters and individuals with time-sensitive travel needs.

The data presented in the below graphs highlights significant trends among bicycle users in terms of trip length and travel time. Specifically, it indicates that a

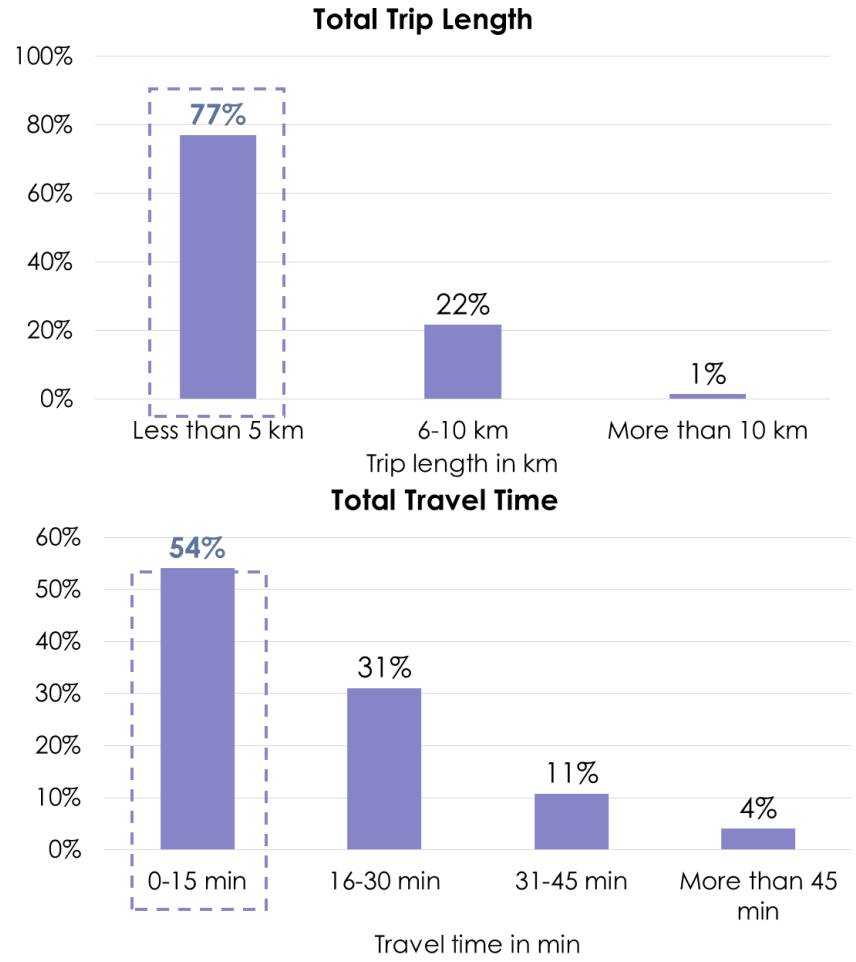


Figure 29 Graph showing the trip length and travel time from the primary data.

substantial majority of bicycle users opt for relatively short trips, with 77% of users covering distances of less than 5 km. This suggests that bicycles are predominantly used for commuting or traveling within proximity, rather than for longer journeys. The graphs in figure 29 illustrate that a considerable portion of bicycle users, accounting for 54%, complete their trips in less than 15 minutes. This further emphasizes the preference for short-distance travel among cyclists, as shorter travel times are typically associated with shorter trip distances. It also reflects the efficiency and convenience of cycling as a mode of transportation for navigating urban environments, particularly for trips of moderate length.

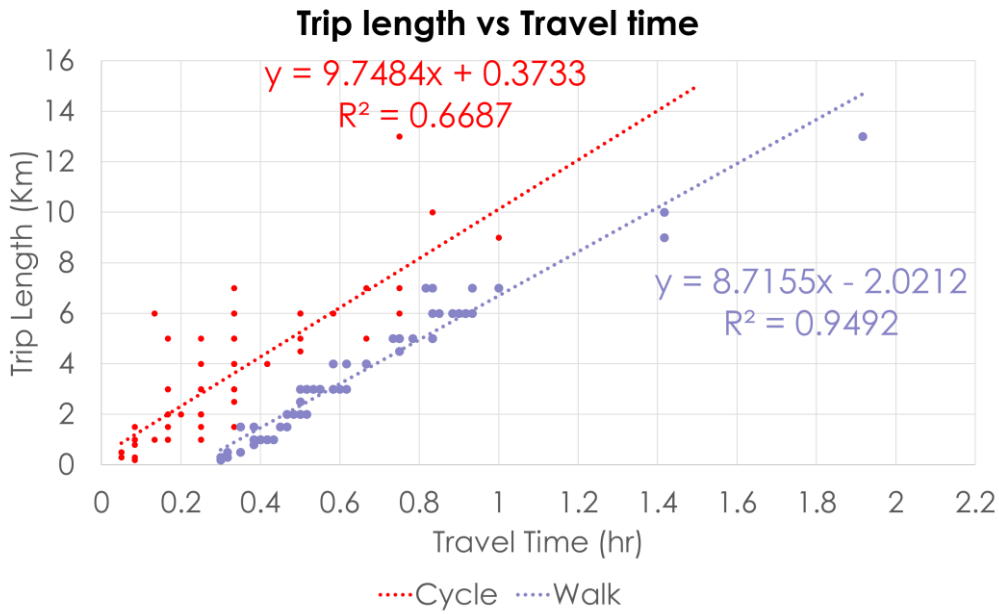


Figure 30 Graph showing the trip length vs travel time for walk and cycle users.

The trendline illustrated in figure 30 presents a noteworthy observation regarding the relationship between distance covered by bicycle trips and the corresponding travel time. It indicates that, within a specific travel time frame, the distance covered by bicycles closely aligns with the distance covered by walking over the same duration. This alignment suggests that the speed at which bicycles travel is notably slower than what might be anticipated, especially when compared to walking speeds. Further analysis of the function y = 9.748x + 0.3733, which represents the relationship between distance (y) and time (x) for cycling, reveals an average speed of approximately 9 kilometers per hour (kmph). This average speed falls considerably below the typical speeds observed among cyclists in urban environments. These findings raise questions regarding the factors influencing cycling speeds and the potential barriers that may impede cyclists from traveling at optimal speed.

These findings emphasize the need for targeted infrastructure improvements and policy interventions aimed at promoting faster and more efficient cycling within urban environments. This may include measures such as enhancing cycling infrastructure, optimizing traffic flow for cyclists, implementing traffic calming measures, and raising awareness about cycling etiquette and safety practices. By addressing these factors and implementing strategic interventions, cities can

create environments that support and encourage faster and more efficient cycling, thereby enhancing overall mobility and sustainability.

4.6 Binary Logit Model Analysis

The binary logit model is a form of regression analysis that models a binary dependent variable by estimating the probability of the dependent variable being in a particular category (e.g., success/failure) based on the values of the independent variables. The logistic function is used to transform the linear combination of the independent variables and their coefficients into a probability value between 0 and 1. The logit function is the inverse of the logistic function and is used to model the log-odds of the dependent variable being in a particular category. The key components of the binary logit model are the binary dependent variable, the independent variables, the logistic function, and the logit function. The dependent variable in a binary logit model can take only two possible values, typically coded as 0 and 1, representing the two categories or outcomes of interest. The independent variables are the predictor variables or explanatory variables that are assumed to influence the probability of the binary outcome. The binary logit model estimates the coefficients of the independent variables using maximum likelihood estimation (MLE), which maximizes the likelihood of observing the sample data given the model parameters. The interpretation of the coefficients in the binary logit model is based on the log-odds or the odds ratios. Here the binary logit model is used to know the interest of the people to shift from cycle to PBS.

The functional form of the binary logit model is represented by the following equation:

$$log\left[\frac{P(Y=1)}{1-P(Y=1)}\right] = \sum_{k=1}^{K} \beta_k x_k$$

Where Y represents the binary dependent variable (e.g., yes/no, pass/fail).

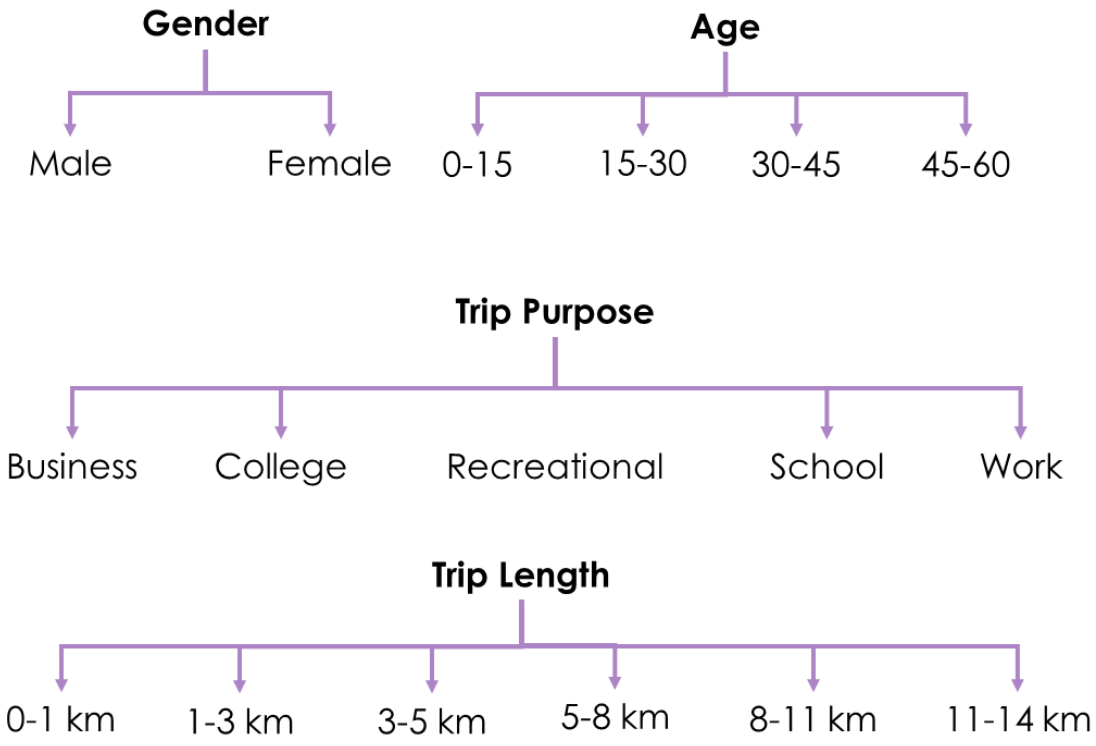
X represents the independent variables.

β represents the coefficients associated with the independent variables.

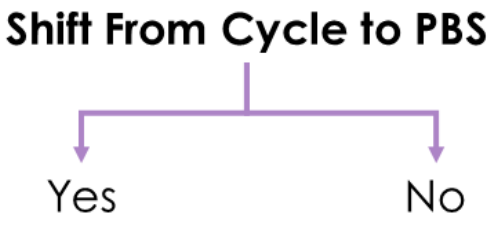
P(Y=1) represents the probability of the dependent variable being 1 given the values of the independent variables.

1-P(Y=1) represents the probability of the dependent variable being 0 given the values of the independent variables.

The independent variable taken are gender, age, trip purpose and trip length.



The independent variable taken is the choice to shift from cycle to PBS with the option of yes and no. where yes is considered as 1 and no is considered as 0.



Variable		Coef.
Gender	Male	2.14
	Female	0
Age in Year	0-15	26.85
	15-30	27.93
	30-45	0
	45-60	1.77
Monthly Income In Rupees	< 10000	3.9
	10000-20000	0
	20000-30000	1.1
	> 30000	1.9
Trip Purpose	Business	26.21
	College	1.3
	Recreational	29.65
	School	29.34
	Work	0
Trip Length in Kilometer	0-1 km	33.04
	1-3 km	34.26
	3-5 km	3.93
	5-8 km	0
	8-11 km	17.1

Figure 31 Showing the binary logit table.

Further binary logistic regression analysis was performed by the primary data of 72 individuals to examine the interest of shift of people from cycle to PBS. The result of binary regression model is shown in figure 31. The Nagelkerke R2 of 0.793 indicates a good model fit.

The reference variable taken from the categorical variable are Gender: (Female), Age: (30-45 year), Monthly Income: (10000-20000), Trip Purpose: (Work), Trip Length: (5-8 km). The model provides important finding on modal shift from cycle to PBS among males aged 15-30 with a monthly income below 10000 for recreational trips spanning 1-3 kilometers. This demographic displays a strong inclination towards adopting alternative modes of transportation, suggesting a potential shift away from conventional methods. The findings underscore a trend towards embracing more sustainable and cost-effective travel options, indicative of changing preferences and priorities among young adults. So further we can consider the variable interest to shift from cycle to PBS of the group identified from the model to increase the PBS system.

4.7 Walkshed Analysis

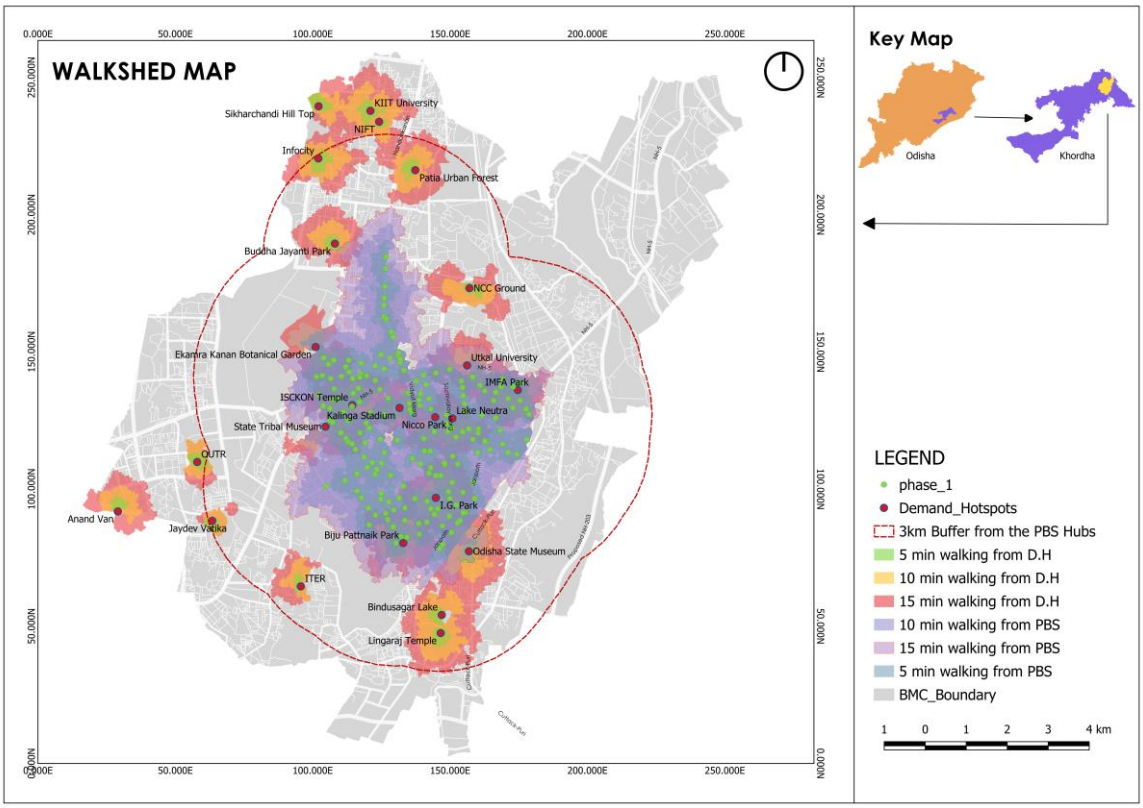


Figure 32 Showing the walkshed map.

Walkshed analysis is a vital geographic analysis technique employed to evaluate the accessibility of different destinations or amenities within walking distance from a designated point or multiple points. The concept of a "walkshed" encapsulates the spatial extent or zone that can be traversed on foot within a predefined time or distance threshold, often expressed in minutes or kilometers. This methodology incorporates various factors such as pedestrian infrastructure (e.g., sidewalks, crosswalks), walking speed, terrain characteristics, and land use patterns to estimate the extent of the walkable area and identify reachable locations within a specified walking time or distance. Walkshed analysis plays a crucial role in promoting pedestrian-friendly urban environments, fostering active transportation, and improving overall public health by encouraging walking as a mode of travel. It also supports efforts to create more sustainable and liveable cities by reducing reliance on automobiles and mitigating traffic congestion and environmental impacts associated with motorized transportation.

As we have found from the logit model that the people traveling for the recreational purpose in the trip length of 1-3 km prefer PBS over their own cycle so a buffer of 3 km is created from the existing PBS hubs and the major demand hotspot or the recreational areas inside the buffer have been identified and a walkshed analysis is run to show the accessibility to the PBS infrastructure from the demand hotspot and vice-versa.

The walkshed analysis between the hotspots of demand and the Public Bike Sharing (PBS) hubs highlights key aspects of urban mobility and accessibility. The analysis gives a view of the considerable disparities in accessibility over the time specified, with issues in access to PBS infrastructure from demand hotspots, as well as returning bikes to these hotspots from the surrounding areas. Starting from demand hotspots, the analysis revealed that within 5, 10, and 15 minutes of walking, many individuals struggled to easily reach PBS infrastructure. This indicates a significant gap in accessibility, particularly for those seeking to utilize PBS services for their transportation needs. The inability to access PBS hubs within a reasonable walking time suggests a potential mismatch between the location of these hubs and the distribution of demand, highlighting the importance of strategically locating PBS stations to better serve areas with high travel demand, such as recreational hotspots or densely populated neighbourhoods. Similarly, from the perspective of PBS hubs, it was found challenging to return bikes and reach demand hotspots within the same time frames due to their considerable distance. This presents a logistical challenge for users wishing to return bikes to the nearest hub after completing their trip or for those seeking to access demand hotspots from PBS stations. The longer walking distances required to reach these destinations within the specified time frames may deter individuals from utilizing PBS services, undermining the effectiveness and convenience of the bike-sharing system.

Filling up this gap requires a multi-faceted approach, including the expansion and optimization of PBS infrastructure to better align with demand patterns, as well as improvements in pedestrian infrastructure to facilitate easier access to and from PBS hubs. Additionally, efforts to enhance connectivity between PBS stations and demand hotspots through the development of safe and convenient walking routes or the integration of other modes of transportation, such as public transit, can help bridge the accessibility divide.

4.8 Identification of Major Demand Route

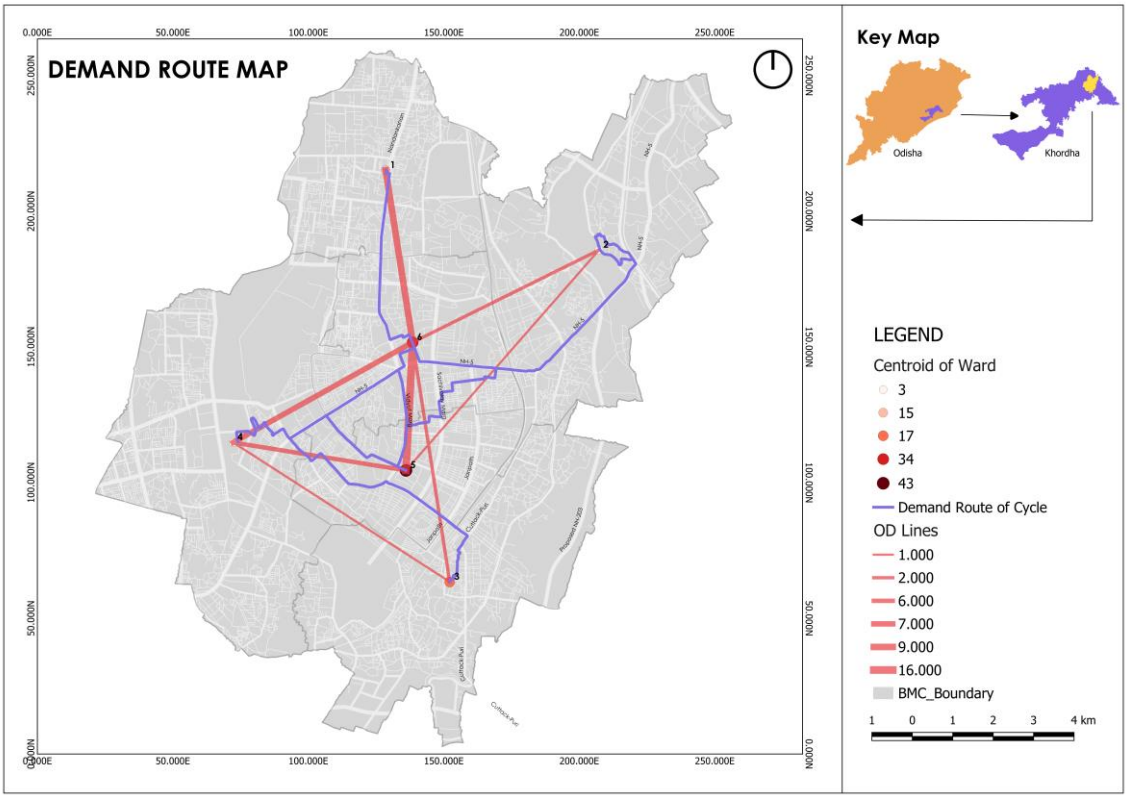


Figure 33 Sowing the demand route map.

The restructuring of Bhubaneswar's 67 wards into six major zones has paved the way for a more streamlined approach to know the transportation route of the cycle users in the city. To gain a deeper understanding of the travel patterns and transportation needs of cyclist across these zones, a primary survey was conducted, meticulously collecting data on the origin and destination points of trips made by residents and commuters. Through these comprehensive surveys, the major demand route of the cycle user was found over the city. Several key corridors emerged as significant trip attractors and generators, witnessing substantial volumes of traffic and movement along their lengths.

Among the identified corridors, the Zone 1 to 6 route emerges as a primary thoroughfare, witnessing significant trip attractions and distributions. This corridor serves as a vital conduit for commuters, connecting key residential, commercial, and recreational areas within the city. Additionally, the Zone 5 to 6 corridor stands out for its notable activity, reflecting a substantial flow of traffic and movement, indicative of its importance in the city's transportation network. The analysis

presented in figure 33, conducted through a comprehensive origin-destination analysis, uncovered a significant demand route spanning an impressive 51.8 kilometers in length. This extensive route emerged as a vital artery for transportation and mobility within the region, highlighting its critical role in accommodating the intricate travel patterns and preferences of commuters.

By understanding the needs of commuters along this extensive route, the service and facilities could be improved which can work towards enhancing connectivity, improving accessibility, and optimizing the overall efficiency and sustainability of the transportation network. Initiatives aimed at growing infrastructure, implementing innovative transportation solutions, and promoting active modes of travel can further enhance the accessibility and liveability of Bhubaneswar.

4.9 Life Cycle Cost Analysis of PBS and Owned Cycle

Life Cycle Cost Analysis (LCCA) is a methodical and structured approach utilized for the purpose of assessing and evaluating the entirety of costs associated with a particular product, asset, or project throughout its complete lifecycle. This method entails the comprehensive examination and evaluation of all costs accrued starting from the initial procurement or construction phase, extending through the phases of operation, maintenance, and ultimately culminating in disposal or decommissioning. The scope of LCCA encompasses not only the upfront expenses related to purchase or construction but also the continuous and ongoing costs such as maintenance, repairs, energy usage, and the expenses linked to end-of-life disposal. Through the meticulous consideration and inclusion of these various costs spanning the entire lifecycle of the product, asset, or project, the practice of LCCA serves to facilitate and empower decision-makers in making well-informed and judicious choices by effectively pinpointing the most financially prudent and cost-efficient option from a pool of competing alternatives. This analytical approach proves to be exceptionally beneficial and valuable in sectors such as infrastructure development, manufacturing industries, and asset management, wherein the aspect of long-term cost implications holds utmost significance in terms of optimizing investments, curbing the overall total cost of ownership, and attaining sustainable and enduring outcomes. By virtue of LCCA, organizations are afforded the capability to meticulously evaluate and scrutinize the economic viability, operational performance, and sustainability quotient of

diverse alternatives, thereby culminating in enhanced and enriched decision-making processes and the more efficient and effective allocation of available resources.

Year Estimated	Cost of PBS use per year	Total PBS use expenses	Cost of owned and maintenance per year	Total Owned and maintenance of cycle expenses
Year -1	999	999	5000	5000
Year -2	1098.1	2097.1	1200	6200
Year -3	1207	3304.1	1212	7412
Year -4	1326.8	4630.9	1224.1	8636.1
Year -5	1458.4	6089.3	1236.4	9872.5
Year -6	1603.1	7692.3	1248.7	11121.2
Year -7	1762.1	9454.4	1261.2	12382.4
Year -8	1936.9	11391.3	1273.8	13656.2
Year -9	2129	13520.3	1286.6	14942.8
Year -10	2340.2	15860.5	1299.4	16242.2
Year -11	2572.4	18432.9	1312.4	17554.7
Year -12	2827.5	21260.4	1325.5	18880.2
Year -13	3108	24368.5	1338.8	20219

Figure 34 Showing the estimated cost of PBS and cycle user for estimated years.

The Life Cycle Cost Analysis (LCCA) compares the costs associated with owning a bicycle versus using a Public Bicycle Sharing (PBS) system to determine which option is more beneficial for individuals as shown in figure 34. The analysis considers various factors such as initial purchase cost, maintenance expenses, and subscription fees. For owning a bicycle, the initial purchase cost is Rs 5000, sourced from the Decathlon website. Additionally, an annual maintenance cost of Rs 1200 is factored in, based on conversations with the Decathlon service provider, assuming an annual growth rate of maintenance expenses at 1%. On the other hand, using the PBS system incurs a subscription fee of Rs 999 per annum, as per the details provided in the request for proposal of the Bhubaneswar Public Bicycle Sharing system. It's important to note that the subscription fee is subject to an annual growth rate of 9.92%.

To conduct the LCCA, the costs associated with each option are calculated over the expected lifespan of the bicycle or the duration of PBS usage. This includes the initial purchase cost, annual maintenance expenses, and subscription fees, factoring in the annual growth rates for both PBS subscription and maintenance costs. By comparing the total costs of owning a bicycle versus using the PBS

system over the designated time, individuals can make an informed decision based on their personal preferences, usage patterns, and financial considerations. The LCCA provides valuable insights into the long-term economic implications of each option, enabling individuals to choose the most cost-effective solution for their transportation needs.

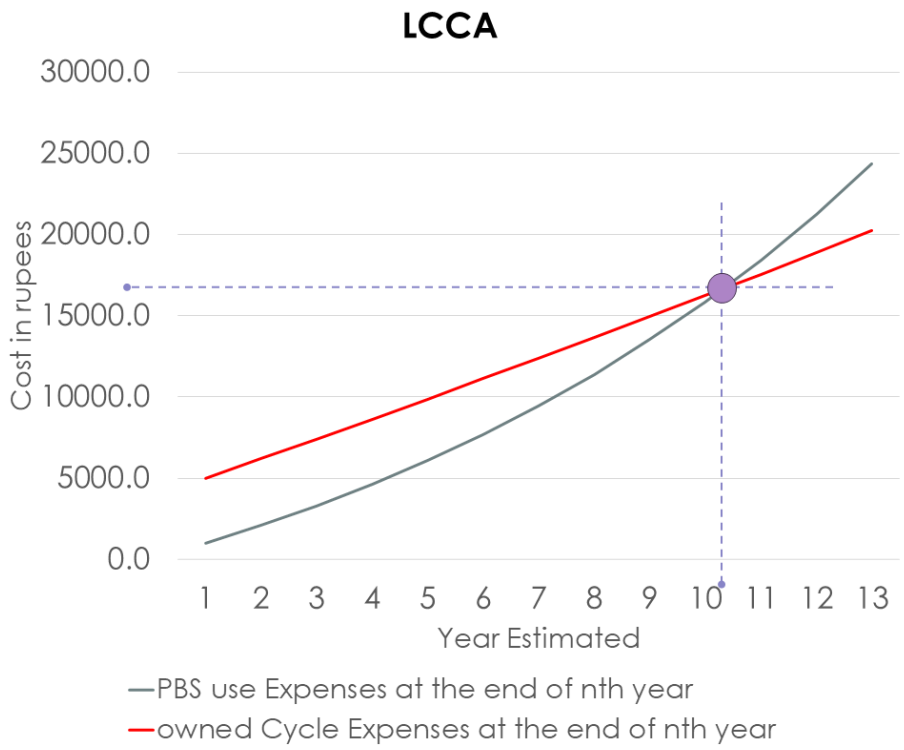


Figure 35 Showing the graph of cost estimated in PBS use and Cycle use.

The graph in figure 35 indicates that for the first ten years of usage, Public Bike Sharing (PBS) systems exhibit greater profitability compared to owning a bicycle outright. Given that the typical lifespan of a bicycle falls within the range of approximately 9-10 years, this analysis suggests that opting for PBS services can yield more favourable economic outcomes over the long term. By leveraging PBS, users can access bicycles conveniently without the upfront costs associated with purchasing, maintaining, and storing a personal bike. Additionally, PBS offers advantages such as flexibility, accessibility, and reduced risk of theft or damage. Therefore, considering the comparable lifespan of bicycles and the profitability demonstrated by PBS within the initial decade of operation, it becomes evident that PBS presents a more financially viable and

efficient mode of transportation for individuals seeking cost-effective and sustainable mobility solutions.

4.10 Issues Identified

From the primary data collection of the perception survey, responses were gathered regarding the challenges faced by individuals while riding their own bicycles and utilizing Public Bike Sharing (PBS) systems. Several key issues for the cycle users emerged, including the lack of dedicated cycle lanes, discontinuous cycle lanes, inadequate signage, proximity to accidents (a road safety concern), cycle theft, time-consuming journeys, and physical exhaustion. These challenges were subsequently categorized into three overarching themes: infrastructural issues and safety concerns, along with physical challenges.

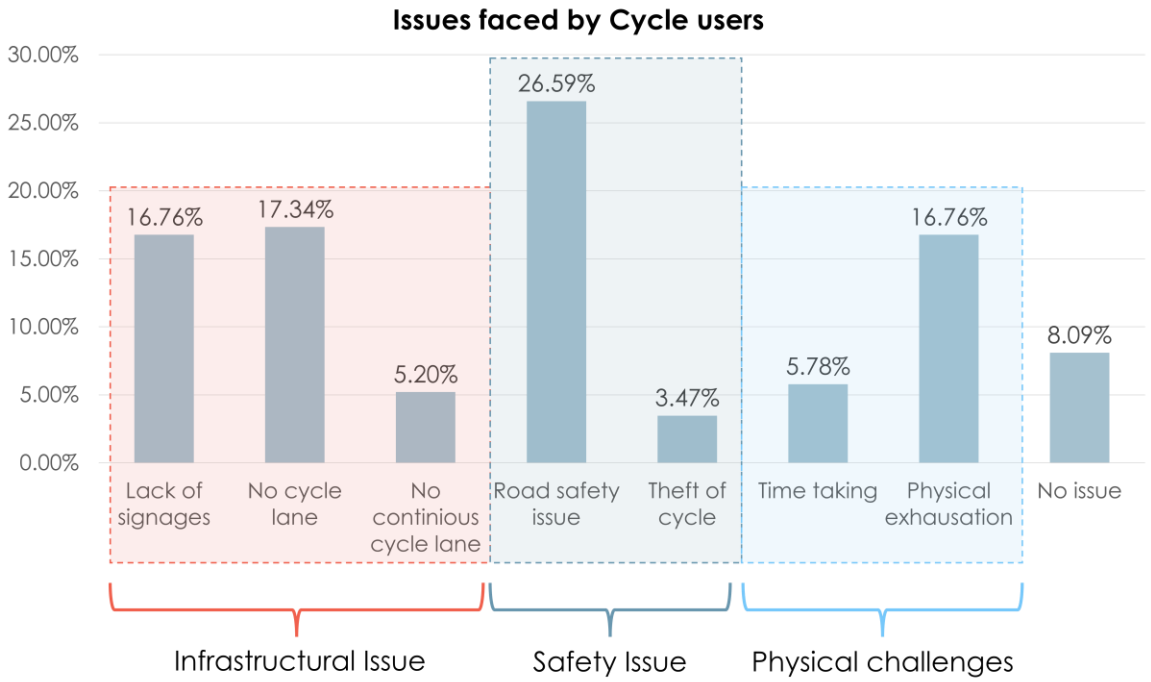


Figure 36 Showing the issues faced by the cycle users.

From the figure 36 it seems for cyclists, safety concerns is prior, with road safety standing out that is 26.59% as the foremost challenge demanding urgent attention. Addressing this issue is paramount to ensuring the well-being and confidence of cyclists. To achieve safer transportation options, infrastructural issues must be meticulously examined and addressed. Enhancing cycling infrastructure, including dedicated lanes, clear signage, and traffic calming measures, is crucial to protecting cyclists and reducing the risk of accidents.

Additionally, fostering a culture of mutual respect and awareness among road users is essential for promoting safer interactions between cyclists and motorists. By prioritizing and tackling infrastructural deficiencies, communities can significantly enhance the cycling experience and encourage more individuals to embrace cycling as a sustainable and enjoyable mode of transportation.

Similarly for Public Bike Sharing (PBS) users, various key issues have surfaced, mirroring those encountered by individual bicycle owners. These challenges include issues with app aggregators, comfort, accessibility, availability of bicycles, road safety, theft, and time constraints. These concerns underscore the need for addressing both infrastructural shortcomings and safety considerations, along with acknowledging the physical challenges associated with cycling.

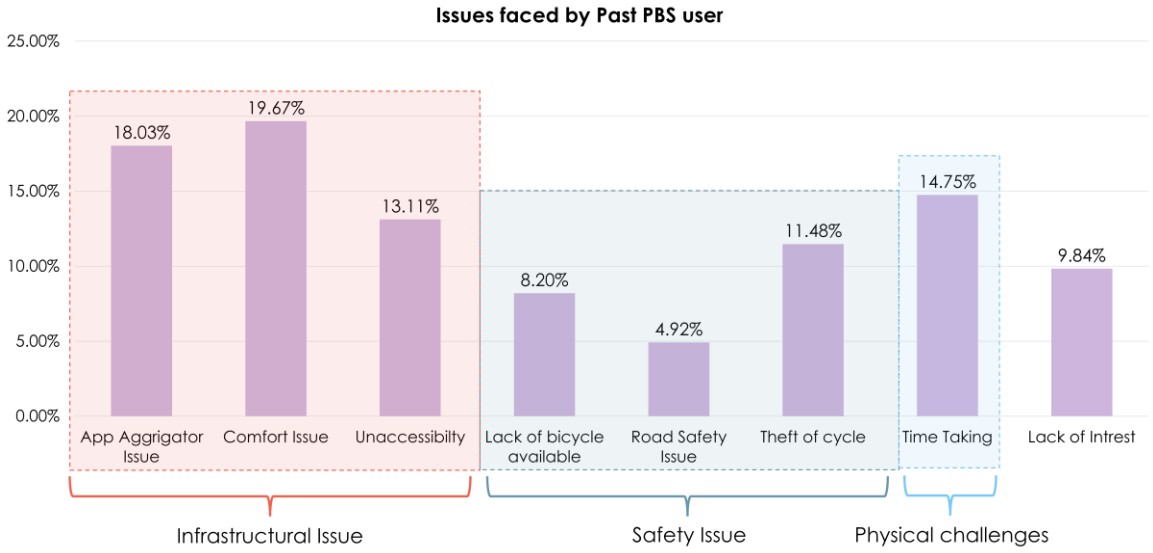


Figure 37 Showing the issues faced by the PBS users.

In Public Bicycle Sharing (PBS) systems, the decline in usage can be largely attributed to infrastructure-related issues as shown in figure 37, with two key factors standing out: lack of comfort that is 19.6% and app aggregator functionality that is 18.03%. The lack of comfort in PBS systems deters users from utilizing the service regularly. Uncomfortable bicycles, poorly maintained docking stations, and inadequate amenities such as seating areas or shelters can make the cycling experience unpleasant for users. This discomfort can discourage individuals from choosing PBS for their transportation needs, especially for longer journeys or in inclement weather conditions.

Secondly, the functionality of app aggregators plays a crucial role in the usability and accessibility of PBS systems. App aggregators serve as the primary interface through which users access information about bike availability, rental processes, and docking station locations. If the app aggregator is poorly designed, unreliable, or difficult to use, it can frustrate users and discourage them from using the PBS system altogether. Issues such as inaccurate bike availability information, technical glitches, or cumbersome rental processes can significantly impact user satisfaction and confidence in the system.

CHAPTER 5: RECOMMENDATIONS

5.1 Proposed Route For Cycle Track

Based on the findings of the binary logit model, individuals who opt for Public Bicycle Sharing (PBS) primarily use it for recreational purposes, typically traveling distances of 1-3 kilometers. To cater to this demand, identifying all recreational hotspots and establishing a buffer zone of 3 kilometers around existing PBS hubs is proposed. Within this buffer zone, a 27.3 kilometer stretch of cycle track is suggested to complement existing infrastructure and connect to recreational hotspots within the 3 kilometer. This initiative aims to enhance accessibility to PBS services for recreational users, promote active lifestyles, and improve connectivity between key destinations and cycling infrastructure. By strategically expanding the cycle track network, cities can accommodate the preferences and travel patterns of PBS users, fostering sustainable transportation options and enhancing urban mobility.

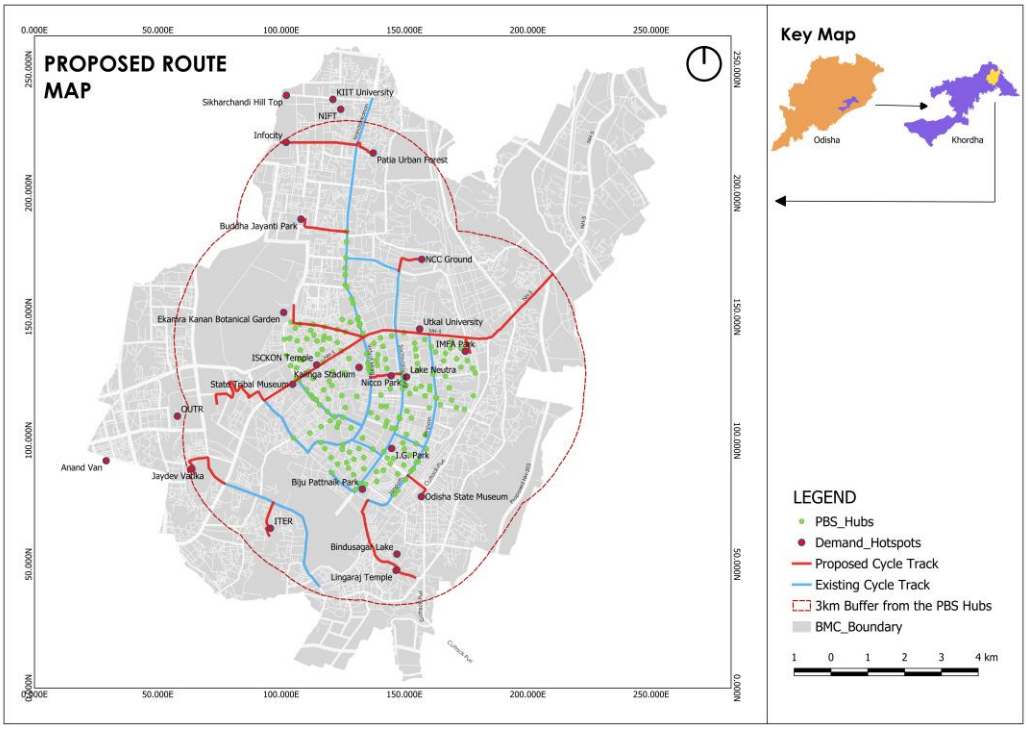


Figure 38 Showing the proposed cycle track inside the buffer area.

5.2 Existing and Proposed Road Sections

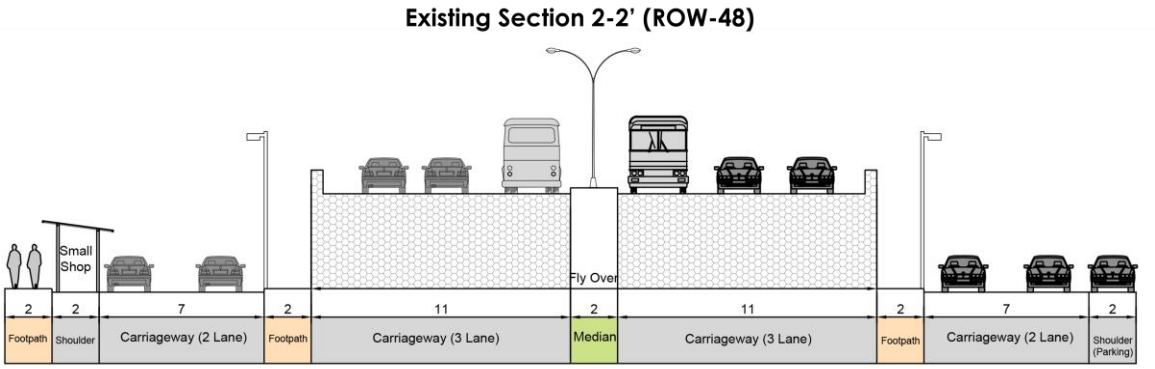


Figure 39 Showing the existing road section of ROW-48.

Based on the observations depicted in figure 39, it is recommended to address the concerns identified along Row 48M. The presence of small vending shops encroaching upon the shoulder and illegal parking of vehicles on the opposite side poses significant challenges for both cyclists and pedestrians. These issues contribute to compromised safety, obstructed pathways, and reduced accessibility for active transportation users. To mitigate these challenges, proactive measures should be taken to enforce regulations against illegal parking and unauthorized vending activities. Additionally, enhancing infrastructure, such as providing designated parking areas and pedestrian walkways, can alleviate congestion and improve the overall mobility experience.

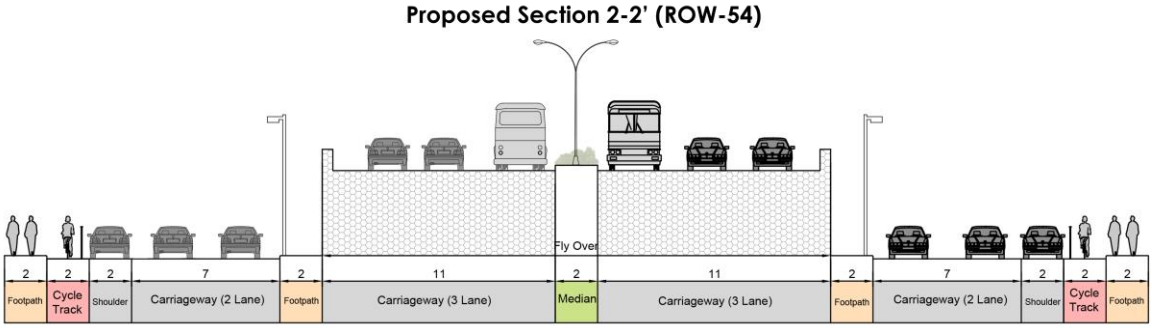


Figure 40 Showing the proposed road section of ROW-54.

In response to the observed challenges along Row 48M, a comprehensive solution has been proposed to enhance safety and accessibility for all road users. The proposed redesign entails the development of a 54 meter wide section shown in figure 40, featuring 2 meter wide cycle tracks on both sides of the road.

Additionally, a 2 meter wide footpath lane is introduced on one side of the road, effectively addressing encroachments on the shoulder and ensuring unimpeded movement for pedestrians. By eliminating encroachments and providing dedicated infrastructure for cyclists and pedestrians, the proposed design promotes safer and more efficient mobility. Furthermore, the inclusion of designated pathways enhances overall urban connectivity and supports active transportation modes, contributing to a more sustainable and inclusive urban environment. Collaboration between relevant stakeholders is essential for the successful implementation of this initiative, fostering community engagement and ownership in creating safer and more accessible streets.

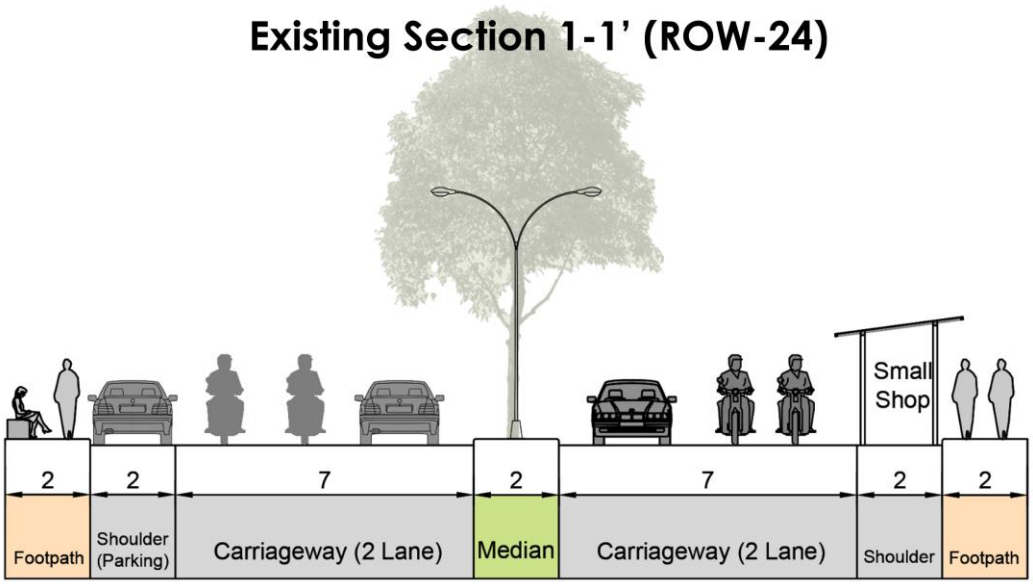


Figure 41 Showing the existing section of ROW-24.

Based on the observations depicted in figure 41, it is imperative to address the issues identified along Row 24M. The encroachment of small vending shops onto the shoulder and the prevalence of illegal parking of vehicles pose significant challenges for road users and pedestrians alike. To alleviate these concerns, proactive measures must be taken to enforce regulations against illegal parking and unauthorized vending activities. Additionally, it is recommended to explore solutions such as providing designated parking areas and creating alternative spaces for vending activities, thereby ensuring unobstructed movement along the shoulder. By prioritizing safety and accessibility, we can create a more conducive environment for all road users while supporting the vitality of local businesses.

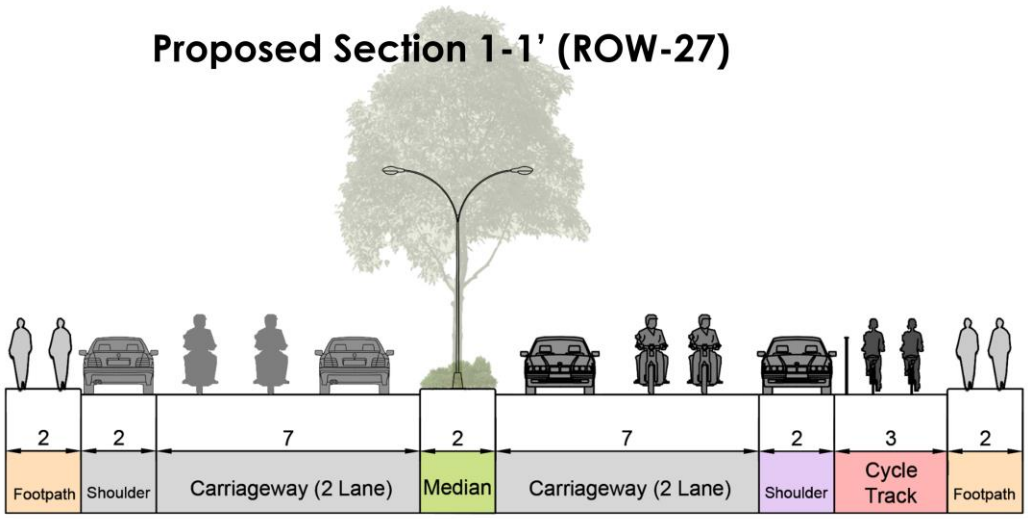


Figure 42 Showing the proposed section of ROW-27.

A proposed solution has been formulated to address concerns along Row 27M. This involves the implementation of a redesigned section spanning 27 meters, featuring a three-meter-wide cycle track. Additionally, measures will be taken to eliminate encroachments on the shoulder, ensuring unobstructed movement for all road users. By prioritizing the removal of encroachments and the provision of dedicated cycling infrastructure, the proposed redesign aims to enhance safety and accessibility. It also contributes to promoting sustainable transportation options and fostering a more inclusive urban environment.

5.3 Proposal for Renting Cost of PBS

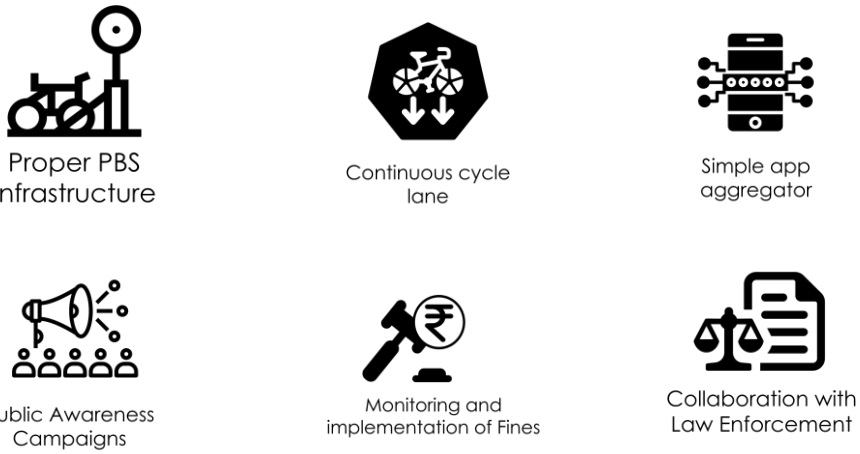
A proposal has been put forward to enhance the efficiency of the Public Bicycle Sharing (PBS) system by implementing a dynamic renting cost structure. Under this proposal, renting costs within the buffer area would be determined based on the travel time of the PBS, while outside the buffer area, costs would be calculated according to the distance travelled. This approach aims to incentivize more frequent usage of the PBS system for both short and long trips. By aligning renting costs with travel time and distance, users are encouraged to utilize PBS services for various trip durations, thereby maximizing the system's accessibility and utility. This innovative pricing strategy not only promotes sustainable transportation habits but also contributes to reducing congestion and carbon emissions in urban areas. Collaborative efforts between stakeholders are essential for the successful implementation of this proposal, ensuring its

effectiveness in meeting the diverse needs of PBS users and enhancing overall transportation efficiency.

Sl. No	Time of Travel (in min)	Cost
1.	0-30	5
2.	30-60	10
3.	60-120	25
4.	120-240	50
5.	240-480	100
6.	More than 480	150

Sl. No	Trip length(in km)	Cost
1.	1-3	5
2.	3-6	10
3.	6-9	25
4.	9-12	50
5.	More than 12	75

5.4 Overall Proposal for PBS



The overall proposal targets to enhance the effectiveness and accessibility of Public Bicycle Sharing (PBS) systems as a sustainable mode of urban transportation. It encompasses several key components, each designed to address different aspects of PBS infrastructure, user experience, public awareness, and enforcement:

Proper PBS Infrastructure: This involves the establishment and maintenance of a robust PBS infrastructure network, including strategically located bike stations, secure docking facilities, and well-maintained bicycles. Emphasis is placed on ensuring sufficient coverage across the city, including residential area, commercial area, and major transit hubs.

Continuous Cycle Lanes: To complement PBS infrastructure, the proposal is carried out for the development of continuous cycle lanes connecting to the existing lane and the identified demand hotspots in the city. These dedicated lanes provide safe and efficient routes for cyclists, separate from motor vehicle

traffic, thereby encouraging more people to cycle and improving overall road safety.

Simple App Aggregator: A user-friendly mobile application serves as a central platform for accessing PBS services, enabling the major users to locate nearby bike stations, check bike availability, and plan routes in real-time. The app should also facilitate seamless registration, payment, and account management, streamlining the user experience and promoting greater adoption of PBS.

Public Awareness Campaign: To promote the benefits of cycling and PBS usage, a comprehensive public awareness campaign is proposed. This campaign aims to educate residents about the environmental, health, and economic advantages of cycling, as well as the convenience and affordability of PBS systems. Through targeted messaging and outreach initiatives, the campaign seeks to encourage behaviour change and encourage a culture of cycling within the community.

Monitoring and Implementation of Fines: Effective monitoring mechanisms, coupled with the implementation of fines for rule violations, are essential for ensuring compliance with PBS regulations and maintaining system integrity. This involves deploying surveillance technology, such as CCTV cameras, at bike stations and along cycle lanes, as well as establishing protocols for enforcing penalties against offenders.

Collaboration with Law Enforcement: Close collaboration with law enforcement agencies is crucial for enforcing traffic laws, addressing safety concerns, and responding to incidents involving PBS users and cycle users. By working in partnership with local police departments, city authorities can enhance security and ensure the smooth functioning of PBS systems, thereby instilling confidence among users and providing a positive cycling environment.

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Annexures

Annexure-1: Survey Questionnaire – Cycle Users

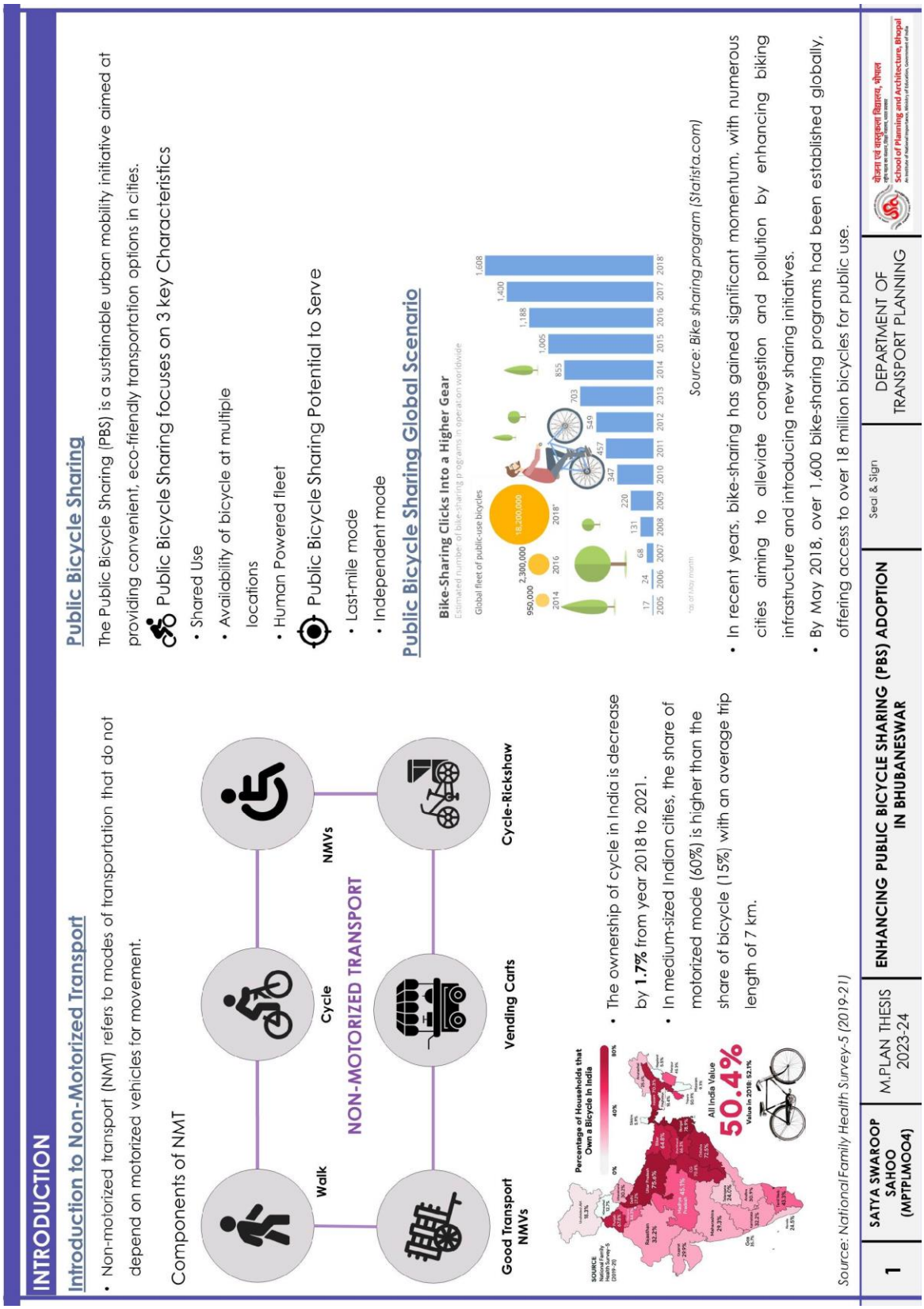
General Characteristics

1. Name: ……..
2. Gender:
    a. Male
    b. Female
3. Age:
    a. Below 15
    b. 15-30
    c. 30-45
    d. 45-60
    e. Above 60
4. Education:
    a. High School
    b. Intermediate
    c. Graduated
    d. Post graduate
5. Occupation:
    a. Service
    b. Business
    c. Self-employed
    d. Student
6. Monthly Income:
    a. < 10000
    b. 10000-20000
    c. 21000-30000
    d. > 30000
7. Household Size:…….
8. Number of vehicle in your house:
    a. Cycle -
    b. 2-wheeler -
    c. 3-wheeler -
    d. 4-wheeler -
    e. Others -

Travel Characteristics

1. Trip Origin: ……..
2. Trip Destination: ……
3. Trip Length: ……..
4. Travel Time: ……..
5. Trip Purpose:
    a. Work
    b. School
    c. Business
    d. College
    e. Recreational/ Social activity
6. Frequency of cycle use:
    a. Daily
    b. Weekly
    c. Monthly
    d. Yearly
7. Types of trip you make in cycle:
    a. Short trips (1-5 km)
    b. Medium trips (5-10 km)
    c. Long trips (Above 10 km)
8. Issues faced while cycling:
    a. No cycle lane
    b. No continuous cycle lane
    c. Time Taking
    d. Lack of signages
    e. Road Safety Issue
    f. Theft of cycle
    g. Physical Exhaustion
9. What intervention you want to be made to make cycling experience better:
10. Have you ever used PBS:
    a. Yes
    b. No
11. How frequently have you used PBS:
    a. Daily
    b. Weekly
    c. Monthly
    d. Yearly
    e. Never
12. Issues Faced in PBS:
    a. App Aggregator Issue
    b. Comfort Issue
    c. Lack of Infrastructure
    d. Road Safety Issue
    e. Inaccessibility
    f. Time Taking
    g. Lack of Interest

Annexure-2: Presentation Sheets

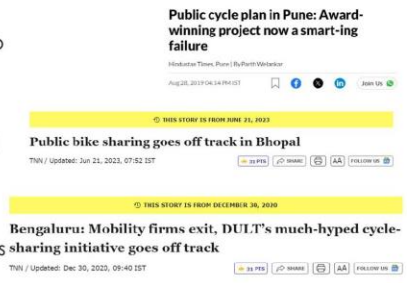


NEED OF THE STUDY

- In international cities public bicycle sharing has solved many of the mobility issues and provided a new mode of transportation to support the existing public transport.

Source: WRI, China

- In Chinese cities, majorly the Public Bicycle Sharing system is used to improve "first- and last-mile" connections to public transit and build fully integrated transport systems.
- India is witnessed very slow growth in bicycle ownership and a decline in the use of bicycle as a form of mobility.
- Since 2008, several efforts were made to introduce Public Bicycle Sharing (PBS) systems in Indian cities.
- But many Indian cities like Pune, Bhopal and Bengaluru have been failed in the implementation of PBS System.
- Majorly it may be due to lack of business model and holistic approach it been a failure beyond the pilot stage.



Public cycle plan in Pune: Award-winning project now a smart-ing failure

Hindustan Times, Pune | By Parth Vebarkar

Aug 28, 2019 04:14 PM IST

THIS STORY IS FROM JUNE 21, 2023

Public bike sharing goes off track in Bhopal

TNN / Updated: Jun 21, 2023, 07:52 IST

THIS STORY IS FROM DECEMBER 30, 2020

Bengaluru: Mobility firms exit, DULT's much-hyped cycle-sharing initiative goes off track

TNN / Updated: Dec 30, 2020, 09:40 IST

Source: Hindustan Times, Time of India

LITERATURE STUDY

Sl. No.	RESEARCH PAPER TITLE	Authors	FINDING	NEED	GAP
1.	Intentions to use bike-sharing for holiday cycling: An application of the Theory of Planned Behavior. [2014]	Sigal Kaplan, Francesco Manca, Thomas Alexander Sick Nielsen, Carlo Giacomo Prato	Security Concerns, Role of Positive Cycling experience, Factors Influencing Holiday Cycling Intentions	Behavioural factors of the tourist to use bike sharing system	Limited consideration of environmental factors, economic factors
2.	Identifying the factors affecting bike-sharing usage and degree of satisfaction in Ningbo, China. [2017]	Yanyong Guo, Jibiao Zhou, Yao Wu, Zhibin Li	Bivariate ordered probit model, factors influencing bike-sharing usage	Identify those factors affecting bike-sharing usage and user satisfaction degree of bike-sharing.	Does not consider the potential impact of marketing or promotional strategies
3.	A stakeholder's perspective on improving barriers in implementation of public bicycle sharing system (PBSS) [2018]	Samir J. Patel, Chetan R. Patel	Social, Institutional and Governance, City Infrastructure, Travel Characteristics	Increase PBSS riders and PT ridership	Evaluate the demand and uneven PBSS infrastructure
4.	Benefits of Cycling in India, An Economic, Environmental, and Social Assessment [2018]	Teri (The Energy and Resource Institute)	Direct Benefits, Indirect Benefits, Transportation Challenges in India	Promoting cycling as a sustainable mode of transport in India	safety concerns, Infrastructure availability, and cultural factors
5.	Planning of Public Bicycle (Bike) Sharing System (PBSS): A Case Study of Surat City [2019]	Samir J Patel, G J Joshi, Chetan R. Patel	Maximum coverage area method and minimum impedance method, Hub & Spoke methods consist of location-allocation method & Gis-based methods	Methods to cover more area providing the service	Policy for Bicycle riders
6.	The Analysis of the Influencing Factors on the Problems of Bike-Sharing System in China [2019]	SHIANGHAU WU, XUXIUNAN LEI	Difficulty picking and parking, Insufficient analysis of operational problems.	It can help policymakers, bike-sharing companies, and other stakeholders to address the problems and ensure the sustainable development of the bike-sharing system.	Pricing model and App interface
7.	Evolution of Public Bicycle Sharing Systems in India [2021]	Juergen Baumann, Laghu Parashar, Laghu Parashar	Reduction of emission, Increase PT ridership, Modal sift from private vehicles to PBS	Long term Planning for PBS, Implementation of Policy Framework	Lack of clarity on impact of business models on the financial viability of PBS system

LITERATURE STUDY

Cycle User

Segment of individuals who regularly use bicycles as their primary mode of transportation or for recreational purposes.

Use of Cycle

- Commuting
- Recreational Activities
- Freedom
- Ownership flexibility

PBS User

Segment of individuals who utilizes shared bicycles provided by a public bicycle sharing system for short trips or commuting purposes and return them to any available docking station within the system's coverage area.

Use of PBS

- Short trips
- Convenience
- Ownership-free accessibility

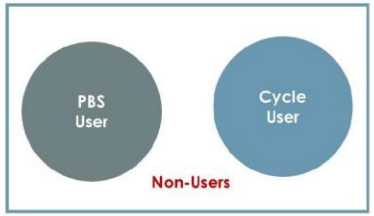
Non-User

Segment of individuals who regularly use their own vehicle other than bicycle as their primary mode of transportation or for recreational purposes.

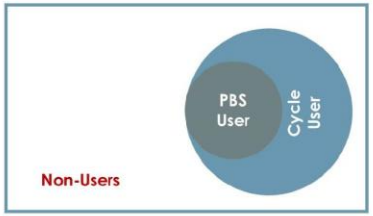
Non-uses

- Embarrassment
- Lack of Safety
- Lack of Infrastructure
- Alt. mode of travel

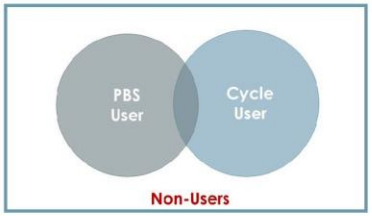
Scenarios based on different users



Scenario-1

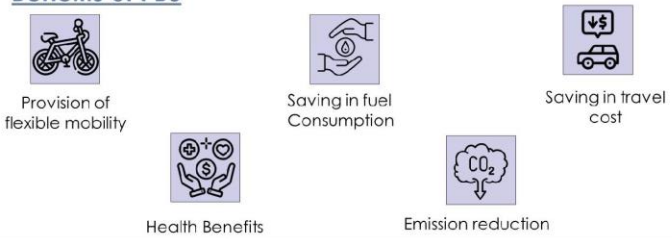


Scenario-2



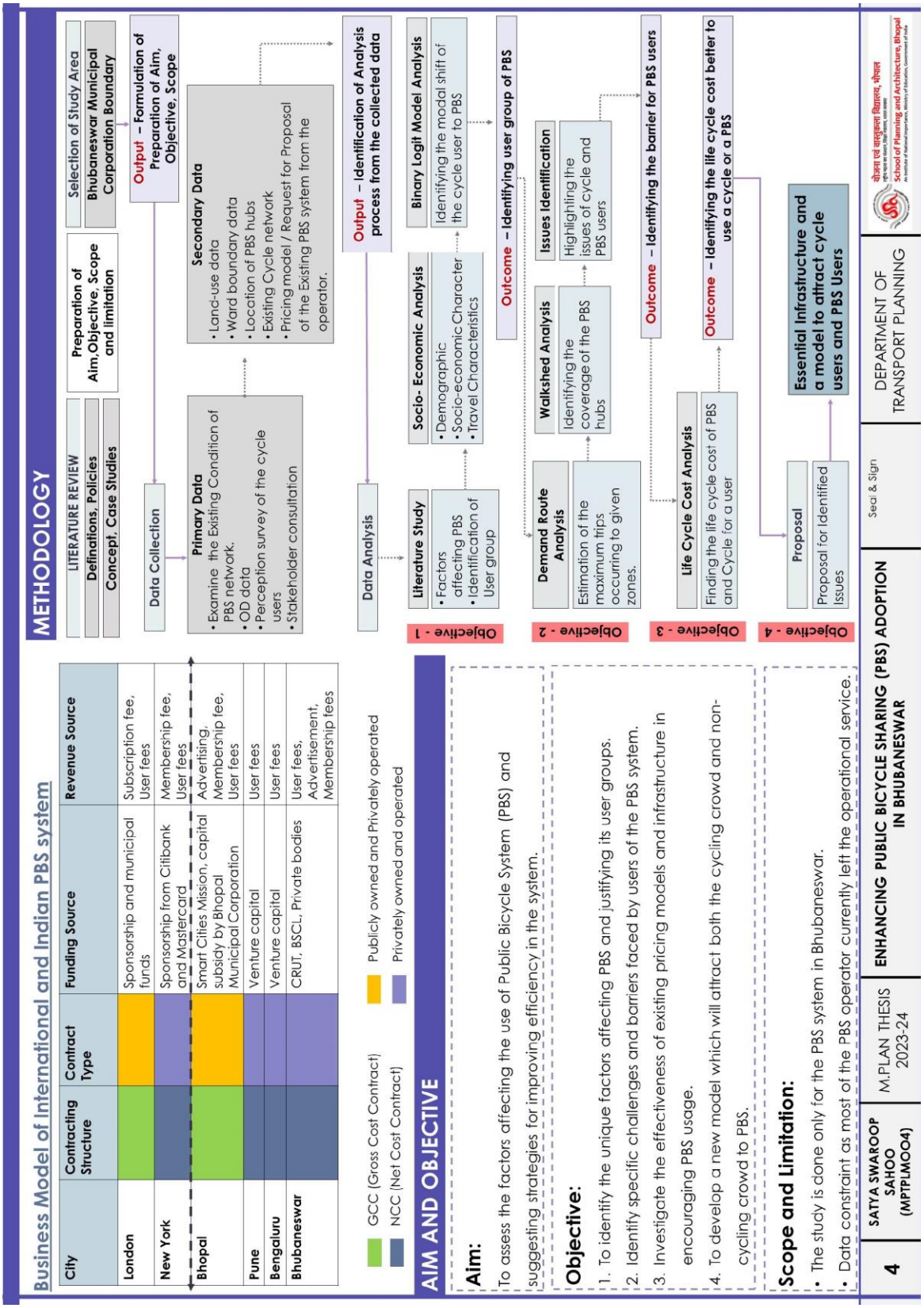
Scenario-3

Benefits of PBS



Factor Affecting PBS

3	SATYA SWAROOP SAHOO (MPTPLMOO4)	M.PLAN THESIS 2023-24	ENHANCING PUBLIC BICYCLE SHARING (PBS) ADOPTION IN BHUBANESWAR	Seal & Sign	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal


Business Model of International and Indian PBS system
City
Contracting Structure
Contract Type
Funding Source
Revenue Source
London
Sponsorship and municipal funds
Subscription fee, User fees
New York
Sponsorship from Citibank and Mastercard
Membership fee, User fees
Bhopal
Smart Cities Mission, capital subsidy by Bhopal Municipal Corporation
Advertising, Membership fee, User fees
Pune
Venture capital
User fees
Bengaluru
Venture capital
User fees
Bhubaneswar
CRUT, BSCL, Private bodies
User fees, Advertisement, Membership fees
GCC (Gross Cost Contract)
NCC (Net Cost Contract)
Publicly owned and Privately operated
Privately owned and operated
AIM AND OBJECTIVE
Aim:
To assess the factors affecting the use of Public Bicycle System (PBS) and suggesting strategies for improving efficiency in the system.
Objective:
1. To identify the unique factors affecting PBS and justifying its user groups.
2. Identify specific challenges and barriers faced by users of the PBS system.
3. Investigate the effectiveness of existing pricing models and infrastructure in encouraging PBS usage.
4. To develop a new model which will attract both the cycling crowd and non-cycling crowd to PBS.
Scope and Limitation:
• The study is done only for the PBS system in Bhubaneswar.
• Data constraint as most of the PBS operator currently left the operational service.
METHODOLOGY
LITERATURE REVIEW
Definations, Policies
Concept, Case Studies
Preparation of Aim,Objective, Scope and limitation
Selection of Study Area
Bhubaneswar Municipal Corporation Boundary
Data Collection
Primary Data
• Examine the Existing Condition of PBS network.
• OD data
• Perception survey of the cycle users
• Stakeholder consultation
Secondary Data
• Land-use data
• Ward boundary data
• Location of PBS hubs
• Existing Cycle network
• Pricing model / Request for Proposal of the Existing PBS system from the operator.
Output – Formulation of Preparation of Aim, Objective, Scope
Output – Identification of Analysis process from the collected data
Data Analysis
Literature Study
• Factors affecting PBS
• Identification of User group
Socio- Economic Analysis
• Demographic
• Socio-economic Character
• Travel Characteristics
Binary Logit Model Analysis
Identifying the modal shift of the cycle user to PBS
Outcome – Identifying user group of PBS
Objective - 1
Demand Route Analysis
Estimation of the maximum trips occurring to given zones.
Walkshed Analysis
Identifying the coverage of the PBS hubs
Issues Identification
Highlighting the issues of cycle and PBS users
Outcome – Identifying the barrier for PBS users
Objective - 2
Life Cycle Cost Analysis
Finding the life cycle cost of PBS and Cycle for a user
Outcome – Identifying the life cycle cost better to use a cycle or a PBS
Objective - 3
Proposal
Proposal for Identified Issues
Essential Infrastructure and a model to attract cycle users and PBS Users
Objective - 4
Seal & Sign
DEPARTMENT OF TRANSPORT PLANNING
4
SATYA SWAROOP SAHOO (MPTPLM004)
M.PLAN THESIS 2023-24
ENHANCING PUBLIC BICYCLE SHARING (PBS) ADOPTION IN BHUBANESWAR

DATA COLLECTION-FRAMEWORK

Identification of Data Source

Primary Data	Secondary Data
• Examine the existing Condition of PBS network. • OD data • Perception survey of the cycle users • Stakeholder consultation	• Land-use data • Ward boundary data • Location of PBS hubs • Existing Cycle network • Pricing model / Request for Proposal of the existing PBS system from the operator.

Data Collection Methods

Quantitative	Qualitative

Tools & Techniques Used

Perception Survey	Meeting with Stakeholders
Group Discussion on PBS failure	Locating the Existing NMT network

Sampling Strategy

Type of Sampling: Non- Probability Sampling (Purposive sampling)

72 Samples

Parameters for Selection of Sample –People who are cycling inside the boundary of Bhubaneswar Municipal Corporation

Secondary Data Checklist

BUKC

- Road Network
- Dedicated Cycle Track
- Location of PBS hubs

BHUBANESWAR DEVELOPMENT AUTHORITY

- Existing Land-use data
- Ward wise data

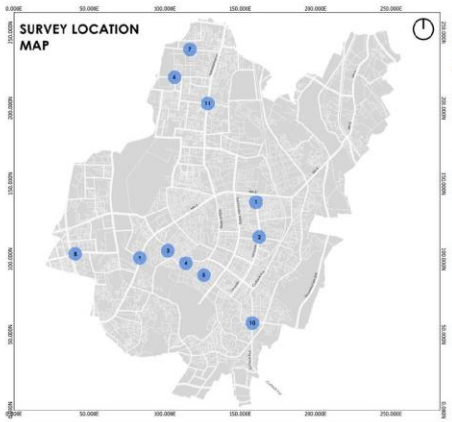
BMC

- Request for Proposal of PBS
- Financial analysist of PBS

BHUBANESWAR Smart

- Ridership data year-wise (2018-2023)
- Year-wise Carbon emission saved data

Survey Locations

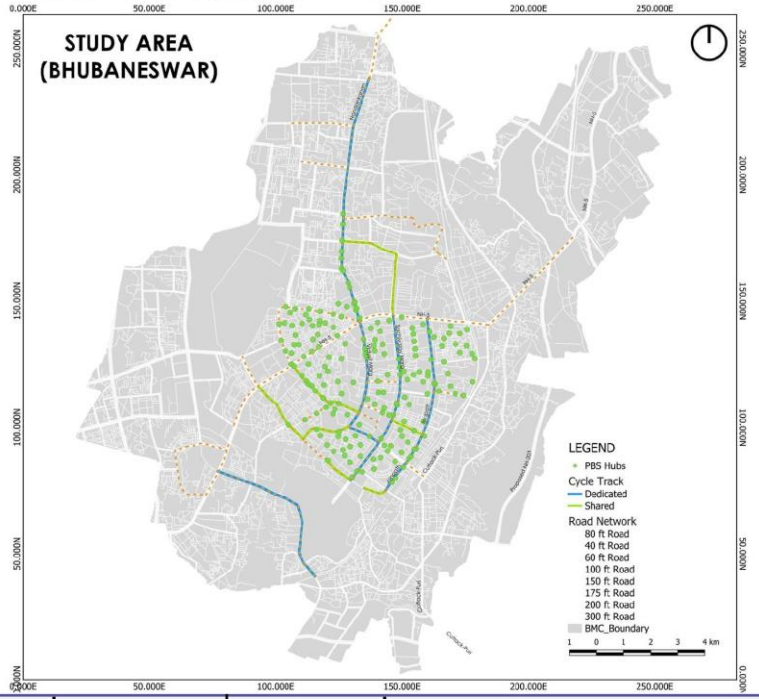


1. Ramadevi College Road
2. K.V-1 Road
3. Govt. Boys High School Unit -8
4. Gopabandhu Square
5. Govt. High School Unit-6
6. Infocity Square
7. KIIT Road
8. Ghatikia Road
9. Baramunda Bus Stand
10. Lingaraj Temple Road
11. Nandankanan Road

5	SATYA SWAROOP SAHOO (MPTPLMOO4)	M.PLAN THESIS 2023-24	ENHANCING PUBLIC BICYCLE SHARING (PBS) ADOPTION IN BHUBANESWAR	Seal & Sign	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal

STUDY AREA

- Bhubaneswar is the capital of Odisha and a regional Hub with growing IT and education hub it is also known as Temple city.
- Initially, Bhubaneswar presents many opportunities to introduce and execute a PBS system as an alternative transportation mode for its residents.



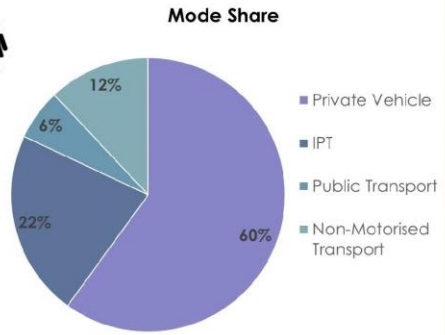
Population
11.07 lakh

Male
6,16,632

Female
4,60,643

Area in sq.km
161 sq.km

Avg. Trip Length
7.75 km



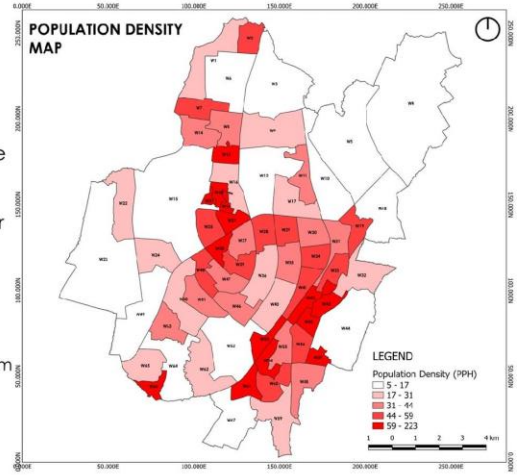
- The PBS was aligned with the existing Public bus service(MO BUS) network
- The PBS network plan made for 2 phases
- Phase 1 - **40 km** of stretch (existing) → = 2000 Cycles
- Phase 2 - **80 km** of stretch

175 Station

Population Density (Person per sq.km)
= 6,878

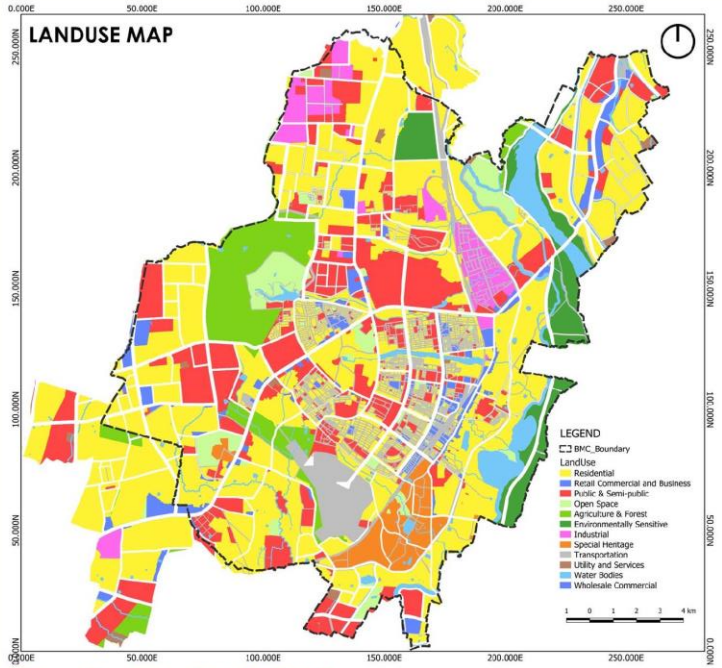
Total Number of Wards – **67**

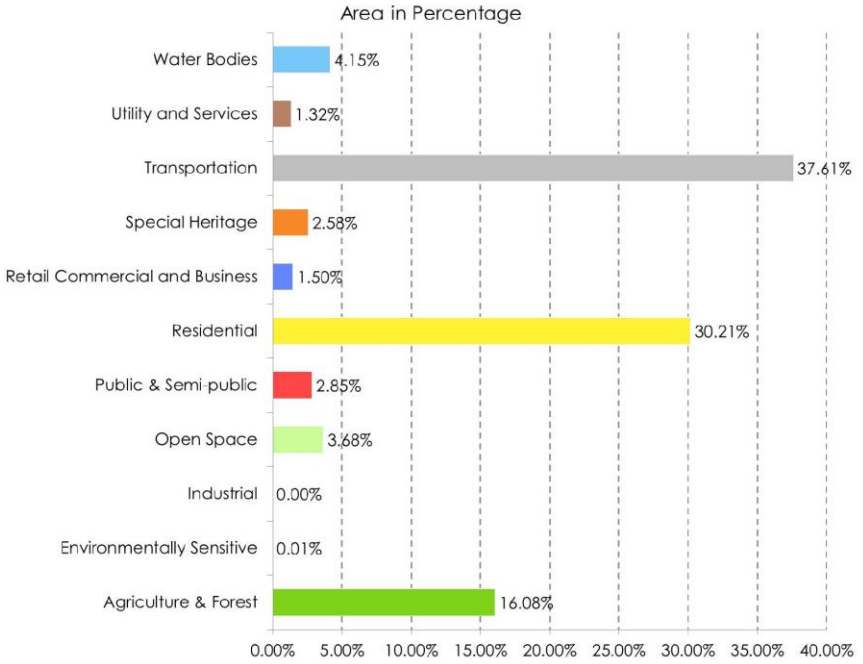
The Population Density of the Southeast part of the Study area is denser than the other region of the city.



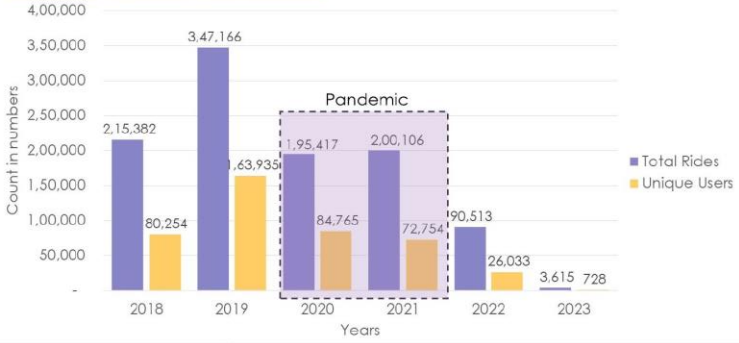
- Road Length – 1783.38 km
- Dedicated Cycle Track – 24.4 km
- Shared Cycle Track – 11 km
- Footpath – 67.4 km

6	SATYA SWAROOP SAHOO (MPTPLMOO4)	M.PLAN THESIS 2023-24	ENHANCING PUBLIC BICYCLE SHARING (PBS) ADOPTION IN BHUBANESWAR	Seal & Sign	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal





Ridership Data (2018-2023)

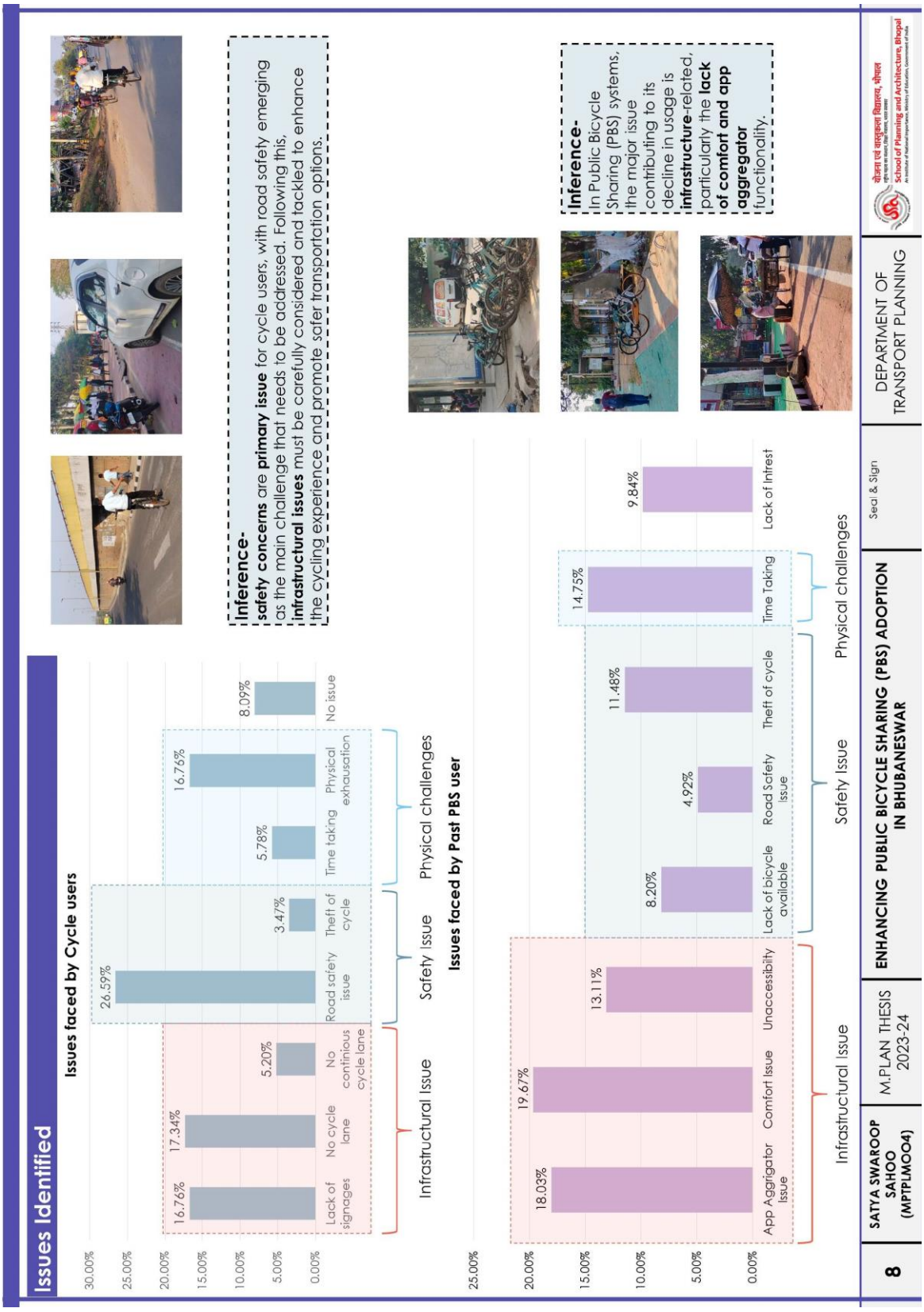


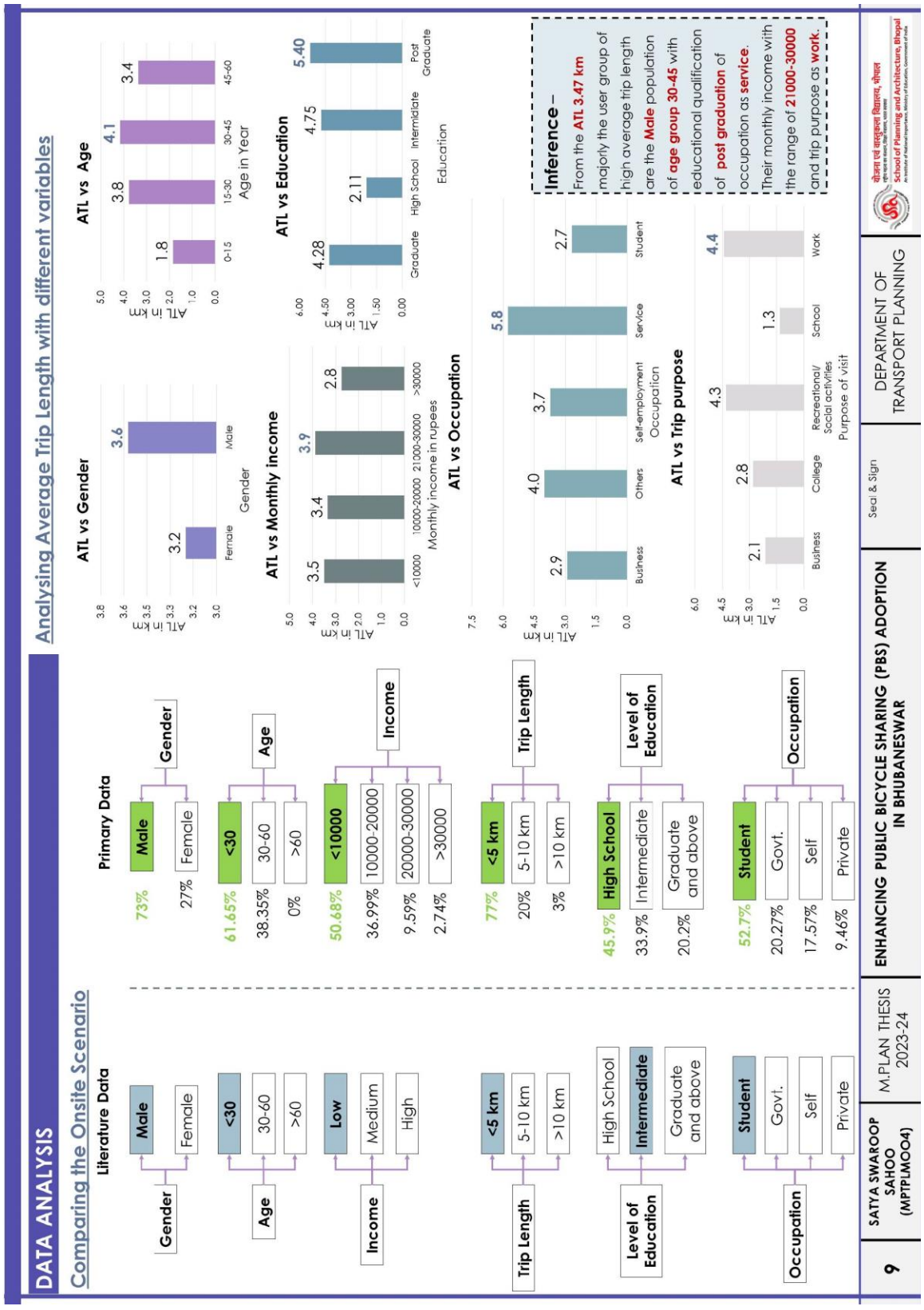
Inference –

The ridership experienced a gradual decline because of the COVID-19 lockdown implemented between the year 2021 and 2022.

Although the pandemic does not put more impact on the PBS user but in the year 2022-2023 it was seen maximum declination in the PBS system.

7	SATYA SWAROOP SAHOO (MPTPLMOO4)	M.PLAN THESIS 2023-24	ENHANCING PUBLIC BICYCLE SHARING (PBS) ADOPTION IN BHUBANESWAR	Seal & Sign	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal


Issues Identified
Issues faced by Cycle users
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
16.76%
17.34%
5.20%
26.59%
3.47%
5.78%
16.76%
8.09%
Lack of signages
No cycle lane
No continious cycle lane
Road safety issue
Theft of cycle
Time taking
Physical exhausation
Infrastructural Issue
Safety Issue
Physical challenges
Issues faced by Past PBS user
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
18.03%
19.67%
13.11%
8.20%
4.92%
11.48%
14.75%
9.84%
App Aggrigator Issue
Comfort Issue
Unaccessibilty
Lack of bicycle available
Road Safety issue
Theft of cycle
Time Taking
Lack of Intrest
Infrastructural Issue
Safety Issue
Physical challenges
Inference-
safety concerns are primary issue for cycle users, with road safety emerging as the main challenge that needs to be addressed. Following this, infrastructural issues must be carefully considered and tackled to enhance the cycling experience and promote safer transportation options.
Inference-
In Public Bicycle Sharing (PBS) systems, the major issue contributing to its decline in usage is infrastructure-related, particularly the lack of comfort and app aggregator functionality.
8
SATYA SWAROOP SAHOO (MPTPLMOO4)
M.PLAN THESIS 2023-24
ENHANCING PUBLIC BICYCLE SHARING (PBS) ADOPTION IN BHUBANESWAR
Seal & Sign
DEPARTMENT OF TRANSPORT PLANNING
योजना एवं वास्तुकला विद्यालय, भोपाल
School of Planning and Architecture, Bhopal


DATA ANALYSIS
Analysing Average Trip Length with different variables
Comparing the Onsite Scenario
Literature Data
Gender
Male
Female
Age
<30
30-60
>60
Income
Low
Medium
High
Trip Length
<5 km
5-10 km
>10 km
Level of Education
High School
Intermediate
Graduate and above
Occupation
Student
Govt.
Self
Private
Primary Data
Gender
Male 73%
Female 27%
Age
<30 61.65%
30-60 38.35%
>60 0%
Income
<10000 50.68%
10000-20000 36.99%
20000-30000 9.59%
>30000 2.74%
Trip Length
<5 km 77%
5-10 km 20%
>10 km 3%
Level of Education
High School 45.9%
Intermediate 33.9%
Graduate and above 20.2%
Occupation
Student 52.7%
Govt. 20.27%
Self 17.57%
Private 9.46%
ATL vs Gender
ATL in km
Female
Male
Gender
ATL vs Age
Age in Year
0-15
15-30
30-45
45-60
ATL vs Monthly income
Monthly income in rupees
<10000
10000-20000
21000-30000
>30000
ATL vs Education
Graduate
High School
Intermidiate
Post Graduate
Education
ATL vs Occupation
Business
Others
Self-employment
Service
Occupation
ATL vs Trip purpose
Business
College
Recreational/ Social activities
School
Work
Purpose of visit
Inference –
From the ATL 3.47 km majorly the user group of high average trip length are the Male population of age group 30-45 with educational qualification of post graduation of occupation as service. Their monthly income with the range of 21000-30000 and trip purpose as work.
9
SATYA SWAROOP SAHOO (MPTPLMOO4)
M.PLAN THESIS 2023-24
ENHANCING PUBLIC BICYCLE SHARING (PBS) ADOPTION IN BHUBANESWAR
Seal & Sign
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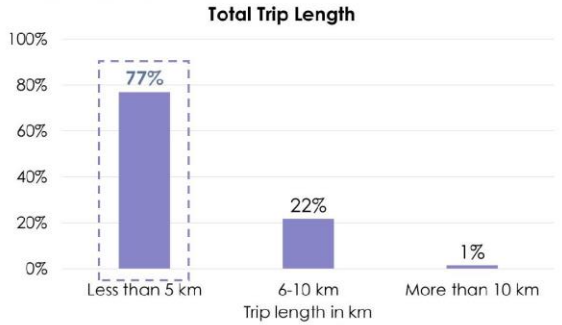
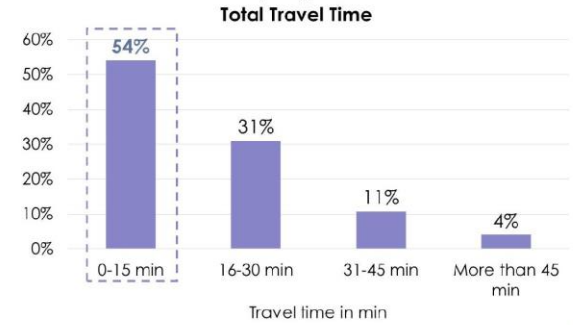
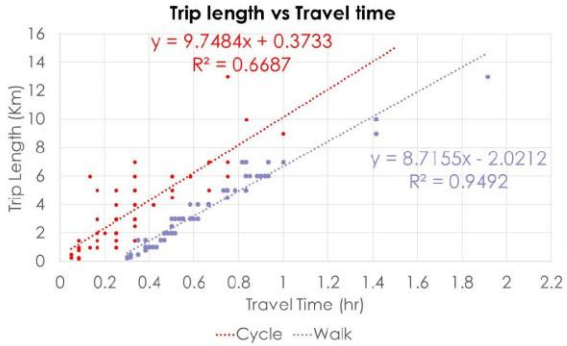
Analysing Trip length and Travel Time

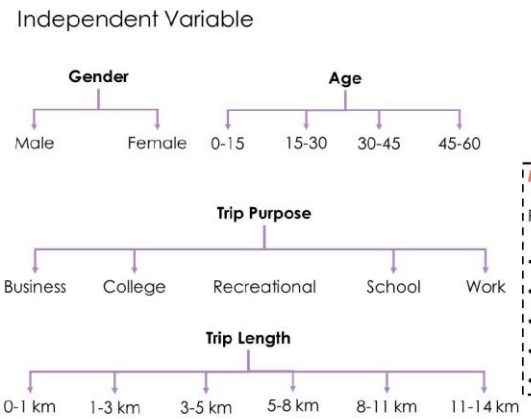






Inference –
The trend line of walk and cycle is close as well as the function of cycle illustrate speed of cycle is **9 kmph (approx.)** which is very slow than the average speed. Due of lack of cycling infrastructure in the city.

Binary Logit Model Analysis



Methodology

Reference Variable taken:

- Gender: (Female)
- Age: (30-45 year)
- Monthly Income: (10000-20000)
- Trip Purpose: (Work)
- Trip Length: (5-8 km)

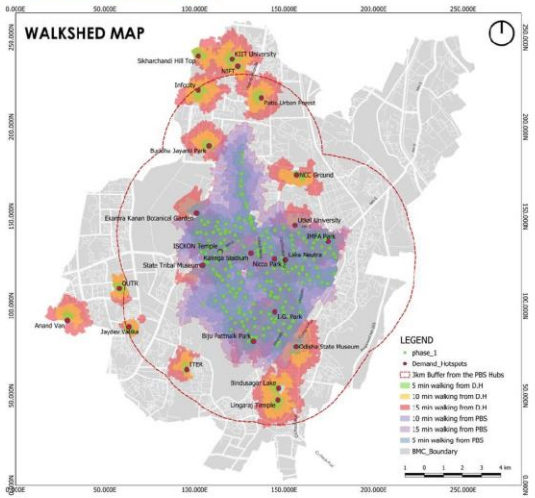
Variable		Coef.
Gender	Male	2.14
	Female	0
Age in Year	0-15	26.85
	15-30	27.93
	30-45	0
	45-60	1.77
Monthly Income In Rupees	< 10000	3.9
	10000-20000	0
	20000-30000	1.1
	> 30000	1.9
Trip Purpose	Business	26.21
	College	1.3
	Recreational	29.65
	School	29.34
	Work	0
Trip Length in Kilometer	0-1 km	33.04
	1-3 km	34.26
	3-5 km	3.93
	5-8 km	0
	8-11 km	17.1

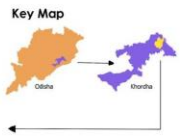
Number of Obs.: 72
Cox & Snell R Square: 0.593
Nagelkerke R Square: 0.794
Pseudo R^2: 0.65
Log Likelihood: (-17.27)

Inference –
The Modal shift is highly positive from the binary logit model, for **male** with age group of **15-30** and monthly income **<10000** moving for the **Recreational trips** within a distance of **1-3 km.**

10	SATYA SWAROOP SAHOO (MPTPLMOO4)	M.PLAN THESIS 2023-24	ENHANCING PUBLIC BICYCLE SHARING (PBS) ADOPTION IN BHUBANESWAR	Seal & Sign	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal

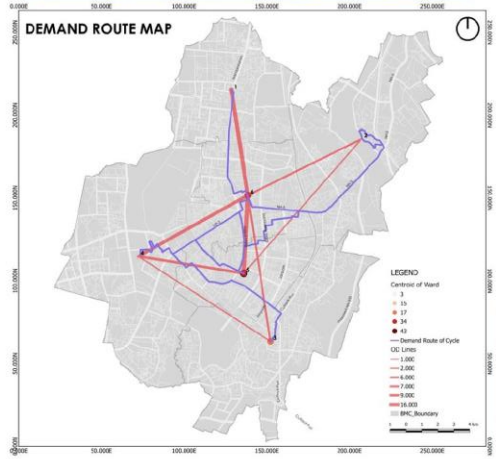
Walkshed Analysis

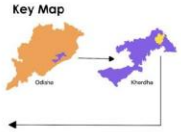




Inference –
Majorly Demand Hotspot can not be reached from the PBS hubs and from the Demand Hotspot also its very difficult to reach the PBS infrastructure.

Identification of Major Demand Route





Methodology

67 Wards into 6 Zones

Origin and destination data primarily collected

Inference –
Major demand route of length **51.8 km** happening from Zone 1-6, Zone 5-6, followed by Zone 6-4 and Zone 5-4.

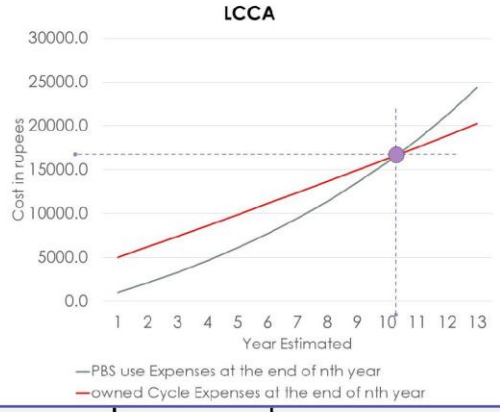
Life Cycle Cost Analysis of PBS and Owned Cycle

Methodology

PBS yearly Subscription price: Rs 999 *(Source: Request for proposal, Bicycle sharing, BBSR)*
Cycle Owning cost: Rs 5000

Annual Growth rate of PBS: 9.92% *(Source: Bike-sharing-india, Statista.com)*
Annual Growth rate of Cycle: 1%* (Survey with the Decathlon agent)

Year Estimated	Cost of PBS use per year	Total PBS use expenses	Cost of owned and maintenance per year	Total Owned and maintenance of cycle expenses
Year -1	999	999	5000	5000
Year -2	1098.1	2097.1	1200	6200
Year -3	1207	3304.1	1212	7412
Year -4	1326.8	4630.9	1224.1	8636.1
Year -5	1458.4	6089.3	1236.4	9872.5
Year -6	1603.1	7692.3	1248.7	11121.2
Year -7	1762.1	9454.4	1261.2	12382.4
Year -8	1936.9	11391.3	1273.8	13656.2
Year -9	2129	13520.3	1286.6	14942.8
Year -10	2340.2	15860.5	1299.4	16242.2
Year -11	2572.4	18432.9	1312.4	17554.7
Year -12	2827.5	21260.4	1325.5	18880.2
Year -13	3108	24368.5	1338.8	20219

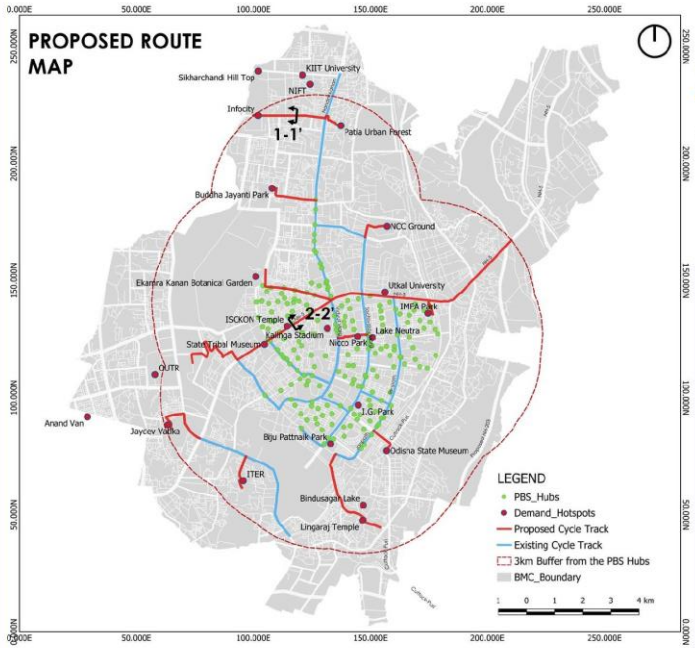


Inference –
In the estimated year between **Year10 – Year11** the PBS use is more profitable for an individual rather to choose its own cycle.

11	SATYA SWAROOP SAHOO (MPTPLMOO4)	M.PLAN THESIS 2023-24	ENHANCING PUBLIC BICYCLE SHARING (PBS) ADOPTION IN BHUBANESWAR	Seal & Sign	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal

Recommendation

Proposed Route Map



Proposed Length of Cycle Track= **27.3 km**

Proposal for renting cost of PBS

Riding PBS within the buffer zone of 3km from the existing PBS hubs

Sl. No	Time of Travel (in min)	Cost
1.	0-30	5
2.	30-60	10
3.	60-120	25
4.	120-240	50
5.	240-480	100
6.	More than 480	150

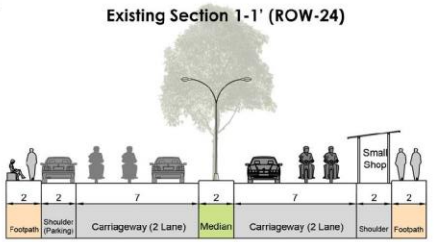
Riding beyond the buffer zone of 3km from the existing PBS hubs

Sl. No	Trip length(in km)	Cost
1.	1-3	5
2.	3-6	10
3.	6-9	25
4.	9-12	50
5.	More than 12	75

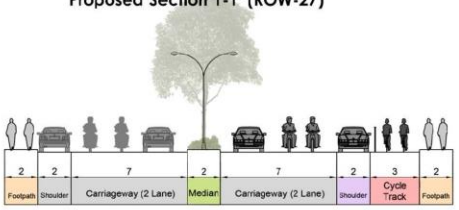
Proposal for PBS

- Proper PBS Infrastructure
- Public Awareness Campaigns
- Continuous cycle lane
- Monitoring and implementation of Fines
- Simple app aggregator
- Collaboration with Law Enforcement

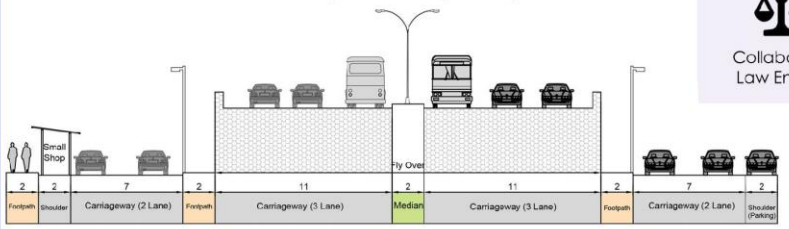
Existing Section 1-1' (ROW-24)



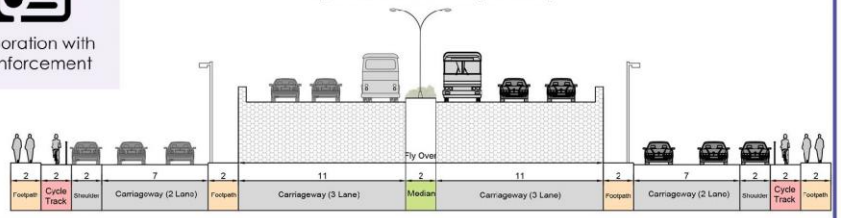
Proposed Section 1-1' (ROW-27)



Existing Section 2-2' (ROW-48)



Proposed Section 2-2' (ROW-54)



12	SATYA SWAROOP SAHOO (MPTPLM004)	M.PLAN THESIS 2023-24	ENHANCING PUBLIC BICYCLE SHARING (PBS) ADOPTION IN BHUBANESWAR	Seal & Sign	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal

Annexure-3: Plagiarism Report

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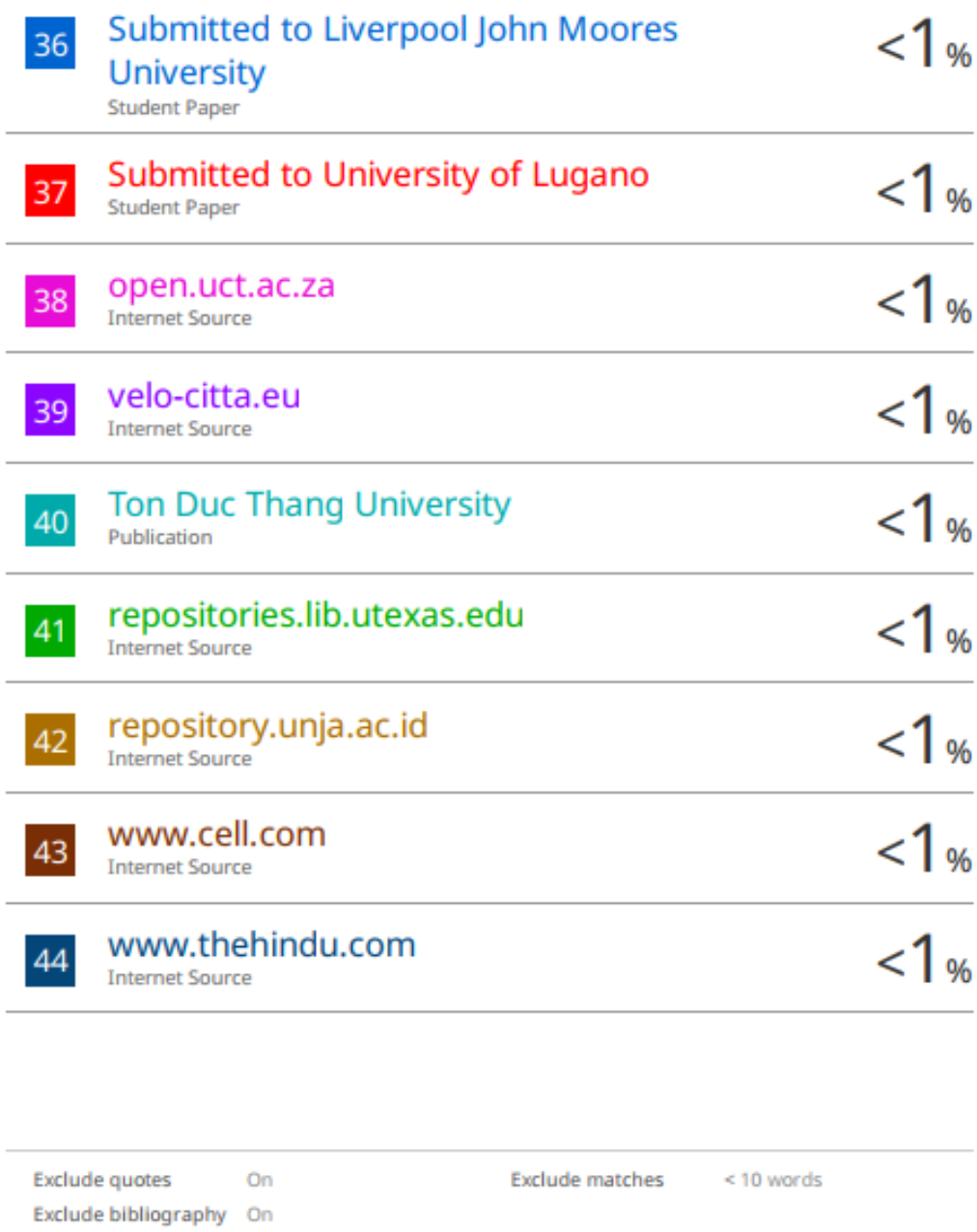

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