COMPARISON OF THE TRANSPORT INFRASTRUCTURE METRICS OF CITIES THAT HAVE SUCCESSFULLY PROMOTED MICROMOBILITY.

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Thesis/Dissertation submitted in partial fulfillment of the requirements for the degree

Master of Engineering in Highway & Traffic Engineering

Department of Civil Engineering

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University of Moratuwa

Sri Lanka

January 2025

DECLARATION

I declare that this is my own work and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

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ACKNOWLEDGEMENT

I am deeply thankful to the University of Moratuwa for granting me the opportunity to delve into this captivating subject matter. The journey through this dissertation has been profoundly enlightening, and I firmly believe it will play a significant role in shaping my professional development.

I am particularly indebted to my supervisor, Professor Pasindu H.R. Hadunneththi, whose unwavering guidance, mentorship, and support have been indispensable throughout this endeavour. His insightful suggestions and patient feedback have greatly contributed to the refinement of my work. I would also like to express my gratitude to the esteemed faculty and mentors of the civil engineering department at the University of Moratuwa for their invaluable guidance and encouragement.

Additionally, I extend my heartfelt thanks to the participants of the questionnaire survey, whose provision of data and information has been pivotal to this study. Their support and encouragement have been a constant source of strength during this challenging period, for which I am sincerely grateful.

ABSTRACT

This extensive report undertakes a comprehensive exploration of the intricate landscape of bicycle transportation metrics across ten micro-mobility-promoted cities. The study adopts a structured approach, organizing its analysis into five fundamental categories: bicycle infrastructure, regulatory environment, user convenience, network connectivity, and safety & security. Each category is meticulously defined and enriched with a comprehensive array of metrics, ensuring a thorough assessment of the multifaceted aspects of bicycle transportation systems.

The process of data collection was exhaustive and methodical, drawing from a diverse range of reputable sources including official websites, regulatory guidelines, scholarly literature, research papers, and an extensive questionnaire survey. This meticulous approach ensured the acquisition of robust and reliable data sets, essential for conducting a rigorous analysis.

Following the meticulous data collection phase, a rigorous analytical framework was employed to establish benchmarks for each individual metric. This methodological approach facilitated a nuanced and insightful performance evaluation, shedding light on both the strengths and areas for improvement within the bicycle transportation systems of the studied cities.

The findings of this comprehensive investigation yield invaluable insights into the effectiveness of bicycle transportation systems within micro-mobility-promoted cities. By offering a detailed examination of performance across various metrics, the report provides actionable recommendations for policymakers and urban planners. These recommendations are tailored to address specific areas of improvement, aiming to enhance both bicycle infrastructure and regulatory frameworks.

Ultimately, the report underscores the importance of fostering sustainable and safe cycling practices within urban environments. By leveraging the insights gleaned from this study, policymakers and urban planners can devise strategies that promote the development of robust bicycle transportation systems, thereby contributing to the creation of healthier, more environmentally-friendly cities.

Keywords: Micro-Mobility, Metrics, bicycle transport, Promoted cities.

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LIST OF ABBREVIATIONS

CO_2	Carbon dioxide
MRS	Marginal rate of substitution
BSIR	Bicycle Safety Index Rating
BLOS	Bicycle Level of Service
BSA	Bicycle Suitability Assessment
BCI	Bicycle Compatibility Index
BSS	Bicycle Suitability Score
BSR	Bicycle Suitability Rating
HIS	Interaction Hazard Score
RCI	Road Condition Index
RDA	Road Development Authority
RDD	Road Development Department
UDA	Urban Development Authority

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CHAPTER 1: INTRODUCTION

1.1 Background study

In our contemporary society, the demand for passenger transportation continues to surge unabated, with a staggering 39% of our total energy consumption directed towards transportation needs alone. This statistic underscores the profound impact that transportation experts on energy resources, highlighting the urgent need for sustainable solutions to address the escalating demand. As societies grapple with the spectre of looming energy crises, recent global initiatives such as the United Nations' sustainable development goals and international agreements have thrust the imperative of sustainable transportation into the forefront of public consciousness. This newfound emphasis on sustainability has sparked widespread attention and catalysed concerted efforts to re-evaluate and revolutionize traditional transportation paradigms worldwide. Nowhere is the call for sustainable transportation more urgent than in developed cities, where the convergence of rapid urbanization, mounting environmental concerns, and the relentless pursuit of efficient mobility solutions creates a crucible of pressing challenges and transformative opportunities. The exponential growth of urban centres, coupled with heightened awareness of environmental degradation, has galvanized municipalities to seek innovative strategies to mitigate the adverse impacts of transportation on both the environment and public health. Within this dynamic landscape, the bicycle has emerged as a beacon of hope—an emblem of eco-friendliness, health-consciousness, and cost-effectiveness in urban mobility solutions.

The bicycle's transformative potential lies in its ability to alleviate the twin scourges of traffic congestion and air pollution while simultaneously curbing carbon emissions, positioning it as a compelling antidote to the transportation challenges confronting developed cities. As such, the promotion of micro-mobility, epitomized by the ubiquitous bicycle, has assumed paramount importance in urban planning discourse. In a bid to elucidate the symbiotic relationship between urban development and bicycle mobility, our study endeavours to scrutinize and analyse various metrics that underpin the promotion and sustenance of bicycle transportation in the urban milieu.

To facilitate a comprehensive examination, we have meticulously selected ten cities for analysis, each representing a diverse tapestry of urban landscapes and transportation policies. From the meticulously planned metropolis of Singapore to the cycle-friendly corridors of Aarhus, Denmark, and from the bustling thoroughfares of Tokyo, Japan, to the verdant byways of Oakland, USA, our selection encompasses a spectrum of urban environments, offering valuable insights into the multifaceted dynamics of bicycle mobility across disparate locales.

1.2 Problem statement

This study is to meticulously identify cities worldwide that actively promote bicycle mobility, regardless of their geographical location, cultural nuances, or economic standing. Our overarching goal is to delve into the intricate fabric of these cities' transportation systems and uncover a diverse array of metrics essential for comprehending and fortifying their bicycle mobility initiatives.

Moreover, we endeavour to scrutinize how varying economic conditions and geographical features influence the efficacy and accessibility of bicycle networks within these urban environments. Through a rigorous examination of the bicycle infrastructure in these locales, our aim is to isolate pivotal metrics that serve as barometers of success or areas necessitating improvement. These metrics will be methodically categorized and aligned with broader thematic categories to facilitate a comprehensive understanding of their significance.

Furthermore, the establishment of precise and unequivocal definitions for the measurable parameters associated with these metrics is paramount. Clarity in defining these parameters will not only streamline data collection and analysis but also ensure the accuracy and reliability of our findings, thereby enhancing the overall validity and impact of our study.

1.3 Objectives

The objective of this studies are;

- Identify the key bicycle transportation metrics in cities that prioritize micro-mobility and categorize them into major groups.
- Establish benchmarks for the required metrics to gauge bicycle transportation performance.
- To compare those with a typical city in Sri Lanka (Colombo) and identify where it falls short, and recommend the improvement by categorize the levels of performance.

1.4 Research approach

To accomplish the research objectives, I employed a series of methodological approaches aimed at comprehensively investigating and analysing bicycle transportation systems. Here's an elaboration of the steps undertaken;

- Literature Review and City Selection: Conducted an extensive literature review to gather insights from past research reports, international rankings. This review enabled the selection of cities for comparative analysis regarding their bicycle transportation modes. By examining sources, I identified cities that have demonstrated excellence &innovation in promoting bicycle transportation.

- Metrics Identification and Parameter Selection: Study the literature review to identify key metrics pertinent to bicycle transportation. This process involved scrutinizing existing literature to discern relevant parameters for measuring these metrics effectively. By synthesizing information from various sources, I established the set of parameters essential for evaluating bicycle transportation.
- Data Collection Methodologies: carryout the multifaceted approach to data collection, utilizing both qualitative and quantitative methodologies. This involved referencing past reports, academic papers presented at conferences, conducting non-structured interviews via phone calls, extracting data from official county websites, reviewing city and country guidelines and regulations related to cycling, and administering structured questionnaires. By leveraging diverse data sources. Also collect Colombo city bicycle mobility situation by questionnaire to facilitate the calculate the defined metrics as earlier.
- Data Analysis and Benchmarking: Utilized strategic analytical methods to process and interpret the collected data. I sought to establish benchmarks and define the required performance levels for bicycle transportation at the city level. Also calculate the metrics value in Colombo city.
- Identify the weaknesses in Colombo city by gathering data through a questionnaire. Assess how Colombo performs according to defined metrics and compare these results with the benchmarks. This comparison will help pinpoint the areas where Colombo falls short.
- Recommend improvements stage by stage to achieve the required benchmark level. Prioritize actions that provide the greatest value for improvement until the desired level of satisfaction is achieved.

Through these methodological approaches, I aimed to contribute to the advancement of knowledge and practice in the field of bicycle transportation, with a particular focus on facilitating sustainable urban mobility in diverse urban contexts.

CHAPTER 2: LITERATURE REVIEW

2.1 Bicycle is the sustainable transportation model in developed city

In this segment, we offer an evaluation of the emission factors delineated in recent literature for various transportation systems over the past decade. Firstly, as elucidated by (Ma, H.; Balthasar, et al. 2012), it is crucial to discern that emission factors are solely applicable to the utilization phase encompassing the production, transportation, and eventual disposal of vehicles, as well as the lifecycle of fuel until its consumption in vehicles. Both conventional and alternative modes of transportation have undergone scrutiny, including walking, cycling (both traditional and electric bikes), mopeds (both traditional and electric), cars, and buses (running on petrol, hybrid, and electric power). Notably, railway systems are excluded since the scope is confined to urban settings where travel distances typically do not exceed 2 km (Brunner, et al 2018) Furthermore, examination is tailored towards passenger transport (Chester, et al, 2021), with freight modes being disregarded. Emission factors are articulated in terms of CO2-equivalents and presented as unit coefficients.

As highlighted in (Mizdrak, et al 2020), active modes such as walking and cycling cannot be characterized as emission-free owing to the physical exertion required, thus necessitating energy expenditure. Consequently, related studies generally address emissions associated with the food production process required for covering distances via walking or cycling (Stott, et al. 2021), (Handy, et al., 2021). The European Cyclists Federation (Blondel, et al, 2021) asserts that the average European diet accounts for 1.44 gCO2-equivalents per calorie of consumed food. Consequently, an estimation can be derived based on the total calorie expenditure. However, the spectrum varies significantly, as a meat-based diet yields higher emissions compared to a vegetarian diet (Poore, et al, 2018) and the respective speeds of pedestrians and cyclists can vary greatly (Chandra, et al, 2013). Naturally, in the context of walking, discussion of life cycle assessment (LCA) is irrelevant, while for cycling, emissions linked to the manufacturing and disposal of vehicles (e.g., conventional bikes) must be factored in when computing emissions within a lifecycle assessment. According to manufacturing emissions associated with conventional bikes amount to 5 gCO2-equivalents per kilometre.

Comparison of carbon emission giving the table 1 below for CO2 emission of user phase and life cycle assessment. According to the data provided in the table, it is evident that bicycles emit significantly less CO2 compared to other modes of transportation. The reference in the table highlights the comparative advantage of bicycles in terms of environmental impact, particularly in terms of carbon dioxide emissions. This observation underscores the potential of bicycles as a sustainable and environmentally friendly mode of transportation. It reinforces the importance of promoting cycling infrastructure and encouraging the adoption of bicycles as a means to reduce greenhouse gas emissions and mitigate the adverse effects of climate change.

The data presented in the table serves as a compelling argument for incorporating bicycles into urban transportation planning and policy-making efforts aimed at promoting sustainable mobility solutions. (Stott, et al 2021, Bielin´ ski, et al 2021, Shaheen, et al 2016, Fan, et al 2019, Koen, et al 2019, Ma, H.; Balthasar et al 2012, Ghosh, et al 2020, Enyedi, et al 2018, Sanguesa, et al 2020, Spreafico, et al 2020).

Table 1: CO2 emission of user phase and life cycle assessment.

Transportation mode	Unit emission factor [gCO2-eq/(pax*km)]	
	Use phase	Life cycle assessment
Bicycle	15-20	20-25
Moped	50-90	80-180
E-moped	25-35	50-75
Hybrid car	80-120	60-180
Electrical car	40-100	80-150
Hybrid bus	9-50	25-75
Electrical bus	10-60	20-30

The potential of micro-mobility to alleviate the challenges faced by densely populated urban areas extends beyond its role in reducing greenhouse gas emissions. While the reduction of emissions is indeed a significant aspect, the appeal of micro-mobility lies in its multifaceted solutions to the intricate transportation issues prevalent in traffic-congested cities worldwide. Advocates recognize micro-mobility vehicles as pivotal components in addressing the persistent challenges associated with first- and last-mile transportation. These modes of transport offer efficient and accessible solutions for commuters to bridge the gap between their homes, workplaces, and public transportation hubs. By providing convenient and eco-friendly options for short-distance travel, micro-mobility not only mitigates traffic congestion but also enhances overall urban mobility, promotes sustainability, and fosters healthier living environments. Thus, the enthusiasm surrounding micro-mobility stems not only from its environmental benefits but also from its transformative potential in redefining urban transportation paradigms and enhancing the quality of life in cities worldwide.

2.2 Identify the micro-mobility promoted cities

The selection process for cities promoting bicycle use involves careful consideration of several factors, including the economic condition of the country and policies related to environmental conservation and transportation. A comprehensive review of existing literature reveals the primary factors that cities consider when choosing to promote cycling. Additionally, this study takes into account the selection of cities from various countries and regions to enable a thorough comparison of metrics. By examining a diverse range of locations, this research aims to capture a comprehensive understanding of the factors influencing the promotion of bicycles as a means of transportation. The chosen cities provide valuable insights into the effectiveness of different strategies and policies in promoting cycling, thus contributing to the development of sustainable urban transportation solutions worldwide.

Established sustainable & Eco-friendly transportation policy

In selecting cities for the promotion of bicycle-based transportation models, it is imperative that they belong to developed countries with governments and relevant authorities committed to advancing sustainable transportation options. The emergence of smart cities has amplified the urgency for on-demand public transportation services, prompting a surge in the adoption of micro-mobility solutions. Regulatory frameworks and the increasing focus on smart city initiatives further propel this movement towards more efficient and eco-friendly transportation methods.

Furthermore, the relentless trend of urbanization is expected to significantly elevate the demand for improved mobility services in cities worldwide. As urban populations continue to grow, so does the need for innovative solutions that alleviate traffic congestion, reduce carbon emissions, and enhance overall urban mobility. In response to these challenges, cities are embarking on transformative endeavours aimed at enhancing the quality of life for residents.

Through strategic investments in urban mobility solutions, cities are poised to revolutionize their transportation systems, paving the way for more sustainable and accessible modes of travel. This steadfast commitment to improving mobility infrastructure will not only result in tangible enhancements to transportation networks but also necessitate a continual evolution of transport policies to adapt to changing urban landscapes and emerging technologies. By prioritizing sustainability and efficiency, cities can create vibrant and liveable environments that cater to the diverse needs of their inhabitants while fostering economic growth and environmental stewardship.

Established transportation infrastructure

In urban centres celebrated for their well-established public transportation networks, commuters often face a myriad of obstacles when navigating the crucial first and last-mile connections. This challenge is not unique to a single city or country; it spans across diverse nations with varying infrastructural landscapes and urban layouts. However, amidst these challenges, micro-mobility emerges as a promising solution to effectively bridge the gap between the initial and final segments of a commuter's journey.

Micro-mobility encompasses a range of compact and agile transportation options such as electric scooters, bicycles, and small electric vehicles, which are ideally suited for short-distance travel within urban environments. By providing flexible and accessible modes of transport, micro-mobility services offer commuters convenient alternatives to traditional public transit systems, particularly for those navigating the first and last-mile segments of their trips.

The integration of micro-mobility solutions into existing transportation frameworks holds the potential to enhance overall mobility experiences for commuters while addressing the inherent challenges associated with first and last-mile connectivity. By leveraging innovative technologies and sustainable transportation solutions, cities can create more seamless and efficient transportation networks that cater to the evolving needs of urban dwellers.

Successfully completed the Bicycle Pilot Program

Cities that have successfully completed their trial initiatives are now moving forward into the developmental stages of integrating micro-mobility solutions. Across various urban areas, the adoption of trial initiatives has become a common practice, serving as a crucial precursor to making larger commitments to providers or rolling out micro-mobility services on a widespread scale. Through these trial phases, cities gain invaluable insights into the practicalities of integrating micro-mobility options within their existing transportation systems.

Experimenting with micro-mobility vehicles on a smaller scale allows cities to carefully assess their compatibility and effectiveness within the broader mobility framework. It provides decision-makers with an opportunity to evaluate the infrastructure requirements, operational challenges, and regulatory considerations associated with incorporating these innovative transportation solutions into the urban landscape. Moreover, pilot programs serve as a valuable platform for engaging with the public and soliciting feedback on the acceptability and usability of micro-mobility technologies.

By conducting pilot programs, cities can gauge public sentiment towards this emerging form of transportation, identify potential concerns or preferences, and refine their strategies for implementing micro-mobility services in a manner that best serves the needs of their communities. Ultimately, these initiatives pave the way for informed decision-making and strategic planning as cities seek to embrace the transformative potential of micro-mobility in enhancing urban mobility

Established Internet infrastructure and Information technology

The viability and success of micro-mobility platforms pivot significantly on the continuous advancements in technology and the operational efficiency of the systems in place. A robust and reliable telecommunications infrastructure serves as the backbone for a multitude of critical functions within micro-mobility operations. These functions encompass essential tasks such as navigation assistance, barcode scanning for vehicle unlocking, seamless payment processing, and efficient parking management systems.

In essence, a dependable telecommunications network forms the bedrock upon which the entire micro-mobility ecosystem operates. It enables real-time communication between users, service providers, and the infrastructure itself, facilitating the smooth flow of information and transactions essential for the effective functioning of micro-mobility services.

Without adequate and improved connectivity, service providers would face formidable challenges in delivering micro-mobility services that meet the expectations of users and adhere to operational standards. Subpar connectivity could lead to disruptions in service, compromised user experiences, and inefficiencies in managing fleets of vehicles.

Based on the aforementioned considerations, I have chosen the cities for the study.

Table 2: Summary of selected micromobility promoted cities

No	Cities	Country
1	Singapore	Singapore
2	Aarhus	Denmark
3	Madtid	Spain
4	Bordeaux	France
5	Hamburg	Germany
6	Eindhovan	Netherland
7	Gothenburg	Sweden
8	Tokyo	Japan
9	Oslo	Norway
10	Oakland	USA

2.3 Identified the bicycling metrics in micro mobility promoted cities.

Identified the bicycle transportation metrics consider the rider, co-user, and government perspective too. Throughout the study collect the possible metrics in bicycle transportation for our analysis.

The comprehensive analysis of bicycle transportation metrics encompasses a multifaceted approach, acknowledging the perspectives of various stakeholders including the rider, co-user, and government entities. Delving into the intricacies of this study involves a systematic collection of diverse metrics pertinent to bicycle transportation, aimed at facilitating a thorough analysis and understanding of the dynamics.

Street connectivity encompasses the level of directness and the accessibility of alternate routes linking residential neighbourhoods to nearby destinations (Frank and

Engelke, 2005). This notion emphasizes the critical function of pathways in enabling mobility. Earlier academic research has defined street connectivity by considering the concentration of intersections featuring three or more junctions within a given land area (Dill, 2004; Wang et al., 2013). This underscores the importance of intersection safety and design within the realm of urban planning and transportation studies.

Previous studies have employed diverse network connectivity metrics to explore different aspects of urban mobility. For example, McNeil (2011) investigated bike accessibility by identifying crucial destination categories such as restaurants, banks, parks, and public spaces. Meanwhile, Faghih Imani et al. (2019) assessed the degree of traffic stress experienced by cyclists across street and path networks. Their findings underscored the importance of evaluating cycling accessibility based on low-stress network connections, which significantly influences individuals' decision to opt for cycling as their preferred mode of transportation.

Areas characterized by low street connectivity typically feature sparse intersection density, obstacles hindering direct travel, and limited route options. Conversely, high connectivity is observed in regions where a grid-based street layout prevails (Handy et al., 2003). This distinction underscores the importance of street design and layout in shaping the accessibility and navigability of urban environments, thereby influencing transportation patterns and overall urban liability.

Lowry et al. (2012) conducted an assessment of community-wide bike-ability using the Bicycle Level of Service (BLOS) metric; however, they did not delve into evaluating the connectivity of the links. Subsequently, Lowry and Loh (2017) introduced a methodology based on the marginal rate of substitution (MRS) for bicycle routing stress analysis, aiming to identify priority projects based on accessibility to key destinations. Nonetheless, the calculation of individual actual MRS values poses challenges, and their simplistic approach to MRS computation may introduce bias, as bicyclists might not necessarily substitute a bike lane for an off-street path at a linear rate.

In a study by Koohsari et al. (2014), the association between street connectivity, utilitarian destination availability, and frequency of walking for transport was examined. Their research revealed a significant correlation, with street connectivity calculated as the ratio of intersections to census collection district land area, thereby deriving an intersection density metric. Despite these insights, uncertainties persist regarding the optimal choice of connectivity measures, warranting further investigation and refinement in this area of study.

The provided list comprises various indices and metrics utilized to assess and evaluate different aspects of bicycle transportation infrastructure and safety standards. Let's delve into each one to understand their significance and scope:

Bicycle Safety Index Rating (BSIR) (Davis, 1995): The BSIR provides a comprehensive rating system aimed at evaluating the safety conditions and hazards pertinent to bicycle transportation infrastructure. It likely considers factors such as road design, traffic patterns, and accident data to generate a safety rating.

Bicycle Level of Service (BLOS) (Jensen, 2007): BLOS assesses the quality and efficiency of bicycle transportation facilities and networks. It encompasses factors like traffic volume, speed, pavement conditions, and intersection design to determine the level of service provided to cyclists.

Bicycle Suitability Assessment (BSA) (Emery, 2018): BSA is a tool used to assess the suitability of roadways and pathways for bicycle travel. It likely considers factors such as road width, shoulder presence, traffic speed, and bicycle-specific infrastructure to determine the overall suitability for cycling.

Bicycle Compatibility Index (BCI) (Harkey and Reinfurt, 1998): BCI evaluates the compatibility of roadways and intersections with bicycle traffic. It may consider factors such as lane width, presence of bike lanes, signage, and intersection design to gauge how well the infrastructure accommodates cyclists.

Bicycle Suitability Score (BSS) (Turner et al., 1997): BSS is a quantitative measure used to assess the suitability of roadways and paths for bicycle travel. It likely assigns scores based on factors such as pavement condition, slope, traffic volume, and intersection design to provide an overall assessment of suitability.

Bicycle Suitability Rating (BSR) (Mitman et al., 2008): BSR is a rating system designed to evaluate the overall suitability of roadways and pathways for bicycle travel. It likely incorporates various factors such as road width, speed limits, traffic volume, and bicycle-specific infrastructure to assign a suitability rating.

Interaction Hazard Score (HIS) (Landis, 1994): HIS assesses the level of interaction hazards between cyclists and other road users. It may consider factors such as road design, traffic volume, presence of bike lanes, and intersection design to quantify potential hazards and risks for cyclists.

Road Condition Index (RCI) (Epperson, 1994): RCI evaluates the condition of road surfaces and infrastructure relevant to bicycle transportation. It likely considers factors such as pavement quality, surface irregularities, potholes, and road maintenance to provide an index indicating the overall condition of roadways for cycling.

I classify the metrics into the following categories for our study as below;

1. Infrastructure
2. Regulatory environment
3. User convenience
4. Network connectivity
5. Safety & security

Under those major classification I assigned the metrics as shown in Appendix A

2.4 Developed the framework & defined the metrics for comparative analysis of bicycling performance

2.4.1 Bicycle infrastructure

a) Length of bicycle network

The length of a bicycle network within a city is influenced by several factors, including the city's population, its total land area, and how the land is utilized. Therefore, comparing cities purely based on their bicycle network length does not provide an effective measure of their bicycling infrastructure or its accessibility to the population. To address this issue, I propose comparing cities based on the bicycle network length per unit area, as well as considering the city's population in relation to the density of the bicycle network. The formulas below are designed to calculate the bicycle network density and the population density index in relation to the bicycle network, offering a more nuanced approach to evaluating and comparing bicycle infrastructure across cities.

Bicycle Network Density (BND)
The Bicycle Network Density (BND) is calculated by dividing the total length of the bicycle network by the total land area of the city. This metric provides insight into how extensively the bicycle network covers the city, regardless of its overall size. The formula for BND is as follows:

BND =Total Bicycle Network Length (km)/ Total Land Area (km2)

Population Density Index Relative to Bicycle Network (PDBN)
The Population Density Index Relative to Bicycle Network (PDBN) considers the population density in relation to the bicycle network's density. This metric helps to understand how well the bicycle network serves the city's population. The formula for PDBN is:

PDBN = Population Density / Bicycle Network Density
By applying these metrics, we can conduct a more comprehensive comparison of bicycle infrastructure across different cities, taking into account both the coverage of the bicycle network and its capacity to serve the population effectively. This method allows for a more equitable comparison and can help identify areas for improvement in urban bicycle infrastructure planning and development.

b) Type of lane & performance

Cities feature a variety of lane types, each performing uniquely based on a range of factors. Through comprehensive analysis and case studies, it has been identified that the performance of bicycle lanes, in particular, is significantly influenced by several key factors. These include Physical Separation, Buffer Zones, Connectivity, Maintenance and Condition, as well as Comfort and Convenience. These factors collectively define the Bicycle Lane Performance (BLP), making it possible to assess and compare the effectiveness of bicycle lanes in enhancing urban mobility and safety.

Bicycle Lane Performance (BLP) Determinants

Physical Separation: Refers to the extent to which bicycle lanes are physically separated from motor vehicle traffic. This separation can significantly impact the safety and perceived safety of cyclists, encouraging more people to choose cycling as a mode of transportation.

Buffer Zones: These are spaces allocated between bicycle lanes and vehicular lanes or parking spaces. Buffer zones provide an additional layer of safety, reducing the risk of collisions with opening car doors or encroaching vehicles.

Connectivity: Measures how well the bicycle lane network connects different parts of the city, facilitating efficient and direct travel by bike. High connectivity in bicycle networks ensures that cyclists can reach a wide range of destinations without significant detours or interruptions.

Maintenance and Condition: The regular upkeep and the overall condition of the bicycle lanes are crucial for cyclist safety and comfort. This includes timely repairs, clear signage, and the removal of hazards such as debris and snow.

Comfort and Convenience: Encompasses factors such as the smoothness of the lane surface, availability of bike parking, lighting, and the directness of routes. These aspects contribute to a more pleasant cycling experience, potentially increasing the usage of bicycle lanes.

The Bicycle Lane Performance (BLP) can be expressed as a function of these determinants:

Function of (Physical Separation, Buffer Zones, Connectivity, Maintenance and Condition, Comfort and Convenience)

c) Bicycle traffic signal & crossing

Urban traffic signal systems are traditionally designed with motorized traffic in mind. However, to create more inclusive and safer urban environments, it's imperative that the design and operation of these systems also cater to the needs of pedestrians and cyclists. Certain types of traffic signals and crossings are known to significantly enhance the safety and efficiency of bicycle travel. Based on extensive research and case studies, several key factors have been identified that influence the performance of traffic signals for cyclists. These include Signal Visibility, Signal Timing for Cyclists, Separate Bicycle Signals, Type of Conflict Points, and User Awareness and Education. Addressing these factors leads to the concept of ***Traffic Signal***

Performance for Cyclists (TSPC), a performance-based measure aimed at evaluating and improving traffic signal systems for the benefit of cyclist safety and mobility.

Key Factors Influencing TSPC

Signal Visibility: Ensures that traffic signals are easily visible to cyclists, reducing the risk of accidents due to missed signals. This can involve the placement of signals at cyclist eye-level or the use of brighter, more conspicuous signalling devices.

Signal Timing for Cyclists: Refers to the adjustment of signal phases to accommodate the average speed and acceleration capabilities of cyclists, minimizing wait times and reducing the temptation to cross against the signal.

Separate Bicycle Signals: The use of dedicated bicycle signals can significantly enhance cyclist safety by providing clear, specific instructions, thereby reducing conflicts with motorized vehicles and pedestrians.

Type of Conflict Points: Identifies areas where cyclists' paths cross with other traffic, necessitating careful signal timing and phasing to minimize the risk of collisions. This includes intersections, vehicle turning points, and busy pedestrian crossings.

User Awareness and Education: Promotes the importance of signal compliance among cyclists and other road users. Educational campaigns can help improve understanding of signalized intersections and reduce accidents.

The Traffic Signal Performance for Cyclists (TSPC) can be evaluated by examining how well traffic signals incorporate these factors:

TSPC=f {Signal Visibility, Signal Timing for Cyclists, Separate Bicycle Signals, Type of Conflict Points, User Awareness and Education}

d) Intersection improvement/ facilities for cyclist

Ensuring efficient traffic flow and creating safer environments are primary goals when signalizing intersections. However, to encourage greater cyclist usage and prioritize their safety, additional considerations and facilities are necessary at these intersections. By analysing the performance of these facilities, we can determine their effectiveness in meeting the needs of cyclists. Extensive literature studies have highlighted several key criteria from the cyclist's perspective when assessing intersection performance. These include Intersection Visibility, Predictability, Intersection Conflict Points, Intersection Maintenance, and Emergency Access. By addressing these factors, we can establish performance-based metrics known as ***Intersection Performance for Cyclists (IPC).***

Key Criteria Influencing IPC

Intersection Visibility: The degree to which cyclists can clearly see and be seen by other road users at the intersection. Improved visibility reduces the likelihood of accidents and increases cyclist confidence.

Predictability: Refers to the consistency and reliability of traffic patterns and signals at the intersection. Predictable intersections enable cyclists to anticipate and react to traffic movements safely.

Intersection Conflict Points: Identifies areas within the intersection where conflicts between cyclists, vehicles, and pedestrians are likely to occur. Minimizing these points reduces the risk of collisions and enhances overall safety.

Intersection Maintenance: Ensures that the intersection infrastructure, including road surfaces, signage, and markings, is well-maintained to provide a smooth and safe riding experience for cyclists.

Emergency Access: Addresses the accessibility of emergency services to the intersection. Clear pathways and adequate space for emergency vehicles ensure timely response to incidents, enhancing overall safety for all road users.

IPC=f {Intersection Visibility, Predictability, Intersection Conflict Points, Intersection Maintenance, Emergency Access}

e) Parking facilities for cyclist

Bicycle parking plays a crucial role in the infrastructure of a bicycle network, providing users with organized and secure facilities to park their bicycles. The availability and quality of bicycle parking can significantly influence user behaviour, especially at transportation intersections, mode-changing points, recreational areas, and residential areas. To analyse the performance of bicycle parking facilities, several key factors have been identified, including Accessibility, Security, and Design of bicycle parking, Technology and user-friendliness, and Maintenance.

Key Factors Influencing ***Bicycle Parking Performance (BPP)***
Accessibility: Refers to the ease of reaching and using bicycle parking facilities. Conveniently located parking encourages cyclists to use bicycles as a mode of transportation.

Security: Encompasses measures to prevent theft and vandalism of bicycles. Secure parking facilities instil confidence in users and reduce the risk of bike-related incidents.

Design of Bicycle Parking: Includes the layout and infrastructure of the parking facilities. Well-designed parking spaces optimize space usage and ensure the safety of parked bicycles.

Technology and User-Friendliness: Incorporates features such as electronic access systems, bike-sharing programs, and user-friendly interfaces. These technologies enhance the user experience and promote the use of bicycle parking facilities.

Maintenance: Addresses the regular upkeep and cleanliness of the parking facilities. Proper maintenance ensures that the facilities remain functional, safe, and aesthetically pleasing to users.

The Bicycle Parking Performance (BPP) is determined through a multi-criteria analysis, considering the above factors. By evaluating the performance of bicycle parking facilities based on these criteria, we can establish a comprehensive understanding of their effectiveness and user satisfaction.

BPP=f {Accessibility, Security, Design of Bicycle Parking, Technology and User-Friendliness, Maintenance}

f) Shear bicycle program

In cities where micro-mobility is promoted, the shared bicycle program stands out as a key feature, facilitating journeys that can start and end anywhere within the network. This program enables individuals who do not own bicycles to enjoy regular usage, thereby promoting sustainable transportation options. Through extensive literature studies, several critical factors have been identified as pivotal to the performance of shared bicycle systems. These factors include Availability and Coverage, User-Friendly and Comfortable Bicycle Design, Technology and Mobile Application Integration, Maintenance, and Integration with Public Transport. Building upon these findings, we have established metrics for assessing the performance of shared bicycle systems, referred to as Share Bicycle Performance (SBP). SBP is a function of the aforementioned factors and is evaluated through a multi-criteria analysis method.
Key Factors Influencing ***Share Bicycle Performance (SBP)***

Availability and Coverage: The extent to which shared bicycles are accessible throughout the city and the comprehensiveness of the network coverage. High availability and extensive coverage enhance the convenience and attractiveness of the shared bicycle program.

User-Friendly and Comfortable Bicycle Design: Encompasses the design features of the bicycles, ensuring they are easy to use, comfortable to ride, and suitable for a wide range of users, including novice cyclists.

Technology and Mobile Application Integration: Refers to the integration of technology, such as mobile applications, for bike rental, payment, and navigation. Seamless integration enhances user experience and accessibility.

Maintenance: Addresses the regular upkeep and servicing of shared bicycles to ensure they remain in good working condition. Proper maintenance is essential for user safety and satisfaction.

Integration with Public Transport: Examines the ease of integrating shared bicycles with existing public transportation networks, allowing for convenient multimodal journeys. Effective integration encourages more people to use shared bicycles as part of their daily commute.

The Share Bicycle Performance (SBP) is evaluated using a multi-criteria analysis method, taking into account the aforementioned factors. By assessing shared bicycle systems based on these criteria, planners and operators can gain insights into their performance and identify areas for improvement.

SBP=f {Availability and Coverage, User-Friendly and Comfortable Bicycle Design, Technology and Mobile Application Integration, Maintenance, Integration with Public Transport}

Share Bicycle Penetration Rate (SBPR)

The Share Bicycle Penetration Rate (SBPR) is a metric that gauges the level of adoption of the share bicycle system within a population. It is calculated by dividing the number of bike share users by the total potential user population and then multiplying by 100 to express it as a percentage. This metric provides insights into the extent to which the share bicycle system has penetrated the target market and is being utilized by the population.

SBPR= (Number of Bike Share Users/Total Potential User Population) ×100

Share Bicycle Revenue (SBR)

The Share Bicycle Revenue (SBR) metric measures the total revenue generated by the share bicycle system over a specific period, typically on a yearly basis. It includes income from user fees, subscriptions, advertising, sponsorships, and any other sources related to the operation of the share bicycle program. SBR provides valuable financial data that reflects the economic viability and performance of the share bicycle system.

Share Bicycle Revenue Growth (SBRG)

Share Bicycle Revenue Growth (SBRG) quantifies the rate of revenue expansion within the share bicycle system over a certain period, usually annually. It compares the revenue generated in the current year to that of the previous year, indicating the system's growth trajectory. SBRG offers insights into the financial sustainability and market acceptance of the share bicycle program over time.

Share Bicycle Expected User Ratio (SBER)

The Share Bicycle Expected User Ratio (SBER) predicts the proportion of the population expected to use the share bicycle system based on population forecasts. It is calculated by dividing the expected number of users by the forecasted population and then multiplying by 100 to express it as a percentage. SBER helps in estimating the potential reach and impact of the share bicycle program within the community.

SBER = (Expected Users/ Population Forecast) ×100

By utilizing these metrics, cities and operators can gain valuable insights into the adoption, financial performance, growth trajectory, and projected user base of the share bicycle system. These metrics aid in strategic planning, decision-making, and optimization efforts aimed at enhancing the effectiveness and sustainability of the share bicycle program within urban environments.

2.4.2 Regulatory environment

a) Traffic laws and regulations

In the realm of transportation planning, government agencies and authorities establish a series of regulations and standards aimed at ensuring the safety and efficiency of cyclist infrastructure and operations. These regulations encompass various aspects, including lane width, speed limits, curve radius, and equipment requirements such as bells, reflectors, and lights. Additionally, regulations may address passing rules, group riding protocols, and personal protective equipment standards. While many of these regulations are broad in scope, they play a critical role in fostering safe cycling environments and may also impact competitive cycling events.

For our study, we have devised a set of metrics based on traffic regulations to facilitate comparisons across cities:

Bicycle Lane Width Requirement (BLWR): This metric evaluates the width of cyclist lanes, considering both one-way and two-way paths. It assesses the adequacy of lane width to accommodate safe and comfortable cycling, taking into account factors such as passing clearance and user comfort.

Bicycle Design Speed (BDS)**:** Cities develop a design speed tailored to accommodate cyclists based on road and traffic engineering criteria. This metric evaluates the intended speed range at which cyclists can safely navigate designated lanes and paths.

Bicycle Recommended Speed (BRS): Government authorities set speed limits specific to bicycle users to ensure safe operation within urban environments. This metric reflects the maximum speed deemed safe for cyclists to adhere to while navigating designated areas.

Bicycle Turning Radius (BTR): Turing radius standards are established based on factors such as speed and road conditions. This metric assesses the minimum turning radius requirements for cyclists, ensuring safe and efficient manoeuvrability at intersections and bends.

Bicycle Stopping Sight Distances (BSSD): This metric denotes the minimum distance required for cyclists to stop safely and avoid collisions under average speed conditions. It accounts for factors such as reaction time and braking distance, ensuring adequate stopping capability in various scenarios.

b) Land use regulations

Government agencies play a crucial role in establishing minimum land use regulations pertaining to bicycle parking allocation, which are often contingent upon factors such as building type and area. To facilitate meaningful comparisons across different locales, we have formulated a set of metrics that delineate bicycle parking requirements based on specific contexts:

Bicycle parking regulation requirement (BPRR): this metrics can measure in several way depend on the nature of the parking facility requirement.

First this metric defines the unit requirement for bicycle parking allocation in residential areas. It outlines the minimum number of parking spaces per residential unit to ensure adequate provision for residents who utilize bicycles for transportation.

In shops parking specifies the number of parking spaces required for shops based on their size and customer traffic. This metric ensures that retail establishments accommodate the parking needs of patrons who arrive by bicycle. Measures the bicycle parking requirement per 1000 square meters of commercial space. It sets forth guidelines to ensure that commercial areas provide sufficient bicycle parking facilities to serve employees, visitors, and customers.

The bicycle parking requirement per 1000 square meters of industrial space. It ensures that industrial facilities accommodate the parking needs of employees and visitors who choose cycling as their mode of transportation.

Bicycle Parking in Recreational Places (BPRP): BPRP specifies the number of parking spaces required in recreational areas such as parks, sports facilities, and entertainment venues. This metric aims to support individuals who cycle to recreational destinations and encourages the adoption of active lifestyles.

When evaluating mixed land use development, it's essential to consider a range of factors that contribute to its overall performance and suitability for cyclists and pedestrians alike. Drawing from extensive literature studies, several key criteria emerge as crucial for conducting a multi-criteria analysis of mixed land use developments:

Cyclist Friendly: This criterion assesses the extent to which mixed land use developments prioritize and accommodate cyclists. It encompasses features such as dedicated bicycle lanes, secure parking facilities, and cyclist-friendly infrastructure like bike repair stations and showers.

Transportation Options: Evaluates the availability and accessibility of various transportation modes within the mixed land use development. This includes public transit options, pedestrian pathways, bike-sharing programs, and connections to major transportation hubs.

Public Space and Plaza: Considers the quality and functionality of public spaces within the development, including parks, plazas, and recreational areas. These spaces provide opportunities for social interaction, relaxation, and community engagement, enhancing the overall liveability of the area.

Proximity to Amenities: Examines the proximity of essential amenities such as grocery stores, schools, healthcare facilities, restaurants, and cultural venues. Access to these amenities within walking or cycling distance promotes convenience and reduces reliance on motorized transportation.

Diverse Land Use: Considers the diversity of land uses integrated into the development, including residential, commercial, recreational, and cultural spaces. A diverse mix of land uses fosters vibrancy, encourages economic activity, and promotes a sense of place and identity within the community.

The ***Performance of Mixed Land Use (PMLU)*** can be conceptualized as a function of these key criteria:

Performance of Mixed Land Use=f (Cyclist Friendly, Transportation Options, Public Space and Plaza, Proximity to Amenities, Diverse Land Use)

c) City transportation planning

In developed cities, the railway network serves as a primary mode of transportation, but there is also a growing emphasis on promoting bicycle usage as a complementary means of transportation. Bicycles are often utilized for the first and last mile of a journey, allowing users to reach railway stations efficiently and sustainably. To assess the integration and accessibility of bicycle infrastructure with the railway network, two key metrics have been identified:

Bicycle Network Length per Number of Railway Stations (BLPNR): This metric evaluates the density of bicycle infrastructure in relation to the number of railway stations within a city or region. A higher BLPNR value indicates a greater provision of bicycle infrastructure relative to the number of railway stations, potentially enhancing connectivity and accessibility for cyclists using the railway network.

Bicycle Network Length per Number of Railway Stations (BLPNR) = Length of bicycle lane/ no of Railway stations

Bicycle Length per Length of Railway Network (BLPRL): BLPRL measures the extent of bicycle infrastructure in proportion to the length of the railway network. It quantifies the coverage and distribution of bicycle infrastructure relative to the railway infrastructure, providing insights into the level of bicycle accessibility and connectivity within the transportation network.

Bicycle Length per Length of Railway Network (BLPRL) = Length of bicycle lanes/ Railway length

Indeed, when assessing transportation systems, additional metrics can provide deeper insights into the usage patterns and preferences of the population. In addition to evaluating the integration between railway and bicycle networks, it's valuable to consider the proportion of the population utilizing each mode of transportation. Two metrics, namely ***Railway Population Percentage (RPP)*** and ***Bicycle Population Percentage (BPP)***, offer a comprehensive understanding of transportation usage within a given area:

Railway Population Percentage (RPP): RPP measures the percentage of the total population that utilizes railway transportation as their primary mode of travel. This metric reflects the reliance on the railway network for commuting, long-distance travel, and other transportation needs. A higher RPP indicates a greater level of dependence on railway infrastructure within the population.

Bicycle Population Percentage (BPP): BPP quantifies the percentage of the total population that uses bicycles as a primary mode of transportation. It reflects the prevalence of cycling as a sustainable and efficient means of travel, particularly for short distances, urban commutes, and recreational purposes. A higher BPP suggests a greater adoption of cycling culture and infrastructure within the community.

d) Funding mechanisms

In many jurisdictions, government regulations play a significant role in controlling rental bicycle fees, with the aim of promoting bicycle usage as a viable and affordable mode of transportation. Affordable rental fees encourage greater adoption of bicycles as a means of travel, particularly for short-distance trips and daily commuting.

Various bicycle providers offer rental services with different pricing structures, including minimum rates for single rides and subscription packages for longer durations. To assess the affordability and accessibility of rental bicycles, two key metrics are commonly considered:

Share Bike Single Ride Fee (SBSRF): This metric represents the minimum fee charged for a single 30-minute ride on a rental bicycle. It provides insight into the cost-effectiveness of using rental bicycles for short-term trips, such as quick commutes or errands within the city.

Share Bike Monthly Subscription Fee (SBMSF): SBMSF refers to the monthly subscription fee for unlimited rides within a specified period, typically 30 days. This metric evaluates the affordability and value proposition of long-term rental plans, which may appeal to regular commuters and frequent users of rental bicycles.

Taxation policies imposed by governments significantly impact the operations and investments of bicycle providers, particularly those offering shared bicycle services. Low tax rates incentivize share bicycle companies to invest more in infrastructure and expand their services, thus promoting the use of bicycles as a sustainable mode of transportation. However, tax rates vary among countries, with some implementing reduced rates for share bicycle investors, while others maintain tax rates equivalent to their corporate tax rates.

To assess the taxation burden on share bicycle providers and facilitate comparisons across countries, the ***Tax for Share Bicycle Providers (TSBP)*** metric is introduced. TSBP represents the percentage of taxes imposed on share bicycle companies relative to their revenue or profits. This metric enables stakeholders to evaluate the tax environment and its impact on the share bicycle industry's growth and viability in different jurisdictions.

e) public engagement

Government regulations and actions play a pivotal role in promoting bicycle usage and fostering opportunities to enhance public engagement in cycling initiatives. Extensive literature studies have identified several key criteria crucial for analysing the performance of public engagement efforts in promoting bicycling:

Language Consideration: Ensuring that communication materials and engagement initiatives are accessible and comprehensible across diverse linguistic backgrounds. Language considerations enable effective outreach to multicultural communities, breaking down language barriers and facilitating inclusive participation.

Cultural Sensitivity: Recognizing and respecting cultural differences and norms when designing engagement strategies and campaigns. Culturally sensitive approaches foster trust, understanding, and resonance within diverse communities, encouraging greater participation and support for bicycling initiatives.

Feedback Mechanism: Establishing mechanisms for collecting, analysing, and responding to feedback from cyclists and the broader community. Feedback channels enable continuous improvement, transparency, and accountability in addressing concerns, soliciting suggestions, and gauging public sentiment towards bicycling programs and infrastructure.

Education Campaigns: Implementing targeted education and awareness campaigns to promote safe cycling practices, etiquette, and the benefits of bicycling for individuals and communities. Education initiatives empower cyclists with knowledge and skills to navigate roadways safely, fostering a culture of respect and responsibility among all road users.

Cyclist Events: Organizing and supporting cyclist events, such as group rides, races, workshops, and community gatherings. Cyclist events serve as platforms for networking, socializing, and advocating for bicycling interests, fostering a sense of belonging and camaraderie within the cycling community.

The ***Engagement Performance for Bicycling (EPB)*** metric is formulated as a function of these key criteria. By evaluating public engagement efforts based on language consideration, cultural sensitivity, feedback mechanisms, education campaigns, and cyclist events, policymakers and stakeholders can assess the effectiveness and inclusivity of bicycling promotion initiatives.

Engagement Performance for Bicycling= f {language consideration, cultural sensitivity, feedback mechanisms, education campaigns, and cyclist events}

f) Enforcement

In cities aiming to create safe environments for bicyclists, pedestrians, and other road users, the enforcement of relevant laws and regulations is paramount. Effective enforcement ensures compliance with traffic laws, minimizes conflicts, and enhances overall safety. Extensive literature studies have identified several critical criteria suitable for measuring the outcome of government enforcement efforts in regulating bicycle rides and other vehicles. These criteria include:

Incident Report Rate: The frequency of reported incidents involving bicycles and other vehicles. Incident reports provide insights into areas of concern, potential hazards, and patterns of behaviour that require attention from law enforcement agencies.

Compliance Rate: The degree to which bicyclists and other road users adhere to traffic laws and regulations. A high compliance rate indicates successful enforcement efforts and a culture of respect for traffic rules, contributing to safer roadways.

Helmet Usage Rate: The proportion of bicyclists observed wearing helmets while riding. Helmet usage is a critical safety measure that can mitigate the severity of head injuries in the event of accidents, and monitoring helmet usage rates provides valuable data on safety awareness and enforcement effectiveness.

Repeated Offense Rate: The frequency of repeated violations committed by bicyclists and other road users. Tracking repeated offenses helps identify persistent offenders and highlights areas where enforcement efforts may need to be intensified or targeted education and intervention programs implemented.

Response Time for Violations: The time taken by law enforcement agencies to respond to reported violations or incidents involving bicycles and other vehicles. Prompt response times enable timely intervention, enforcement action, and resolution of safety concerns on the roads.

The ***Bicycle Regulation Enforcement Performance (BREP)*** metric is formulated as a function of these critical criteria. By evaluating enforcement outcomes based on incident report rates, compliance rates, helmet usage rates, repeated offense rates, and response times for violations, policymakers and law enforcement agencies can assess the effectiveness and impact of regulatory enforcement efforts

2.4.3 User convenience

a) Information technology

In ensuring the convenience and safety of bicyclists, the provision of relevant information through various channels is crucial. Bicyclists rely on accurate and accessible information to navigate routes, identify hazards, and make informed decisions during their rides. Considering these factors, metrics have been established to assess the performance of key criteria:

Evaluates the effectiveness of road signage: designed specifically to guide and inform bicyclists along their routes. This metric assesses factors such as visibility, clarity, and placement of signage to ensure that bicyclists can easily interpret and follow directions while riding.

Measures the functionality and usability of mobile applications: designed to assist bicyclists in planning and navigating their rides. This metric considers factors such as user interface, real-time updates, route customization options, and integration with other features like bike-sharing services or route tracking.

Evaluates the accuracy and reliability of live location updates provided to bicyclists during their rides: This metric assesses the responsiveness of location tracking systems, the frequency of updates, and the precision of location data to ensure that bicyclists can accurately monitor their positions and receive timely information about potential hazards or alternative routes.
Base on those studies set the metrics ***performance of information technology for bicyclist (PITB)***

b) Amenities for cyclist

Ensuring the availability and quality of amenities is essential for enhancing the cycling experience and promoting the adoption of bicycling as a mode of transportation. Considerable factors such as water points, rest areas, shelters, and repair stations contribute significantly to the convenience, comfort, and safety of bicyclists during their journeys. To evaluate the performance of these amenities, a comprehensive metric called ***Performance of Amenities for Bicyclists (PAB)*** is established.

PAB encompasses the following key aspects:

Water Points: The accessibility and availability of water points along cycling routes are essential for bicyclists, especially during long rides or in hot weather conditions. PAB evaluates the distribution and functionality of water points, ensuring that bicyclists have access to clean and potable water for hydration.

Rest Areas: Rest areas provide bicyclists with opportunities to take breaks, relax, and rejuvenate during their rides. PAB assesses the presence of well-designed and strategically located rest areas equipped with seating, shade, and facilities like restrooms or picnic areas to enhance the overall comfort and convenience of bicyclists.

Shelters: Shelters offer protection from inclement weather conditions, including rain, wind, and extreme temperatures. PAB evaluates the availability and quality of shelters along cycling routes, ensuring that bicyclists have access to adequate shelter when needed, thereby promoting safety and comfort during their rides.

Repair Stations: Repair stations equipped with tools and equipment for basic bicycle repairs and maintenance are valuable assets for bicyclists, providing assistance in case of mechanical issues or emergencies. PAB measures the accessibility and functionality of repair stations, ensuring that bicyclists can easily access the tools and resources necessary to address minor repairs and keep their bicycles in optimal condition.

c. Accessibility

Enhancing user convenience and accessibility from a cyclist's perspective involves addressing various factors to ensure seamless and efficient travel experiences. Key considerations include the presence of ramps for overhead bridge crossings, lift facilities for vertical mobility, distances between parking areas and connecting transport modes or other destinations, and overall accessibility within public spaces. To comprehensively evaluate and improve accessibility for bicyclists, a metric called the ***Performance of Accessibility for Bicyclists*** **(PAFB)** is established.

PAFB encompasses the following essential components:

Ramps for Overhead Bridge Crossings: Bicyclists often encounter overhead bridge crossings along their routes, and the presence of ramps facilitates smooth and safe passage. PAB assesses the availability and usability of ramps, ensuring that bicyclists can easily traverse overhead crossings without encountering barriers or obstacles.

Lift Facilities for Vertical Mobility: In urban environments with multi-level infrastructure, lift facilities provide bicyclists with vertical mobility options, particularly in the case of elevated pathways or structures. PAB evaluates the availability, reliability, and accessibility of lift facilities, ensuring that bicyclists can navigate vertical transitions with ease and convenience.

2.4.4 Network connectivity

a) Comprehensives network coverage

Creating a comprehensive network connectivity for bicycles involves ensuring that the bicycle infrastructure effectively connects key destinations such as schools, employment centers, and shopping centers. Evaluating the coverage and performance of this network requires a multifaceted approach that considers factors such as mapping, route evaluation, and analysis of traffic patterns. However, in your study, which covers a larger scale, a metrics evaluation method called ***Evaluation of Comprehensive Network Coverage (ECNC)*** is proposed. This evaluation method relies on user feedback to assess the performance and convenience of the network.

The ECNC evaluation method encompasses the following key element;

Soliciting feedback from bicyclists and other stakeholders: who utilize the network is crucial for understanding their experiences, challenges, and preferences. User feedback provides valuable insights into the effectiveness of the bicycle network in connecting various destinations and meeting the needs of different user groups.

b) Interconnectivity with other modes of transportation

Integrating the bicycle network with other modes of transportation, such as public transit, is essential for providing users with seamless and convenient options for long-distance travel. To measure the effectiveness of this integration and assess the performance of bicycle interconnectivity, a set of measurable metrics called ***Performance of Bicycle Interconnectivity (PBI)*** is proposed. Drawing from literature studies, PBI is influenced by several key factors:

Transportation Connectivity Hub: The presence of transportation connectivity hubs, such as transit stations or intermodal terminals, enhances the accessibility and convenience of bicycle-train or bicycle-bus transfers. PBI evaluates the availability and functionality of these hubs in facilitating smooth transitions between different modes of transportation.

Average Last Mile Connected to Major Transportation Mode: Assessing the average distance between bicycle network endpoints and major transportation hubs provides insights into the accessibility and efficiency of last-mile connections. PBI considers the proximity of bicycle routes to transit stations or bus stops, minimizing travel times and enhancing user convenience.

Parking Facilities: Adequate and secure bicycle parking facilities at transportation hubs encourage bicycle usage and provide users with a convenient option for storing their bicycles while utilizing other modes of transportation. PBI evaluates the availability, capacity, and accessibility of bicycle parking infrastructure at transit stations and intermodal hubs.

Share Bike System in Interconnectivity Locations: The availability of bike-sharing systems at transportation hubs further enhances the accessibility and flexibility of bicycle interconnectivity. PBI assesses the integration of bike-sharing services with public transit networks, promoting seamless transitions and multi-modal travel options for users.

Multi-Model Ticketing: The availability of integrated fare systems or multi-modal ticketing options simplifies the process of planning and paying for multi-modal journeys involving bicycles and other modes of transportation. PBI considers the impact of multi-model ticketing solutions on user convenience and adoption of intermodal travel.

Performance of Bicycle Interconnectivity (PBI) = f {Transportation Connectivity Hub, Average Last Mile Connected to Major Transportation Mode, Parking Facilities, Share Bike System in Interconnectivity Locations, Multi-Model Ticketing}

c) Consistent infrastructure standards

Maintenance plays a crucial role in ensuring the consistency and quality of bicycle infrastructure, which directly impacts network connectivity standards. Consistency with design guidelines and specifications is essential for providing cyclists with safe and reliable infrastructure. Key aspects such as lane width, surface quality, intersection designs, colour coding, maintenance conditions, and coordination with other infrastructure elements contribute to the overall performance of bicycle infrastructure standards. To measure the effectiveness of these standards, a set of metrics called ***Performance of Infrastructure Standards (PIS)*** is proposed.

d) Strategic route planning

To ensure that the bicycle network effectively serves users and encourages cycling as a mode of transportation, strategic planning is essential. This planning involves designing routes that are direct, convenient, and accessible, while also considering factors such as terrain and barriers that may impact user experience. A key metric for assessing the effectiveness of ***bicycle network planning and connectivity is Bicycle Network Density (BND)***.

Analysing the actual performance of strategic route plans provides more accurate and actionable insights into the effectiveness of bicycle network infrastructure. To measure this performance comprehensively, a set of metrics termed ***Performance of Strategic Route Plan (PSRP)*** is proposed. PSRP incorporates various factors essential for evaluating the functionality and impact of strategic route planning efforts.

The components of the Performance of Strategic Route Plan (PSRP) if functions of Network Connectivity with Residences, Integration of Recreational Routes, Policy Support for Strategic Planning, Technology Support.

By integrating these components, the Performance of Strategic Route Plan (PSRP) provides a comprehensive framework for evaluating the effectiveness and impact of bicycle network planning efforts.

e) Connectivity to adjacent neighbourhoods and communities

Ensuring that bicycle networks effectively connect adjacent neighborhoods and communities is essential for promoting accessibility, equity, and social cohesion. To measure the ***performance of connectivity to neighborhoods and communities (PCNC),*** a comprehensive set of metrics is established. PCNC encompasses various factors that contribute to the effectiveness and inclusivity of bicycle network connectivity. Neighbourhood Network Connectivity, Interconnected Routes, and Equitable Distribution are considerable.

2.4.5 Safety & security

a) Separation from motor vehicle traffic

Analysing the performance of separation between bicycles and motor vehicles involves assessing the effectiveness of physical barriers and safety measures implemented to ensure the safety and comfort of cyclists. To measure this performance, a set of metrics known as the ***Performance of Separation of Bicycles (PSB)*** is proposed.

b) Intersection safety

Ensuring intersection safety for bicyclists is crucial for promoting their confidence and security while navigating urban environments. The effectiveness of intersection design elements such as protected intersections, signal designs, advance stop lines or bicycle boxes, and clear signage and markings significantly influences bicyclist safety. To establish metrics for measuring the performance of intersection safety, a comprehensive approach is necessary.

Performance of intersection safety (PIS) if the functions of protected intersections, signal designs, advance stop lines or bicycle boxes, and clear signage and markings.

c) Conflict points

Addressing conflict points in interaction areas and enhancing visibility and technology to reduce conflicts are significant safety improvements for cyclists. To establish metrics for measuring the ***performance of conflict reduction (PCR).***

By integrating these components, the Performance of Conflict Reduction (PCR) metrics provide a comprehensive framework for evaluating the effectiveness of safety improvements aimed at reducing conflicts between cyclists and other road users.

e) Traffic calming measures

Creating a safe environment for cyclists involves implementing traffic calming measures such as speed humps, roundabouts, or traffic circles to reduce vehicle speeds and enhance overall safety. These measures significantly improve cyclist safety by reducing the risk of high-speed collisions and creating a more conducive environment for cycling. To establish metrics for measuring the ***performance of traffic calming measures (PTCM)*** and comparing cities, a comprehensive approach is necessary.

By integrating these components, the Performance of Traffic Calming Measures (PTCM) metrics offer a comprehensive framework for evaluating the effectiveness of traffic calming interventions in improving cyclist safety. Summary of the metrics for our study shows in Appendix B.

2.5 Colombo Present Bicycle mode transportation issues

Colombo, the dynamic capital of Sri Lanka, boasts a district area sprawling over 699 square kilometres, with the bustling city core occupying a mere 38 square kilometres. Despite its relatively compact size, the urban landscape of Colombo is marked by dense population clusters and notoriously congested streets. Within this bustling metropolis, the bicycle network within the Colombo district grapples with inefficiencies and a host of associated challenges.

In Colombo, several studies have been conducted to evaluate and promote bicycle mobility. These studies highlight the potential for bicycles to become a sustainable mode of transportation in Sri Lanka. However, the implementation of their recommendations remains limited. Below is a review of the key studies and their findings, along with the challenges in implementing bicycle-friendly infrastructure.

Integration of Bicycle Networks with Highways: S.T. Salawavidana (2014) conducted a comprehensive study focusing on the integration of bicycle networks with highways. The research aimed to address the challenges of incorporating cycling infrastructure into existing road systems, proposing a set of guidelines for effective implementation. These guidelines included recommendations for various types of bicycle lanes, treatments at intersections to ensure cyclist safety, and specific measures to mitigate risks such as crashes caused by car door openings. The study also emphasized the importance of determining appropriate lane widths and providing additional facilities to enhance the overall cycling experience. However, despite the detailed nature of these recommendations, their implementation in the study areas has been partial at best. Compared to internationally recognized bicycle-friendly cities, Sri Lanka's approach lacks the robust methodologies and strategies required to establish optimal lane widths and ensure infrastructure quality. The study highlights the need for adopting advanced planning techniques and drawing lessons from global best practices to bridge this gap. Ensuring the integration of these guidelines into local urban planning processes could significantly improve the safety and accessibility of bicycle networks, encouraging greater adoption of cycling as a sustainable mode of transportation.

Safety for Pedestrians and Cyclists: Chamali Hewawasam (2019) conducted a detailed case study in Rathmalana West to assess the safety of road infrastructure for pedestrians and cyclists after the implementation of stormwater drainage improvements. The study involved comprehensive mapping of road widths, pathways, and intersections to evaluate their suitability for non-motorized transport users. It emphasized that promoting walking and cycling requires seamless integration with public transportation, as such infrastructure ensures connectivity and convenience for users. Despite these findings, significant gaps remain in aligning public transport systems with cycling facilities. This disconnect has limited the effectiveness of initiatives aimed at encouraging sustainable mobility. The study highlighted the need for improved planning and collaboration among transportation authorities to create integrated networks that support multi-modal transport. Furthermore, it stressed the importance of addressing the specific needs of pedestrians and cyclists by enhancing pathway quality, intersection design, and overall connectivity. Bridging these gaps could significantly improve mobility options, safety, and user confidence, ultimately fostering a more inclusive and sustainable urban transport environment.

Bicycle Sharing Systems: Tharuka Karunarathne (2019) conducted a comprehensive study on the feasibility of implementing a bicycle-sharing system in Sri Lankan cities. This research highlighted key factors influencing such systems, including topography, climate, safety concerns, and infrastructure priorities. The study revealed that while most respondents primarily relied on public transport such as buses and trains for their daily commutes, bicycles were not used for last-mile connectivity. Instead, walking, company-provided transport, and three-wheelers dominated this segment. A critical barrier identified was the lack of parking facilities at destinations, which deterred potential users. Respondents expressed a preference for secure bicycle parking facilities at bus and railway stations, as well as workplaces, underscoring the importance of integrating parking infrastructure into the system. The study also explored the technological dimension, finding that a majority of respondents were open to using mobile applications to access and manage bicycle-sharing services. This indicates a readiness for a technology-enabled system, provided the necessary infrastructure and safety measures are in place. The findings underscore the need for holistic planning that addresses parking, safety, and technological integration to make bicycle-sharing a viable and attractive option for urban commuters in Sri Lanka.

Prioritizing Bicycle Networks: N.P. Madhumali M (2023) conducted an in-depth analysis of factors influencing the development of bicycle networks using Geographic Information Systems (GIS) combined with a participatory approach. The study identified several critical issues affecting bicycle users, including inadequate road conditions that compromise safety, insufficient lighting along cycling routes, and heightened safety risks during nighttime hours. Additionally, the research highlighted hazards such as dog attacks and wildlife crossings, which create unsafe conditions for cyclists, especially in rural or suburban areas. Another significant challenge was flooding, which not only disrupts cycling routes but also creates hazardous conditions, particularly during monsoonal periods. These findings underscore the necessity for comprehensive planning to design and implement safe, well-lit, and user-friendly bicycle networks. Addressing these issues requires a multi-faceted approach that includes improving infrastructure quality, ensuring adequate lighting, and integrating flood-resilient designs into cycling pathways. Such measures are essential to provide cyclists with a secure and comfortable riding environment, encouraging wider adoption of bicycles as a sustainable mode of transport. By prioritizing these aspects, urban planners and policymakers can overcome existing barriers and foster the growth of efficient and safe cycling infrastructure across Sri Lanka

Challenges in Newly Established Bicycle Lanes: Niranjala Dahanayaka (2018) conducted a detailed case study examining the challenges faced by cyclists on newly established bicycle lanes between Piliyandala Junction and Kospalana Bridge. The study identified several pressing issues, including motor vehicles frequently parking on bicycle lanes, which significantly reduced the available space for cyclists and compromised their safety. Additionally, motor traffic often encroached into cyclist-designated zones, creating a hazardous environment. Another critical problem was the incomplete nature of the bicycle lane network, which forced cyclists to share the road with motor vehicles for significant portions of their journeys. These conditions not only reduced the comfort and safety of cycling but also acted as a deterrent to potential users, further exacerbating the risk of accidents and undermining efforts to promote cycling as a viable mode of transportation. The findings underscore the urgent need for stricter enforcement of traffic regulations, comprehensive network planning, and infrastructural enhancements to ensure the safety and convenience of cyclists.

Broader Challenges in Bicycle Mobility Development: A significant issue is the lack of designated bicycle pathways along most of Sri Lanka's roadways, leaving cyclists to navigate shared pathways. This contributes to traffic congestion, frequent accidents, and delays for motor vehicle users (Kumarage A.S., Bandara M., and Munasinghe D., 2010). Additionally, many roads in Colombo are narrow and poorly maintained, further compromising cyclist safety.

Key city transportation authorities, including the Road Development Authority (RDA), Road Development Department (RDD), and Urban Development Authority (UDA), have failed to integrate bicycle infrastructure into the initial planning and design stages. This oversight has resulted in missed opportunities to improve connectivity and accessibility for cyclists. Alternative measures, such as congestion pricing, widely used in other cities, remain unregulated in Sri Lanka. Implementing such measures could encourage greater adoption of bicycles.

The inadequate integration of public transportation networks also hinders bicycle usage. Trains and buses often lack first and last-mile connectivity options. Furthermore, concerns about safety, rising crime rates, and a lack of secure parking facilities discourage potential users from choosing bicycles as a viable transportation mode (Kumarage A.S., Wirasinghe S.C., 1997).

While numerous studies have highlighted the potential for bicycle mobility in Sri Lanka, the lack of implementation remains a critical barrier. To promote cycling as a sustainable transport mode, the country needs to address infrastructure deficiencies, integrate cycling with public transportation, and ensure safety through well-designed bicycle networks. Additionally, fostering public awareness and regulatory measures like congestion pricing could drive the adoption of bicycles, contributing to a more sustainable urban transportation system.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

Methodology serves as the structured approach to resolving research problems. This chapter delineates the systematic process for addressing specific research inquiries, often referred to as the research problem. Methodology elucidates data collection methods, techniques, approaches for data aggregation, and research strategies. Various criteria and sources are employed in research to derive results (Industrial Research Institute, 2010). Men and Mory (2009) define research methodology as a systematized approach for generating new knowledge.

Our research employs both Quantitative and Qualitative methodologies to engage bicycle users and achieve research objectives. A case study methodology enriches our understanding of bicycle metrics.

3.2 Aim and Objectives

The research aims to identify bicycle transportation metrics in cities promoting micro-mobility, establish a scoring system, and setup the benchmark for performance requirement and comparing the metrics scoring with Sri Lankan typical city (Colombo) to identify the fall from the benchmarks.

3.3 Strategies and Approaches

Two primary strategies, quantitative and qualitative, are utilized in this research, each offering distinct data generation methods. Quantitative methodologies yield textual data and various types of measurable analyses, focusing on measurement, aggregation, predictive behaviour, and modelling. Contextual methods encompass participant observation and interviews for comprehensive population coverage.

Qualitative research emphasizes contextual understanding and furnishes qualitative insights. This approach solicits input from stakeholders, captures opinions, and allows for analytical control, providing space for stakeholders to shape the analytical framework (Mukherjee, 1995).

Qualitative and quantitative approaches offer distinct perspectives and insights. Both methodologies are informative and instrumental in gathering data, understanding research figures, and informing policy decisions.

Our research encompasses both field studies and literature reviews aimed at developing bicycle transportation metrics in cities promoting micro-mobility. The literature review draws from reports, textbooks, academic journals, and online studies. Fieldwork involves questionnaire surveys and interviews with bicycle users in selected cities worldwide. We employ various methods such as personal meetings, telephone conferences, and emails to conduct the surveys and interviews.

Summary of the data collection methods shows in Appendix C

CHAPTER 4: DATA COLLECTION

4.1 Requirement and collection of data

In any research project, a critical step is identifying the requirements and characteristics of the data that will be covered in the literature studies. This phase lays the groundwork for the entire research endeavour, as it informs the system derived from theories and the collection of data. One essential aspect involves discerning various methods of conversion, such as hypothesis testing, analysis, storing, filtering, and sorting. These methods are instrumental in extracting meaningful insights and generating a comprehensive summary of the research requirements.

In our specific research project, which aims to identify bicycle transportation metrics in cities promoting micro-mobility, the data collection process is divided into three sections. Firstly, quantitative data is gathered directly from each city, utilizing diverse analytical techniques to explore and interpret the data comprehensively. Secondly, outcomes from unstructured questions are systematically organized into a point system, streamlining the analysis process and facilitating a more structured approach to data interpretation.

Furthermore, we introduce a point system tailored to the nature of the data collected, ensuring that each question is assessed relative to its significance and impact. By applying relevant importance indices, we can effectively assign scores to each question, thereby ranking the importance of various issues and proposed solutions. This structured approach enhances the precision and efficacy of our analysis, enabling us to derive meaningful insights and make informed decisions based on the research findings.

In our research methodology, the structured questionnaire metrics are designed to encompass multiple criteria, reflecting the diverse facets of the research objectives. To effectively evaluate and quantify the metrics for each city, I do the multi-criteria analysis method. This approach allows us to systematically assess and assign scores to the various criteria considered in the questionnaire.

The multi-criteria analysis method provides a structured framework for decision-making, enabling us to weigh and prioritize different factors based on their significance and relevance to the research objectives. By considering multiple criteria simultaneously, we gain a more holistic understanding of the dynamics shaping bicycle transportation metrics in micro-mobility-promoted cities.

Through this method, we are able to objectively evaluate the performance of each city across a range of metrics, taking into account the unique contextual factors and challenges they face. This enables us to identify patterns, trends, and areas for improvement, thereby informing strategic interventions and policy recommendations aimed at enhancing the quality and efficiency of bicycle transportation systems in urban environment.

4.2 Data Presentation

4.2.1 Infrastructure

Length of bicycle network

As discussed in the literature review, it is imperative to establish the Bicycle Network Density and Population Density Index. To achieve this, we have gathered data on the Bicycle network length, Land areas, and population density of each city. The data for these two metrics are presented in the table below;

Table 3: Data of BND and PDBN

City	Length of bicycle network (Km)	Land area (Km^2)	Population density (No of people/Km^2)	Bicycle network density	Population density index
Singapore	525	728	8292	0.7211	11499.1
Aarhus	500	91.8	1080	5.4466	198.3
Madtid	354	604.3	5322	0.5858	9102.1
Bordeaux	245	49.36	4583	4.9635	923.3
Hamburg	1300	755	2367	1.7218	1374.7
Eindhovan	570	88.84	2512	6.416	391.9
Gothenburg	880	450	1252	1.9555	640.2
Tokyo	2900	2194	6158	1.3218	4658.8
Oslo	470	454	1270	1.0352	1226.8
Oakland	155	202.4	2812	0.7658	3671.9

Type of bicycle lane

In the literature review, various types of bicycle lanes have been identified, each serving similar functions but distinguished by different names. The following list and table illustrate the types of bicycle lanes. However, their effectiveness may vary depending on specific criteria.

1. On road bicycle lane: bicycle shared the pathway with moto traffic
2. Park connectors: Which is consider the recreational method pathway include the bicycle tracks as well.
3. Designated cycling path/ Bicycle Lane: Which specified only for cyclist & allocate separate pathway in pavements

4. Bicycle Tracks: Totally separate from pedestrian walkway
5. Green Routes: Directly connect to residential place to cycling network
6. Bicycle Priority Streets/ Bike-friendly Streets: prioritize cyclists by limiting motor vehicle access or reducing speed limits
7. Segregated Bicycle Lanes: which means dedicated lanes for bicycles that are physically separated from motor vehicle traffic.
8. Buffered Bicycle Lanes: similar to segregated lanes but have additional space between the bicycle lane and the adjacent vehicle lane
9. Contraflow Bicycle Lanes: designed for cyclists traveling in the opposite direction of motor vehicle traffic on one-way streets
10. Shared Bicycle and Pedestrian Paths: Pedestrian & bicyclist shared the pathway, especially parks or recreational spaces implement that. Signage & pavement markings indicate the Shared methods.
11. Bicycle Boulevards: prioritize bicycle traffic over motor vehicle traffic.
12. Bike Lanes on Urban Roads: lanes are typically marked with painted lines and symbols to indicate from moto traffic.
13. Protected Bicycle Lanes/ Separated Bicycle Lanes: dedicated lanes for bicycles that are physically separated from motor vehicle traffic.
14. Bicycle Highways: direct efficient bicycle highway (with less intersection)
15. Red Asphalt Bicycle Lanes: red-colored asphalt bicycle lanes. The red color makes them more visible and distinguishes them from the adjacent lane.
16. Two-Way Bicycle Lanes: two-way bicycle lanes that allow cyclists to travel in both directions on a single side of the road. Signage and pavement markings to indicate the direction of travel.
17. Shared Sidewalks: bicycles are allowed to share the sidewalk with pedestrians.
18. Bicycle Streets: bicycle-friendly features, such as reduced speed limits, traffic calming measures
19. Green Lanes: which are painted green to provide a clear visual distinction from the regular roadway.
20. Shared-Use Paths: Shared-use paths are paths or trails designed for both cyclists and pedestrians.
21. Neighbourhood Greenways: traffic calming measures and reduced speeds to create a safer environment for cyclists.
22. Bike Lanes on Urban Roads: marked with painted lines and symbols to indicate their purpose and provide separation from moto traffic.

Appendix D shows the type of bicycle lane use in each city

Below factors mainly consider for each type of bicycle lanes performance

1. Physical Separation
2. Buffer Zones
3. Connectivity
4. Maintenance and Condition
5. Comfort and Convenience

From the gathered data's, refer the case studies and articles rate the factor performance of each city in below list.

Table 4: Bicycle Lane factor performance

Factor performance					
Cities	Physical Separation	Buffer Zones	Connectivity	Maintenance and Condition	Comfort and Convenience
Singapore	Moderate to High	Moderate	High	High	High
Aarhus	High	High	High	Moderate to High	High
Madtid	Moderate	Moderate	High	Moderate	Moderate
Bordeaux	High	Moderate to High	Moderate to High	High	High
Hamburg	High	High	High	High	High
Eindhovan	High	Moderate	High	High	High
Gothenburg	High	High	High	High	High
Tokyo	Moderate to High	Moderate	Moderate	Moderate to High	Moderate
Oslo	High	Moderate to High	Moderate to High	High	Moderate to High
Oakland	Moderate	Moderate	Moderate	Moderate to High	Moderate

<u>Bicycle traffic signal & crossing</u>

Study about the intersection signal and crossing signal facilities for cyclist in cities & identified different type of signals practice of each city.

1. Standard traffic signal/ Bicycle traffic signal- control the vehicle and bicycle with same signal light
2. Separate bicycle traffic signal/ Bicycle only signal: specifically design for bicycle movement control, which is separate operation from vehicle signal light.
3. Bicycle-Pedestrian Hybrid Signals: signals provide dedicated signal phases for cyclists and pedestrians.
4. Bicycle crossing signal: specified crossing signal allocate for bicyclist.

As in our literature review defined metrics influence by Signal visibility, Signal timing for cyclist, Separate bicycle signals, Type of conflict points and User awareness and educations.

Below soring taken from the unstructured Interviews;

Table 5: Bicycle traffic signal & crossing scoring

Cities	Signal visibility	Signal timing for cyclist	Separate bicycle signals	Type of conflict points	User awareness and educations
Singapore	8	7	6	7	9
Aarhus	8	9	8	8	9
Madtid	7	6	7	7	8
Bordeaux	8	7	7	7	8
Hamburg	9	8	8	8	9
Eindhovan	9	9	9	8	9
Gothenburg	8	8	8	7	9
Tokyo	8	8	7	7	8
Oslo	9	9	8	8	9
Oakland	8	7	7	7	8

<u>Intersection improvement/ facilities for cyclist</u>

From our literature review identified the type of intersections and criteria from cyclist perspective in intersection given below.

1. Bicycle boxes: painted boxes allow the cyclist to wait. Located before the moto traffic
2. Advance stop line: allow the cycles to reach the front line, that increase the visibility and reduce the conflicts
3. Bicycle turning box: similar to the bicycle box, allow the first turn before moto traffic.
4. Bicycle-Specific Signal Phases: cyclists to have a separate green light or priority in crossing the intersection
5. Protected Bicycle Intersections: physical barriers that separate cyclists from other road users at intersections
6. Roundabouts with Dedicated Cycling Infrastructure: Dedicated cycling lanes or paths around the roundabouts ensure smooth and safe cycling movements
7. Bicycle-Priority Crossings: bicycle zebra crossings or parallel crossings, provide cyclists with priority over motor vehicles at certain locations
8. Bicycle lane: dedicated bicycle separate lane for cyclist in junction zone also.
9. Green paint marking: indicate the area where cyclist can cross, create the attention for cyclist

10. Shared space and zone: vehicle, cyclist, pedestrian used for same pathway, that zone ensure the safety
11. Signage and wayfinding: provide the clear information and navigation for cyclist riding in intersection.
12. Traffic calming measures: reduce the vehicle speed to create the safe environmental for cyclist.
13. Zebra crossing: prioritize for cyclist and pedestrian
14. Roundabout art: with the attractive landscaping, ensure benefit for cyclist for visibility.
15. Sharrows: indicated for share way and encourage the driver to more aware about cyclist.

Appendix E shows the type of intersection available in each cities for cyclist

Major criteria are;

1. Intersection Visibility
2. Predictability
3. Intersection Conflict point
4. Intersection Maintenance
5. Emergency access

Get the scoring from case studies details, feedbacks and interviews given below the data;

Table 6: Intersection factor performance scoring

Cities	Intersection Visibility	Predictability	Intersection Conflict point	Intersection Maintenance	Emergency access
Singapore	8	7	7	9	7
Aarhus	9	8	8	9	8
Madtid	7	7	7	7	7
Bordeaux	8	8	7	7	7
Hamburg	8	8	8	9	9
Eindhovan	9	8	9	9	8
Gothenburg	8	7	7	7	7
Tokyo	8	7	6	7	6
Oslo	9	9	8	9	8
Oakland	8	8	7	8	7

<u>Parking facilities for cyclist</u>

Based on the articles and case studies, let's identify key considerations and types of parking prevalent in urban areas.

1. Public transportation parking: parking located at MRT interchanges, bus interchanges
2. Park connector parking: one of the types of bicyclist route is park connector. Located the parking facilities in park connector pathways.
3. Residential parking: New HBD regulation include the bicycle parking area in there plan. Most of the HBD building located the bicycle parking.
4. Commercial area parking: parking located at shopping mall, office building, and shops with advance parking system
5. Recreation area parking: bicycle parking at parks, beach area.
6. Parking in public institution: schools, universities allocate the bicycle parking for students and staffs.
7. Bike shear station: shear bicycle station popular in Denmark, which is include the parking facility in huge amount
8. Cycle street and land parking: located the parking in designated bicycle street
9. Bicycle tracks: located the parking in public transportation place, commercial places, and popular designation
10. BiciMAD bike shearing park: shear system called BiciMAD facilitated the visitors and resident park after short trip
11. V^3 Bike shear parking: shear bike provider located the parking facility across the city
12. Tram & Bus stops parking: This is the connection points with public transportation which is located the bicycle parking for users.
13. Carryout the urban development project: some bicycle parking facilities not even the city plan but urban development authorities carried out the more bicycle parking facilities.
14. StadtRAD Bike shear: there is bike shear system in Germany- Hamburg, provided the bicycle parking facilities in cites.
15. Train and bus station: This is the connection points with public transportation which is located the bicycle parking for users.
16. Bicycle friendly roads: those roads include the parking facilities too

Appendix F show the parking facilities in each cities

Additionally, we will examine the significant factors for analysing parking performance in these cities.

1. Accessibility: that is very important to encourage the bicycle users in cities, so those parking have the connection with public transportation, other public interact areas such as parks, commercial areas, schools.
2. Security: also major important factors from the user perspective. That does include the locking system, surveillance cameras.
3. Design of bicycle parking: include the layout plan, type of bicycle tracks, mechanism, and weather proofing

4. Technology and user friendly: easy identification of locations, allowable slot live information, accesses the disables and cargo transport.
5. Maintenances: Regular Maintenance, safe and efficient functions.

Taken the data from the case studies and phone call interviews;

Table 7: Parking facility performance

Cities	Accessibility	Security	Design of bicycle parking	Technology and user friendly	Maintenances
Singapore	High	High	Moderate	Moderate to High	High
Aarhus	High	High	High	Moderate to High	High
Madtid	Moderate	Moderate	High	Moderate	Moderate
Bordeaux	High	Moderate to High	Moderate to High	High	Moderate to High
Hamburg	High	High	High	High	High
Eindhovan	High	Moderate	High	High	Moderate to High
Gothenburg	High	High	High	High	Moderate to High
Tokyo	Moderate to High	Moderate	Moderate	High	Moderate
Oslo	High	Moderate to High	Moderate to High	Moderate to High	Moderate to High
Oakland	Moderate	Moderate	Moderate	Moderate to High	Moderate

Shear bicycle program

All ten cities included in our study offer a shared bicycle program. The names of the shared bicycle providers are provided in the table below. Type of share bicycle provider names show in Appendix G

As detailed below, we will describe the factors considered for performance analysis.

1. Availability & coverage
2. User-friendly and comfortable bicycle
3. Technology and mobile application
4. Maintenance
5. Integration with public transport

Carryout the unstructured questions & case study references taken the data for the point system in below table.

Table 8: Scoring for bicycle parking factor performance

Cities	Availability & coverage	User-friendly and comfortable bicycle	Technology and mobile application	Maintenance	Integration with public transport
Singapore	9	8	9	8	9
Aarhus	8	7	9	8	9
Madtid	8	7	8	7	9
Bordeaux	9	8	8	8	9
Hamburg	9	8	8	8	9
Eindhovan	9	8	8	9	9
Gothenburg	8	7	8	8	9
Tokyo	8	7	8	9	9
Oslo	9	8	9	8	9
Oakland	7	7	8	7	8

In Other way data that share bicycle scoring with other metrics such as Penetration rate, revenue, revenue growth, and Expected user rate in 2027. Below table shows that;

Table 9: Bicycle penetration rate, Revenue & Revenue growth in 2023

Cities	Penetration rate 2023	Revenue 2023 (USD Million)	Revenue Growth
Singapore	4.6	5	10.0%
Aarhus	4.70	2	5.7%
Madtid	8.1	31	7.9%
Bordeaux	12.4	72	8.8%
Hamburg	8.1	68	9.1%
Eindhovan	11.6	24	8.9%
Gothenburg	9.4	11	4.5%
Tokyo	4.3	19	6.3%
Oslo	8.95	5	-1.6%
Oakland	6.35	31.2	4.6%

Other way taken the expected share bicycle user % & projected population in 2027. The data in below table;

Table 10: Expected bicycle user forecast in 2027

Cities	Expected	Population	% of users
Singapore	156.8K	5.76 million	2.72
Aarhus	70.0K	5.97 million	1.17
Madtid	2.2millon	48.47 million	4.54
Bordeaux	1.9millon	66.67 million	2.85
Hamburg	2.5 million	83.87 million	2.98
Eindhovan	1.1 million	17.91 million	13.90
Gothenburg	0.6million	11.17 million	5.13
Tokyo	0.8million	14.3 million	5.59
Oslo	162.9K	1144K	14.23
Oakland	4.6million	341.7 million	1.34

Table 11: Last 5 Year penetration rate for bicycle user

Cities	2019	2020	2021	2022	2023
Singapore	3.9	4.1	4.25	4.45	4.6
Aarhus	4.48	4.52	4.6	4.25	4.7
Madtid	7.1	7.4	7.5	7.7	8.1
Bordeaux	10.9	11.2	11.6	12	12.4
Hamburg	7.1	7.4	7.5	7.6	8.1
Eindhovan	10.4	10.5	10.9	11	11.6
Gothenburg	8.5	8.6	8.7	9	9.4
Tokyo	4	4.05	4.15	4.15	4.3
Oslo	8.35	8.5	8.7	9	9.75
Oakland	5.9	6	6.2	6.05	6.35

4.2.2 Regulatory environment

We have collected data on all regulations pertaining to the bicycle network in each country, as well as how these regulations support cyclists.

Traffic laws and regulations

Taken the data from transportation authorities, and other government agencies set the standard of cyclist lane width, speed limit, min curve radius, device requirements such as bell, braking, reflector or light on night time, passing rule which are include the min safe distance between other vehicles or cyclist, safe min stopping distance, group riding regulation, and personal protection equipment requirements. Most of the regulations are to general but some of that can make competition.

Appendix H shows the Key Agency’s and Authorities involve the bicycle network development

Data’s according to the Government authorities (guideline/ manuals) required minimum width of cycle path below.

Table 12: Required minimum width for cyclist pathway

City	One way path (m)	Two-way path (m)
Singapore	1.5	2.0
Aarhus	1.8	3.0
Madtid	1.2	2.5
Bordeaux	1.5	2.2
Hamburg	2.5	3.0
Eindhovan	3.0	4.0
Gothenburg	2.5	4.0
Tokyo	2.5	3.0
Oslo	1.5	2.2
Oakland	1.5	2.0

Another data Set of Here competition of bicycle speed, curve radius, and minimum stopping sight distances (SSD) for bicycle according to the authority recommendation

Table 13: Minimum Speed, Turing radius, stopping sight distances

City	Design	Average	Turing radius	SSD
Singapore	25	15	18	30
Aarhus	30	20	20	30
Madtid	30	20	20	35
Bordeaux	30	20	20	30
Hamburg	30	20	35	35
Eindhovan	35	20	35	42
Gothenburg	30	20	35	42
Tokyo	30	20	20	42
Oslo	25	15	20	17
Oakland	30	20	20	30

Land use regulations

Supportive land use regulation improves the bicycle friendly environmental such as Connectivity and last mile solution, Green and sustainable planning, Neighbourhood design Bicycle parking requirements, Distance of destination, Environmental impacts, Mixed use development

Bicycle parking requirement in various location shows in Appendix I

For the mixed-use land development, we have compiled data based on our literature study, which is presented in the table below. Data's points for out of 10.

Table 14: Score for mixed-use land development factor performances

City	Cyclist friendly	Transportation options	Public space and plaza	Proximity amenities	Diverse land use
Singapore	8	10	8	8	10
Aarhus	10	8	8	10	10
Madtid	8	10	6	8	8
Bordeaux	8	8	6	8	10
Hamburg	6	8	8	10	8
Eindhovan	10	10	8	10	8
Gothenburg	8	10	8	10	8
Tokyo	6	8	6	8	8
Oslo	10	10	8	10	10
Oakland	6	6	8	6	6

City transportation planning

We have gathered data on the number of railway stations, the length of the rail network, and the length of the bicycle network to determine our designed metrics. The table below displays this data.

Table 15: Length and Number of Railway station in cities

City	Number of Railway station	Length of bicycle lanes	Railway length (Km)
Singapore	134	525Km	257.8
Aarhus	167	500Km	263
Madtid	242	354Km	294
Bordeaux	130	245Km	77.5
Hamburg	89	1300Km	100.7
Eindhovan	146	570Km	283
Gothenburg	25	880Km	104
Tokyo	190	790Km	273.3
Oslo	101	470Km	85
Oakland	50	155Km	211.5

Another set of data for percentage of railway network users of population and bicycle user of total population.

Table 16: Data for percentage of railway network users of population and bicycle user

City	Percentage of rail users of total population	Percentage of bicycle users of total population
Singapore	57.7	10
Aarhus	47.2	48
Madtid	61.2	47
Bordeaux	9.2	13
Hamburg	23.9	14.5
Eindhovan	40	36
Gothenburg	15	12
Tokyo	22	16
Oslo	20	28
Oakland	37.4	29

Funding mechanisms

The following data pertains to rental bicycle fees regulated by the government. Included are rates for a 30-minute single ride and a 30-day package.

Table 17: Rates for a 30-minute single ride and a 30-day package for share bicycle

City	single ride (min 30 min)	Monthly subscription (Min 30 days package) rate
Singapore	1 SGD	9.90 SGD
Aarhus	20 DKK	300 DKK
Madtid	2 Euro	17 Euro
Bordeaux	1.7 Euro	7 Euro
Hamburg	1.0 Euro	15 Euro
Eindhovan	3.85 Euro	10 Euro
Gothenburg	8 SKE	100 SKE
Tokyo	100 JPY	1400 JPY
Oslo	49 NOK	299 NOK
Oakland	1 USD	14 USD

Each country's government implements taxes on bicycle providers. Low taxes serve as an incentive for shared bicycle companies to invest more.

Table 18: Government reduced tax percentage for share bicycle providers

City	Government tax percentage
Singapore	17%
Aarhus	22%
Madtid	25%
Bordeaux	28%
Hamburg	7%
Eindhovan	9%
Gothenburg	12%
Tokyo	10%
Oslo	12%
Oakland	21%

<u>Public engagement</u>

With the following question, we aim to determine the factors identified in the literature study. Average score collected as the data from the participant.

Table 19: Sourcing for Language Consideration

Questions- Language Consideration	Singapore	Aarhus	Madtid	Bordeaux	Hamburg	Eindhovan	Gothenburg	Tokyo	Oslo	Oakland
Rate your satisfaction with the availability of information related to bicycle regulations in languages that you are comfortable with?	9.3	7.2	7.1	6.2	6.0	6.2	7.0	9.4	8.8	5.4
What is the rate the language options in official communications regarding bicycle infrastructure and regulations?	9.4	6.9	6.8	5.8	5.7	5.6	6.7	9.6	9.0	5.6
Have you encountered any challenges in understanding or interpreting government communications related to bicycling due to language barriers	8.8	6.7	7.3	6.1	5.8	6.3	6.7	9.0	9.1	6.2
How would you rate the clarity of language used in official communications about bicycle infrastructure and safety?	9.1	7.4	6.7	7.1	6.1	5.9	6.9	9.1	8.7	5.1

Table 20: Scoring for Cultural Sensitivity

Cultural Sensitivity	Singapore	Aarhus	Madtid	Bordeaux	Hamburg	Eindhovan	Gothenburg	Tokyo	Oslo	Oakland
Rate that what extent do you feel that government communications about bicycling take into account cultural differences and nuances?	9.2	7.4	7.2	6.8	6.1	6.7	7.1	9.0	9.4	6.2
Rate of you notice any efforts by the government to incorporate cultural elements into bicycle-related campaigns or initiatives?	9.3	7.1	6.7	7	6.2	6.4	7.3	8.9	8.7	6.1

Rate for the bicycle infrastructure planning considers the diverse cultural needs and preferences of the community	7.2	7.7	7.8	7.5	7.1	7.2	7.7	8.1	8.3	6.6
How important do you think cultural sensitivity is in promoting cycling as a mode of transportation in your community?	8.8	8.0	7.7	7.5	6.5	6.6	7.3	8.7	9.1	8.2

Table 21: Scoring for Feedback Mechanism

Question- Feedback Mechanism	Singapore	Aarhus	Madtid	Bordeaux	Hamburg	Eindhovan	Gothenbur	Tokyo	Oslo	Oakland
Rate public awareness of any official channels or mechanisms provided by the government for cyclists to provide feedback on bicycle infrastructure and regulations?	9.7	7.3	4.2	3.6	7.0	4.4	3.9	9.2	8.8	6.8
Rate your satisfaction with the responsiveness of government authorities to feedback and concerns raised by the cycling community?	9.1	6.2	3.8	4.1	6.3	3.9	4.4	9.4	9.2	6.2
Rate that how you personally utilized any feedback mechanisms to communicate with the government about bicycle-related issues?	7.2	7.0	3.0	3.2	6.6	3.5	3.2	7.2	7.7	5.5
Rate that effeteness of feedback mechanisms to better serve the needs of cyclists?	7.0	7.2	4.0	3.7	7.3	4.2	4.2	8.0	7.9	5.0

Table 22: Scoring for Education Campaigns

Question- Education Campaigns	Singapore	Aarhus	Madtid	Bordeaux	Hamburg	Eindhovan	Gothenburg	Tokyo	Oslo	Oakland
Rate that how effective do you think government-led education campaigns have been in promoting safe cycling practices?	7.6	4.8	6.1	5.0	5.6	4.8	5.4	9.6	8.1	7.7
Rate that how involve participation in any educational workshops or programs organized	7.7	5.0	6.3	5.2	5.4	4.7	5.3	9.5	8.0	8.1

by the government to enhance cyclists' knowledge and skills?										
What is the rating for awareness campaigns to educate the public about the benefits of cycling and bicycle safety?	7.2	4.2	5.3	4.9	5.1	4.4	5.2	9.4	7.7	8.0
What is the rating for the government to improve its educational efforts to better reach and engage the cycling community?	7.3	4.3	5.4	5.5	5.3	4.5	5.5	9.5	7.9	8.2

Table 23: Scoring for Cyclist Events

Question- Cyclist Events	Singapore	Aarhus	Madtid	Bordeaux	Hamburg	Eindhovan	Gothenburg	Tokyo	Oslo	Oakland
What is the rating for attending any government-organized cyclist events or activities in your community?	4.4	3.6	4.1	3.9	6.3	3.8	4.2	7.8	6.6	6.4
How would you rate the impact of cyclist events in fostering a sense of community among cyclists?	4.5	3.9	3.8	3.7	7.6	4.1	4.3	9.1	7.2	7.0
What is the rating for government-supported events to promote cycling and community engagement?	4.3	3.7	4.0	4.1	6.8	4.2	3.9	8.8	7.1	6.8
What is the rating for government-sponsored cyclist events be improved to better meet the needs and interests of the cycling community?	3.1	3.3	3.4	3.3	6.1	3.6	3.1	8.1	6.8	6.5

Table 24: Scoring for Enforcement

Question- Enforcement	Singapore	Aarhus	Madtid	Bordeaux	Hamburg	Eindhovan	Gothenburg	Tokyo	Oslo	Oakland
Rate it how frequently have you observed incidents involving cyclists in your local area over the past year?	5.5	4.3	4.7	4.6	3.8	3.7	4.5	6.2	6.1	5.2
If people witnessed incidents, how often were they reported to the relevant authorities?	4.3	4.1	3.9	4.3	4.0	4.1	3.7	5.9	6.0	4.8

Rate of cyclists in your community follow traffic rules and regulations?	7.6	5.5	5.8	5.3	5.1	4.9	4.7	7.8	6.9	5.7
Rate it how often do you observe cyclists wearing helmets while riding?	5.5	4.8	5.2	5.7	5.0	5.5	5.8	6.7	6.5	5.9
Rate cyclists who receive citations for traffic violations are likely to repeat the same offenses?	6.0	4.2	4.8	5.1	4.6	4.9	5.2	6.9	6.4	6.2
Rate how satisfied are you with the response time of authorities to reported cyclist violations in your area?	5.4	4.8	4.9	5.2	4.8	4.4	6.1	7.1	6.8	6.4

4.2.3 User convenience

Through the following inquiry, we seek to ascertain the factors highlighted in the literature review. The average score, derived from participant responses, serves as our collected data.

Table 25: Scoring for Information technology

Questions-Information technology	Singapore	Aarhus	Madtid	Bordeaux	Hamburg	Eindhovan	Gothenburg	Tokyo	Oslo	Oakland
Rating the road signage for cyclists consistent in design and placement throughout the city?	8.6	4.5	4.3	5.1	6.7	5.3	4.5	8.8	6.6	6.8
How would you rate the uniformity of bicycle-related signage in different areas you cycle through?	8.9	4.3	4.6	5.0	6.9	5.1	4.6	8.7	6.7	7.1
Rating the road signs for cyclists easily visible to you while cycling?	6.9	4.0	4.1	4.3	4.7	3.9	4.1	8.5	4.3	4.2
Rating the placement of signage is effective in providing timely information to cyclists	5.5	3.9	4.2	4.3	4.4	4.0	4.2	7.6	4.0	4.1
Rate for issues with the reflectivity of road signs, especially during night-time cycling	7.2	5.0	4.7	4.4	4.5	4.7	4.9	8.1	4.5	5.1
Rate the road signs are adequately illuminated for clear visibility in low-light conditions?	7.6	5.2	4.6	4.9	5.6	5.2	5.1	8.2	4.9	5.3
Rate the satisfied of you with the overall performance of	9.1	6.2	5.8	5.4	5.7	5.3	5.5	9.2	5.1	6.2

the cyclist mobile application?										
Have you experienced any issues with the functionality of the app while cycling?	8.8	6	5.6	5.4	5.4	5.4	5.6	9.0	5.5	6.1
How confident are you in the accuracy of the route information provided by the mobile application?	9.5	6.5	6.1	6.2	6.2	6.5	6.4	9.4	6.2	6.3
Have you encountered any discrepancies in speed or distance measurements while using the app?	9.0	6.1	5.3	5.4	5.6	5.3	5.7	8.8	5.1	5.7
Do you feel that the data provided by the app is reliable for your cycling needs?	9.1	7.1	7.3	6.6	7.2	6.9	7.4	9.2	6.7	6.4
Are you concerned about the security of your personal data when using the cyclist mobile application?	8.1	6.4	6.7	6.3	6.1	6.6	6.2	8.2	6.2	6.1
How well-informed do you feel about the measures taken by the app to protect your data?	7.2	5.3	5.7	5.1	5.6	4.9	4.7	7.3	5.9	6.1

Table 26: Scoring of Amenities for cyclist

Question- Amenities for cyclist	Singapore	Aarhus	Madtid	Bordeaux	Hamburg	Eindhovan	Gothenburg	Tokyo	Oslo	Oakland
How satisfied are you with the availability of water points along your cycling routes?	7.5	4.2	4.3	5.2	4.7	4.5	5.1	8.5	6.7	6.2
Are the existing water points conveniently located for cyclists, and do you find them easily accessible?	9.1	6.3	5.9	6.2	6.0	6.3	6.2	9.2	8.5	8.0
How would you rate the cleanliness and maintenance of the current water points for cyclists?	9.5	6.7	6.9	7.4	7.3	7.2	7.0	9.3	8.0	8.2
How frequently do you utilize rest areas during your cycling journeys?	5.5	5.3	5.7	7.6	7.4	7.8	6.9	6.8	6.4	6.1
Are the existing rest areas equipped with amenities that meet your needs for a comfortable break?	8.2	4.6	4.8	4.5	4.9	4.2	5.3	7.5	6.2	6.4
Do you think there is a sufficient number of rest areas along your typical cycling routes?	7.5	5.2	5.3	5.6	5.4	5.5	5.4	7.7	6.0	6.5

How important do you consider the availability of shelters for cyclists during adverse weather conditions?	7.3	4.3	4.7	4.5	9.4	4.8	4.3	5.5	9.2	8.7
Have you encountered situations where the lack of shelter negatively impacted your cycling experience?	5.3	4.2	3.9	3.4	7.4	3.9	4.0	4.3	7.7	7.1
Have you ever used bicycle repair stations along your cycling routes, and if so, how satisfied were you with the experience?	6.2	4.5	5.3	5.8	4.2	4.6	5.2	7.5	7.1	7.7
Are there locations where you believe bicycle repair stations would be particularly useful?	5.2	6.2	6.3	6	5.5	5.2	4.8	7.5	7.0	8.2

Table 27: Scoring for Accessibility

Question- Accessibility	Singapore	Aarhus	Madrid	Bordeaux	Hamburg	Eindhovan	Gothenburg	Tokyo	Oslo	Oakland
Are you generally aware of the presence of accessibility features, such as ramps and lifts, in public spaces and buildings?	8.8	3.9	5.9	5.2	5.4	6.1	5.5	9.1	8.9	6.2
Are these features easy to locate and use, or do you find them challenging to access?	8.6	3.7	6.0	5.7	5.6	6.3	5.3	9.0	9.1	6.7
Based on your experience, how effective are the ramps, lifts, and other accommodations in facilitating your movement in public spaces?	8.9	4.2	6.2	5.9	5.3	6.7	5.5	9.2	8.8	6.5
Do you find that accessibility features are consistently implemented across various public spaces, or do you encounter inconsistencies?	8.7	3.9	6.1	6.0	5.6	6.6	5.6	8.9	8.9	6.4
Are there channels or mechanisms in place for users to provide feedback on the accessibility of public spaces?	9.0	4.5	6.2	5.8	5.7	6.5	5.4	9.1	9.0	6.6
Can you identify specific challenges or difficulties you face related to mobility when navigating public spaces?	8.8	5.0	4.3	5.6	5.2	6.3	5.5	9.0	9.2	5.9
How well-informed do you feel about the accessibility features in a new public space before visiting it for the first time?	9.1	4.7	5.8	5.4	5.5	6.8	5.7	9.2	9.1	6.1

Do you think there is a need for more awareness and training programs for the general public to understand and respect the needs of individuals with mobility impairments?	8.7	5.2	5.3	6.0	6.2	6.3	5.9	9.4	8.3	6.9

4.2.4 Network connectivity

The data collection of identified metrics from the literature study is conducted through the questionnaire provided below, which includes the data gathered by surveyors.

Table 28: Scoring for Comprehensives network coverage

Comprehensives network coverage- Questions	Singapore	Aarhus	Madtid	Bordeaux	Hamburg	Eindhovan	Gothenburg	Tokyo	Oslo	Oakland
How would you rate the overall connectivity of the bicycle network to employment centers, schools, and shopping areas in your area?	9.2	5.3	5.6	5.8	5.5	5.9	6.1	9.1	8.9	6.8
Rate the challenges or barriers when cycling to these destinations?	8.9	5.1	5.5	6.0	5.7	6.1	6.7	8.8	9.1	6.7
How satisfied are you with the existing cycling infrastructure (bike lanes, paths, intersections) connecting to employment centers, schools, and shopping areas?	8.8	5.5	5.2	6.2	5.9	6.3	6.3	9.3	9.0	6.4
Rate the route where you believe improvements to cycling infrastructure are needed.	8.7	5.4	5.9	6.7	6.1	6.5	6.2	9.2	9.2	6.3
How satisfied are you with the availability and quality of bicycle parking facilities at employment centers, schools, and shopping areas?	9.1	5.8	5.3	6.3	6.3	6.5	6.7	8.9	9.3	6.6

Table 29: Scoring for Interconnectivity with other modes of transportation

Interconnectivity with other modes of transportation- Question	Singapore	Aarhus	Madtid	Bordeaux	Hamburg	Eindhovan	Gothenburg	Tokyo	Oslo	Oakland
Rate how satisfied are you with the availability of bicycle parking	8.8	5.0	5.5	6.2	6.6	6.3	6.5	9.2	9.1	6.9

facilities at these transportation hubs or interchanges?										
Rate your usage of bicycle for the last mile of your commute to or from transportation hubs or interchanges?	8.7	5.3	5.2	6.5	6.2	6.5	6.2	9.0	9.1	6.4
Rate how well do you think the bicycle infrastructure facilitates last-mile connectivity at these locations?	8.9	5.7	5.7	6.8	6.3	6.8	6.8	9.2	8.9	6.8
How would you rate the overall connectivity of the bicycle network with other modes of transportation or interchanges in your area?	9.0	5.5	5.3	6.2	6.7	6.3	6.3	9.1	8.5	6.3
Rate how seamless is the integration between cycling and public transport in your experience?	9.3	5.2	5	6.4	6.3	6.1	6.4	8.9	8.6	6.6
Rate people involvement in any community engagement or advocacy efforts related to improving bicycle network connectivity in your city?	7.0	4.6	4.4	5.2	5.4	5.1	5.3	7.2	6.7	5.4

Table 30: Scoring for Consistent infrastructure standards

Consistent infrastructure standards- Question	Singapore	Aarhus	Madtid	Bordeaux	Hamburg	Eindhovan	Gothenburg	Tokyo	Oslo	Oakland
How would you rate the consistency of lane width across different bicycle paths and lanes within the city?	8.8	4.2	3.9	4.1	5.3	6.9	5.7	8.9	8.3	7.5
How would you describe the overall surface quality of bicycle paths and lanes in the city?	8.6	4.6	4.2	4.5	5.6	6.5	5.5	9.1	8.5	7.3
How well does the color coding help you identify and navigate through the bicycle network?	9.0	4.6	3.8	4.4	5.3	6.8	5.6	8.5	8.1	7.4
How satisfied are you with the overall maintenance conditions of bicycle infrastructure in the city?	9.1	4.1	3.5	4.8	5.5	6.4	5.4	8.7	8.3	7.7
Are there clear protocols and standards for regular maintenance and repairs of bicycle paths and lanes?	8.9	4.4	3.9	4.5	5.9	6.9	5.5	8.5	8.0	7.3
Are there visible signs of collaboration between different infrastructure projects to enhance overall connectivity?	8.4	4.9	4.5	4.4	5.3	6.6	5.9	8.9	8.2	7.3

Table 31: Scoring for Strategic route planning

Strategic route planning- Question	Singapore	Aarhus	Madtid	Bordeaux	Hamburg	Eindhovan	Gothenburg	Tokyo	Oslo	Oakland
How easy is it for you to access the bicycle network from your residence?	9.2	5.4	5.9	6.2	7.1	5.6	6.6	9.3	8.8	7.5
How frequently do you use the bicycle network for commuting or recreational purposes?	9.1	5.2	6.1	6.1	6.4	5.5	6.5	9.1	8.4	7
Have you observed an increase in the number of cyclists since the implementation of the strategic plan?	8.9	5.7	5.7	6.3	6.9	5.8	6.6	9.3	8.6	7.3
Have you noticed any positive changes in the city's policies that support cycling?	8.5	5.9	5.8	5.9	6.5	5.3	6.9	8.9	8.8	7.7
Have you utilized any technology or apps that support cycling in the city?	9.1	5.5	6.0	5.8	6.7	5.9	6.4	8.8	7.9	6.9
How effective do you find technology in enhancing the safety and convenience of cycling?	9.0	4.9	6.2	6.3	6.9	6.0	7.1	8.6	8.2	8.0

Table 32: Scoring for Connectivity to adjacent neighbourhoods and communities

Connectivity to adjacent neighbourhoods and communities- Question	Singapore	Aarhus	Madtid	Bordeaux	Hamburg	Eindhovan	Gothenburg	Tokyo	Oslo	Oakland
How would you rate the connectivity of the bicycle network in your neighbourhood to adjacent areas?	9.1	6.0	5.5	3.9	4.1	5.6	6.4	9.6	8.2	7.9
Have you been involved in any community initiatives or discussions related to bicycle network connectivity?	9.4	5.9	5.3	4.2	4.0	5.0	6.1	9.3	8.4	8.2
How satisfied are you with the level of community involvement in improving bicycle connectivity?	8.9	6.3	5.5	4.5	4.3	5.2	6.6	9.4	8.5	8.8
How satisfied are you with the bicycle network connectivity in your neighborhood?	8.5	6.4	5.1	4.7	4.5	5.5	6.2	8.9	8.8	8.4

4.2.5 Safety & security

Average score in below table;

Table 33: Scoring for Separation from motor vehicle traffic

Separation from motor vehicle traffic- Questions	Singapore	Aarhus	Madtid	Bordeaux	Hamburg	Eindhovan	Gothenburg	Tokyo	Oslo	Oakland
Rate your satisfaction with our city's current infrastructure regarding bicycle pathways and separation from motor vehicle traffic	8.4	4.7	4.5	4.9	5.2	6.5	6.3	8.9	7.7	7.4
Rate your experienced discomfort or felt unsafe while cycling due to proximity to motor vehicle traffic?	8.5	4.2	4.7	5.1	5.5	6.2	6.0	8.7	7.9	7.6
Rate the physical barrier separating bicycles from motor vehicles on shared roadways?	8.0	4.9	4.4	4.7	5.4	6.4	6.5	9.1	7.5	7.7
Rate how feel that separate pathways designated specifically for bicycles would enhance safety for cyclists?	7.9	4.6	4.6	4.8	5.0	6.6	6.2	8.8	7.4	7.3
Rate how satisfied are you with the current level of safety for cyclists in the city?	8.3	4.2	4.2	4.4	5.1	6.3	6.6	9.0	7.6	7.4

Table 34: Scoring for Intersection safety

Intersection safety	Singapore	Aarhus	Madtid	Bordeaux	Hamburg	Eindhovan	Gothenburg	Tokyo	Oslo	Oakland
Rate your experienced discomfort or felt unsafe while navigating intersections on your bicycle?	9.0	4.9	5.1	5.5	5.4	6.5	6.3	9.2	8.7	7.7
Rate that How dedicated traffic signals bicycle would improve safety for cyclists at intersections?	9.1	4.7	4.9	5.6	5.6	6.4	6.7	9.1	8.6	7.9
Rate that for encountered bike boxes (advanced stop lines for cyclists) at intersections in our city, do you find them effective in enhancing cyclist safety?	8.8	5.0	5.0	5.6	5.4	6.7	6.4	8.9	8.4	7.6
Rate it how important do you think clear signage and markings are at intersections to indicate the presence of bicycle-specific infrastructure?	8.7	5.1	4.7	5.4	5.7	6.5	6.8	8.5	8.6	7.8

Rate that implementing protected intersections and dedicated bicycle traffic signals would encourage more people to cycle in our city?	8.9	4.9	5.3	5.3	5.4	6.8	6.3	9.2	8.3	7.5
Rate that how satisfied are you with the current level of intersection safety for cyclists in our city?	9.2	4.6	5.1	5.6	5.8	6.3	6.6	9.0	8.6	7.4

Table 35: Scoring for Conflict points

Conflict points	Singapore	Aarhus	Madtid	Bordeaux	Hamburg	Eindhovan	Gothenburg	Tokyo	Oslo	Oakland
Rate safety concerns or experienced conflicts while navigating interaction areas?	8.9	4.8	5.2	5.7	5.6	6.6	6.5	9.3	8.5	7.6
Rate observed any measures in our city aimed at enhancing visibility in interaction areas, such as improved lighting, clear signage, or road markings?	9.3	4.6	4.9	5.5	5.5	6.4	6.9	9.0	8.8	7.9
Rate the Satisfy the implemented to reduce conflicts and improve safety in interaction areas?	9.1	4.9	4.7	5.3	5.3	7.0	6.7	9.3	8.1	7.9
Rate how satisfied are you with the current visibility and safety measures in interaction areas in our city?	8.8	4.5	4.8	5.8	5.8	6.4	6.3	8.8	8.3	7.7
Rate that satisfy the technology could play in improving visibility and safety in interaction areas?	8.6	4.4	4.6	6.0	5.9	6.1	6.5	9.2	8.6	8.0

Table 36: Scoring for Traffic calming measures

Traffic calming measures	Singapore	Aarhus	Madtid	Bordeaux	Hamburg	Eindhovan	Gothenburg	Tokyo	Oslo	Oakland
Rate that ever-encountered safety concerns or felt at risk while cycling due to vehicle speeds in certain areas?	8.9	4.6	4.9	5.6	5.4	6.5	6.9	9.1	8.5	7.7
Rate about your aware of the concept of traffic calming measures, such as speed humps, roundabouts, or traffic circles, aimed at reducing vehicle speeds?	9.0	4.9	4.3	5.3	5.8	6.8	6.4	9.2	8.4	7.3

Rate that use of roundabouts or traffic circles as traffic calming measures to improve cyclist safety?	9.3	4.4	4.6	5.9	5.6	6.2	6.3	8.9	8.8	7.3
Rate the important do you think it is for city authorities to prioritize cyclist safety when implementing traffic calming measures?	9.1	4.7	5.2	5.4	5.3	6.4	6.6	9.3	8.7	7.6
Rate the implementation of traffic calming measures would encourage more people to cycle in our city?	9.0	5.0	4.7	5.5	5.9	6.6	6.5	9.2	8.5	7.2

4.3 Colombo Bicycle mode transportation data collection

Our literature review indicates that Colombo city has not placed significant emphasis on developing bicycle transportation-related metrics. Recognizing this gap, I decided to collect data using simplified questions that do not delve deeply into all the sub-metrics and factors. This approach was chosen because many of these factors have not been implemented in any single location within the city. By focusing on broader, more general questions, the study aims to capture an overview of the current state of bicycle transportation infrastructure and usage without getting bogged down by the complexity and variability of specific, unimplemented metrics.

Take the average participant score for each question and display the results in Appendix J.

CHAPTER 5: DATA ANALYSIS

5.1 Introduction

In the data collection process, we employ various methods to gather both qualitative and quantitative data. While some qualitative data lend themselves to direct application of equations derived from literature studies, others cannot be measured directly using established metrics. In such cases, we resort to utilizing scaling methods to derive composite scores for each city.
To establish a standardized framework for evaluating the performance of different factors, we assign numerical values to varying levels of performance: High (10), Moderate to High (8), Moderate (6), Low (4), and Very Low (2). This scaling system allows us to quantitatively assess the effectiveness of each factor across cities.

Our data collection also involves the use of questionnaires, which capture influential factors and outcomes relevant to metrics. Through a multi-criteria analysis method, we compute the aggregated impact of these factors on the overall performance of each city's defined metrics.

In the initial phase of our analysis, we prioritize calculating the central tendency and variability of the collected metrics. This involves computing measures such as mean, median, mode, standard deviation, and range. These statistical analyses provide insights into the typical values and spread of the data, enabling us to identify trends, patterns, and outliers across cities' bicycle transport metrics.

In our analytical approach, we prioritize conducting regression analyses wherever applicable to discern the influence of various predictors on bicycle transport mode. These predictors encompass a spectrum of factors including policy interventions and investments tailored towards enhancing bicycle infrastructure.

Regression analysis serves as a robust statistical tool enabling us to model the relationships between predictor variables such as policy interventions and investment levels, and the corresponding outcomes in terms of bicycle transport mode adoption or effectiveness. By employing regression techniques, we can quantify the impact of these predictors on the promotion and utilization of bicycle transportation within urban settings.

5.2 General data Analysis

To get the participant logistic, as shown below results gather 10 participants from each city for this study. Total 100 participation.

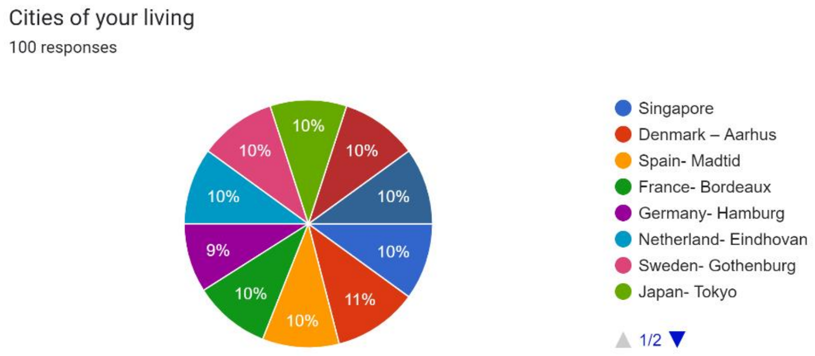

Figure 1: Responses cities

Another day set collect that Frequency of bicycle usage per week from participant, responses shown in below chart.

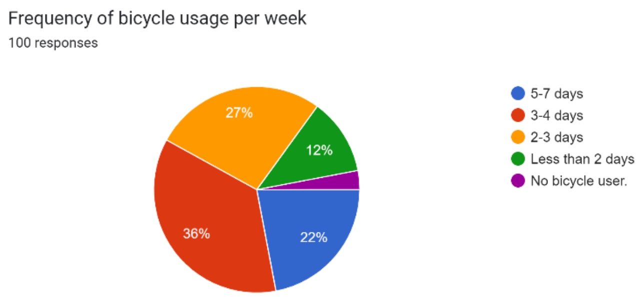

Figure 2: Frequency of bicycle usage per week

Distance to cover by the bicycling, data shown below;

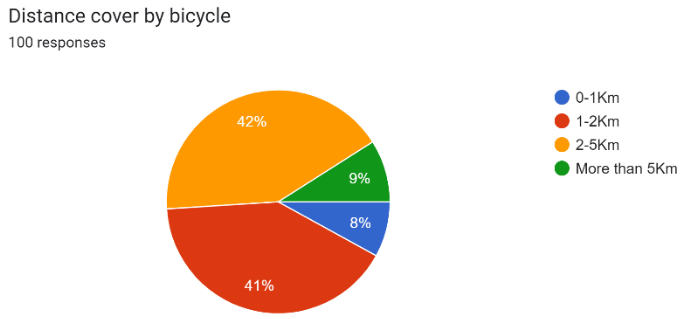

Figure 3: Distance to travel by bicycle

Find out the purpose of bicycle usage, responses shown below;

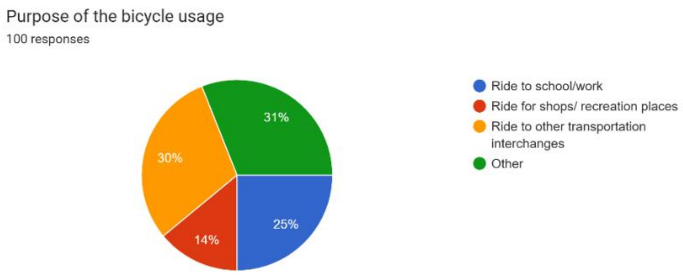

Figure 4: Purpose of bicycle usage

Type of bicycle usage which means own the bicycle or rental bicycle.

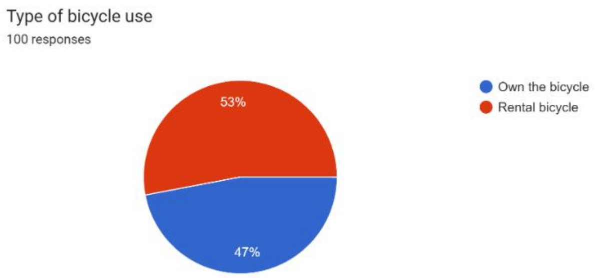

Figure 5: Type of bicycle usage

5.3 Metrics data analysis

Analysis the data set and find the most suitable value for the metrics benchmark; each metrics benchmark justify why I select the value from the analysis data set.

5.3.1 Bicycle infrastructure

Bicycle Network Density (BND) & Population Density Index Relative to Bicycle Network (PDBN)

Table 37: BND & PDBN metrics values

City	Length (Km)	Area ($Km^{2)}$)	Population density ($No/Km^{2)}$)	Bicycle network density	Population density index
Singapore	525	728	8292	0.72	11499.10
Aarhus	500	91.8	1080	5.45	198.30
Madtid	354	604.3	5322	0.59	9102.10
Bordeaux	245	49.36	4583	4.96	923.30
Hamburg	1300	755	2367	1.72	1374.70
Eindhovan	570	88.84	2512	6.42	391.90
Gothenburg	880	450	1252	1.96	640.20
Tokyo	2900	2194	6158	1.32	4658.80
Oslo	470	454	1270	1.04	1226.80
Oakland	155	202.4	2812	0.77	3671.90

Central tendencies, variables values of BND and PDBN shown in Appendix K; Cities like Singapore, Tokyo, and USA demonstrate high population density index and relatively extensive bicycle networks, indicating potentially effective transportation solutions for densely populated areas.

Cities with high bicycle network density, such as Eindhoven and Aarhus, may have more developed cycling infrastructure, which could contribute to higher levels of cycling activity and potentially lower reliance on motor vehicles.

The data suggests a complex interplay between urban planning, population density, and the development of cycling infrastructure. Future urban planning efforts could benefit from considering these factors to promote sustainable and efficient transportation systems.

The median bicycle network density is substantially lower than the mean, with a median of 1.52 km/km² compared to a mean of 2.49 km/km². This suggests that there may be a skewness towards lower density values in the dataset.

To analysis the Population density index data, to find the central tendencies, variables, and proportions.

Taken from the Population density index data the median population density index (1300.75) is substantially lower than the mean (3368.71), indicating a potential skewness towards lower density indices in the dataset. This suggests that while some locations have relatively high population density indices, others exhibit lower values.

Bicycle Lane Performance (BLP)

As Calculation shown in Appendix K; the Bicycle Lane Performance (BLP) analysis, the mean (0.86) and median (0.90) of Relative important index (RII) values are close, indicating a symmetrical distribution and consistency. The standard deviation (0.14) and coefficient of variation (16.07%) show moderate variability. The range (0.36) is small, but the data shows some dispersion. The data is slightly left-skewed as the median (0.90) is higher than the mean (0.86). The first quartile (Q1) is 0.73 and the third quartile (Q3) is 0.95, suggesting most values concentrate around the median. The median values are recommended as benchmarks for BLP metrics.

Traffic Signal Performance for Cyclists (TSPC)

As Calculation shown in Appendix K; Traffic Signal Performance for Cyclists (TSPC) analysis we can conclude that the mean value of 0.77 and the median value of 0.74 suggest a distribution that is slightly positively skewed. This means that there may be some higher values pulling the mean slightly above the median. The standard deviation (SD) of 0.07 and the coefficient of variation (CV) of 9.44% indicate a relatively low level of variability within the data set. This suggests that the observations are relatively close to the mean. With that strategic information conclude the benchmark as the median RII value for the TSPC metrics.

Intersection Performance for Cyclists (IPC)

As Calculation shown in Appendix K; Intersection Performance for Cyclists (IPC) metrics, we find that the data exhibits a consistent distribution with a relatively low level of variability. The observations tightly cluster around the mean and median values, indicating uniformity in the data. Therefore, the conclusion drawn from this analysis is that the variable under Consideration demonstrates a stable and consistent pattern with minor fluctuations around the central tendency. As a result, we utilize the median RII value of 0.76 as the benchmark for city-level performance assessment.

Bicycle Parking Performance (BPP)

As Calculation shown in Appendix K; The analysis of bicycle parking performance (BPP) metrics suggests that the data exhibits a moderately positively skewed distribution with a moderate level of variability. While the majority of observations cluster around the median, there is some spread around the mean. Therefore, the conclusion drawn from this data is that the variable under consideration demonstrates a moderately stable pattern with some fluctuations around the central tendency. As a result, we establish the median value of 0.88 as our benchmark from the above study.

Share Bicycle Performance (SBP)

As Calculation shown in Appendix K; Suggests that the data exhibits a symmetrical distribution with a low level of variability. The observations are tightly clustered around the mean and median values, indicating uniformity in the data. Therefore, the conclusion drawn from this data is that the variable under consideration demonstrates a highly stable pattern with minimal fluctuations around the central tendency. Take as the benchmark for median value 0.83 to our study.

Share Bicycle Penetration Rate (SBPR)

As Calculation shown in Appendix K; Share Bicycle Penetration Rate (SBPR) the data exhibits a moderately negatively skewed distribution with a moderate to high level of variability. While the median is slightly higher than the mean, indicating some lower values, the observations are dispersed around the mean with some notable fluctuations. Moreover, this data is that the variable under consideration demonstrates a moderately stable pattern with noticeable fluctuations around the central tendency.

Penetration rate trend increase of each of individual cities, the mean value of 0.22 and the median value of 0.20 indicate that the data is positively skewed, with the mean higher than the median. This suggests that there may be some higher values pulling the mean up. The standard deviation (SD) of 0.20 suggests a moderate level of variability within the data set. This implies that the observations are dispersed around the mean, with some degree of fluctuation.

Share Bicycle Revenue (SBR)

Through our data analysis, we have derived insights regarding the central tendencies and limitations inherent in the dataset. Furthermore, we have conducted an analysis of the relationship between revenue and penetration within the dataset to discern patterns and behaviours associated with this interaction.

As Calculation shown in Appendix K; Share Bicycle Revenue (SBR) mean revenue per city is $26.82, while the median revenue is $21.50. This suggests that there may be some cities with relatively high revenue values that are pulling the mean up, leading to a higher mean compared to the median. Also, standard deviation (SD) of $25.08 indicates a high level of variability in bicycle revenue across the cities. This means that there are significant differences in revenue between different cities, with some cities having much higher or lower revenue than others. We take the mean value as our benchmark revenue. But however, suggests that factors such as population size, tourism, infrastructure, and economic conditions may play significant roles in determining bicycle revenue for each city. Therefore, further analysis may be needed to understand the specific factors influencing revenue generation and to identify strategies for maximizing revenue in each city.

Share Bicycle Revenue Growth (SBRG)

A subsequent dataset, akin to the previous analysis, has been examined. The outcomes reveal patterns and behaviours pertaining to revenue growth within this dataset.

This growth percentage underscores the resilience and appeal of shared bicycle systems, showcasing their ability to meet evolving transportation needs and preferences. Moreover, it suggests a positive response from consumers towards shared mobility options, highlighting the increasing demand for convenient, eco-friendly transportation alternatives. The close-to 6% annual revenue growth rate signifies a thriving industry poised for further development and innovation. It emphasizes the growing importance of shared bicycles in the urban transportation landscape and underscores their potential to contribute significantly to sustainable urban mobility initiatives.

Share Bicycle Expected User Ratio (SBER)

As Calculation shown in Appendix K; Share Bicycle Expected User Ratio (SBER) in 2027 mean value is relatively high, the median is considerably lower, indicating a positively skewed distribution with a wide range of values. The high standard deviation further underscores the variability within the data set. Therefore, the conclusion drawn from this data is that the variable under consideration exhibits a positively skewed distribution with considerable variability in the observations. Taken the mean value 5.45 as benchmark from our study.

5.3.2 Regulatory environment

Bicycle Lane Width Requirement (BLWR)

The analysis focuses on the width requirement and involves plotting the collected data. Through this process, the average width is determined based on regulatory requirements, ensuring compliance and providing valuable insights into the necessary dimensions.

We can set the mode value of 1.5m width for one-way lanes and 3.0m width for two-way lanes as the benchmark for Bicycle Lane Width Requirement (BLWR) from our study. These values are the most appropriate for users to reference in their design guidelines.

Bicycle Design Speed (BDS) & Bicycle Recommended Speed (BRS)

The data set selected pertains to both the design speed and the recommended speeds for cyclists. The subsequent analysis is presented below, outlining the findings and insights derived from the examination of this data.

The mode values of 30 km/h for Bicycle Design Speed (BDS) and 20 km/h for Bicycle Recommended Speed (BRS) are set benchmarks taken from the design guidelines. These benchmarks have the same application.

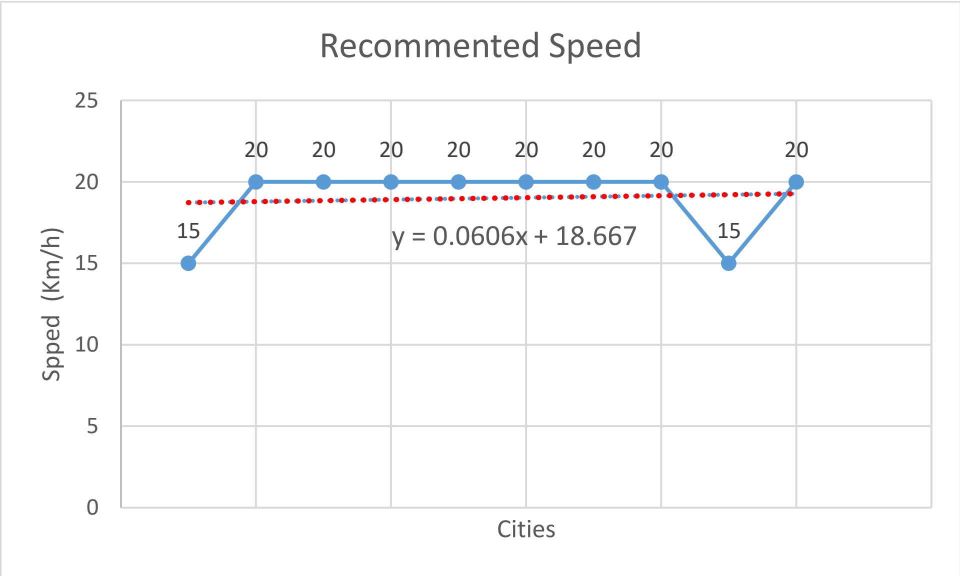

Figure 6: Chart of Recommended speed in guidelines

Bicycle Turning Radius (BTR)

The calculation of radius is associated with the design speed, aiming to understand the relationship between the radius of each city and its corresponding design speed. The analysis reveals the outcomes of this investigation, shedding light on the relationship between city radius and design speed across the dataset.

Upon examining the correlation between Bicycle Turning Radius (BTR) and speed, we have identified a clear relationship in the field. Our analysis reveals a correlation represented by the equation $Y=0.1X^{1.62}$. And also, Bicycle Stopping Sight Distances (BSSD) correlated with speed relationship $Y=0.04X^{2.}$

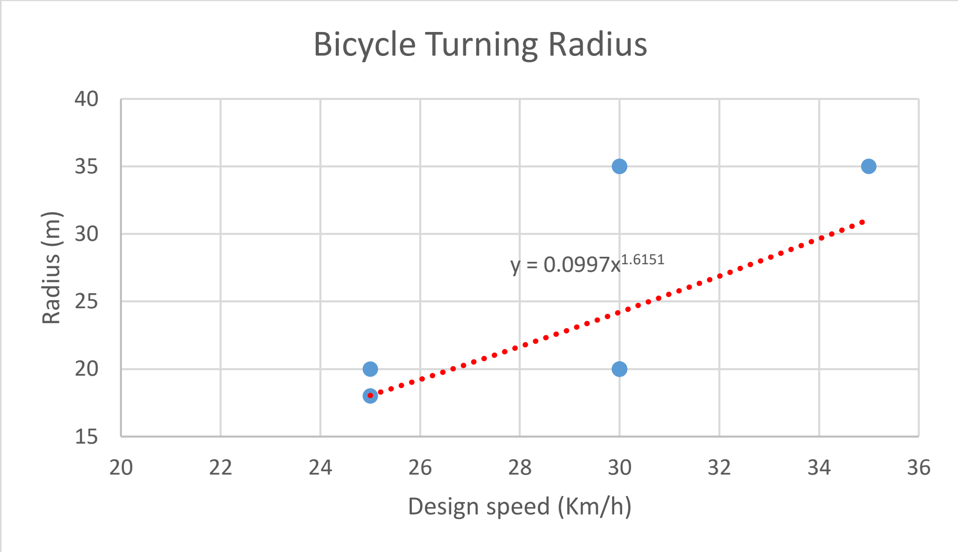

Figure 7: Relationship with design speed and turning radius

<u>*Bicycle Stopping Sight Distances (BSSD)*</u>

Stopping sight distance is a critical factor that correlates with the speed of vehicles. In this context, the aim is to examine the relationship between stopping sight distance and speed using the collected data. Subsequently, the analysis derived from this examination will guide the selection of appropriate analytical approaches and provide insights into the implications of speed on stopping sight distance.

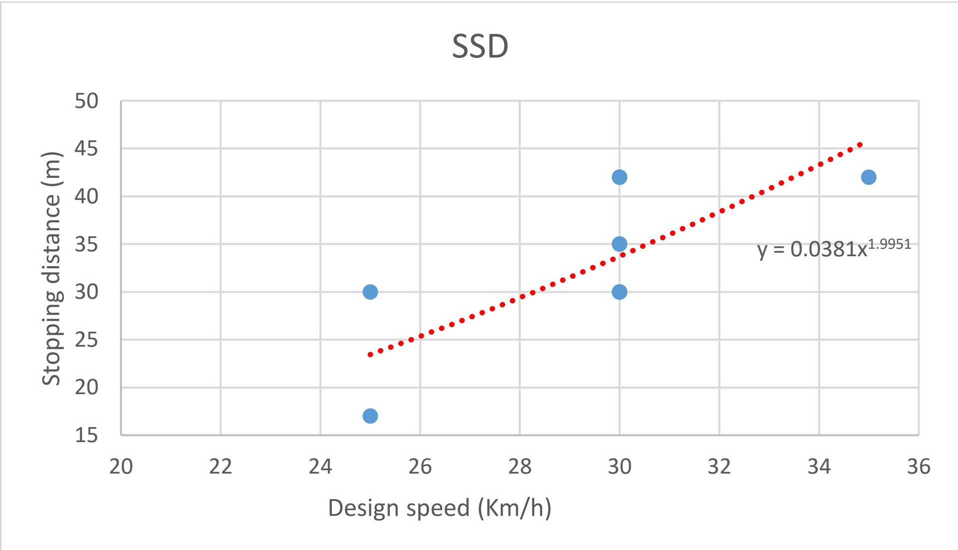

Figure 8: Relationship with Design speed and stopping sight distances

<u>*Bicycle parking regulation requirement (BPRR)*</u>

In the preceding study, the bicycle parking regulations were carefully delineated, necessitating a thorough examination of various parking dynamics. Through a comprehensive analysis, the study segregated different parking scenarios based on their nature and subsequently synthesized the findings into a concise summary.

Table 38: Bicycle parking regulation requirement (BPRR) Central tendencies

Central tendencies	Parking/ residential units	shops	Commercial parking/ 1000m^2	Industrial place	Sports & recreations place
Mean	1.25	24	**13.23**	**12.8**	34
Median	1.5	**22.5**	15.5	15	30
Mode	**1.5**	20	20	20	**30**
Max	2	30	20	20	50
Min	0.25	15	3.3	4	25

In determining BPRR, we tailor our selection of values—mean, median, and mode—based on individual cases. The summary benchmarks for various settings are as follows: 1.5, the mode value for residential units; 22.5, the median value for shops; 13.23, the mean value for commercial parking per 1000m^2; 12.8, the mean value for industrial spaces; and 30, the mode value for sports and recreational area.

Performance of Mixed Land Use (PMLU)

As Calculation shown in Appendix K; In order to assess the performance of mixed land usage, a multifaceted approach is employed, integrating multi-criteria techniques and RII evaluation methodologies. This comprehensive analysis aims to identify central tendencies within the dataset, considering various variables. Subsequently, the findings are presented graphically for enhanced visualization and interpretation, as illustrated below.

From the analysis of the Performance of Mixed Land Use (PMLU) strategical information fairly symmetric distribution with a moderate level of variability. While the mean and median are close, indicating consistency, there is some spread around the mean. Therefore, the conclusion drawn from this data is that the variable under consideration demonstrates a moderately stable pattern with some variability around the central tendency. We take the median 0.84 as the benchmarks form our study.

Bicycle Network Length per Number of Railway Stations (BLPNR) & Bicycle Length per Length of Railway Network (BLPRL)

As Calculation shown in Appendix K; The dataset has undergone thorough analysis, allowing us to extract meaningful insights and trends. Subsequently, the results have been meticulously plotted and are presented below for clear visualization and interpretation.

The values for Railway Population Percentage (RPP) and Bicycle Population Percentage (BPP) exhibit a wide range of variations, influenced by factors such as city population and economic conditions. In order to establish benchmarks, we have selected the mean values for both RPP and BPP, which are 33.4 and 25.4 respectively.

Railway Population Percentage (RPP) & Bicycle Population Percentage (BPP)

After conducting the analysis, we have opted for the railway population percentage and bicycle population percentage Netherlands and/or USA data points that closely approximate the mean values derived from our investigation. This selection process ensures that the chosen data points effectively represent the mean values of the analysis, providing a reliable basis for further examination and decision-making.

Share Bike Single Ride Fee (SBSRF) & Share Bike Monthly Subscription Fee (SBMSF)

The analysis of the fee structure of shared micro-mobility services is presented, focusing on determining the mean and standard deviation values of the dataset. This comprehensive examination allows us to understand the central tendency and variability inherent in the fee structures, providing valuable insights into the distribution and range of pricing within the shared micro-mobility market.

Among the fee structures analysed, those of Spain, Germany, and the USA exhibit greater acceptability, being closer to the mean rate observed in our study. Conversely, the monthly rate in Denmark and the single ride fee structures in the Netherlands and Norway deviate significantly from the standard rate. Based on this analysis, we can ascertain the metrics values of SBSRF and SBMSF, shedding light on their comparative effectiveness and alignment with the established standards.

Share Bike Single Ride Fee (SBSRF) and Share Bike Monthly Subscription Fee (SBMSF), it is prudent to consider the mean values as most suitable. Accordingly, the mean fee for a single ride is $2, while for a monthly subscription, it is $16.5.

Tax for Share Bicycle Providers (TSBP)

In order to conduct a comprehensive analysis and determine the mean, median, and standard deviation from the dataset, we have plotted the following graphical representation to present additional insights and information. This graphical display enhances the understanding of the dataset's distribution and variability, facilitating a more thorough examination of the data and its characteristics.

Tax for Share Bicycle Providers (TSBP) strategies are fairly symmetric distribution with a moderate level of variability. While the mean and median are close, indicating consistency, there is some spread around the mean. I select the mean value 16% for the benchmark for our study.

Engagement Performance for Bicycling (EPB)

To conduct a comprehensive multi-criteria analysis, particularly when factors are identified with equal scores, it is imperative to employ robust methodologies. In this context, the first step involves calculating central tendencies and variables derived from the dataset collected across various cities. By meticulously analysing these metrics, we aim to present a nuanced understanding of the comparative factors influencing our analysis.

Table 39: Engagement Performance for Bicycling (EPB)

Criteria	Singapore	Aarhus	Madtid	Bordeaux	Hamburg	Eindhovan	Gothenburg	Tokyo	Oslo	Oakland
Language Consideration	9.15	7.05	6.97	6.3	5.9	6	6.82	9.27	8.9	5.57
Cultural Sensitivity	8.62	7.55	7.35	7.2	6.47	6.72	7.35	8.67	8.87	6.77
Feedback Mechanism	8.25	6.92	3.75	3.65	6.8	4	3.92	8.45	8.4	5.87
Education Campaigns	7.45	4.57	5.77	5.15	5.35	4.6	5.35	9.5	7.92	8
Cyclist Events	4.07	3.62	3.82	3.75	6.7	3.92	3.87	8.45	6.92	6.67
Average score	**7.51**	**5.95**	**5.54**	**5.21**	**6.25**	**5.05**	**5.47**	**8.87**	**8.21**	**6.58**

Engagement Performance for Bicycling analysis suggests that the data exhibits a slightly positively skewed distribution with a moderate level of variability. While the mean and median are close, indicating consistency, there is some spread around the mean. Take the means value 6.46 as benchmark from our study outcome.

Bicycle Regulation Enforcement Performance (BREP)

As Calculation shown in Appendix K; In order to undertake a thorough multi-criteria analysis, especially when factors carry equal weight, it is crucial to utilize rigorous methodologies. The initial phase entails computing central tendencies and variables extracted from the dataset gathered across diverse cities. Through meticulous examination of these metrics, our goal is to provide a nuanced comprehension of the comparative factors that impact our analysis.

Bicycle Regulation Enforcement Performance (BREP) mean value of 5.33 and the median value of 5.02 suggest that the data is slightly positively skewed, with the mean slightly higher than the median. This indicates that there may be some higher values pulling the mean up, variable under consideration demonstrates a moderately stable pattern can recommend to take the mean 5.33 as our reference.

5.3.3 User convenience

Performance of information technology for bicyclist (PITB)

As Calculation shown in Appendix K; Data analysis on this part, to determine the suitable figure of performance and find the optimal benchmarks, involves utilizing central tendencies and variables to analyse the data comprehensively. Through this process, we delve into the dataset to identify key performance indicators and establish metrics that effectively capture the nuances of the analysed factors.

Performance of information technology for bicyclist (PITB) mean value of 6.03 and the median value of 5.47 suggest that the data is slightly positively skewed, with the mean slightly higher than the median. This indicates that there may be some higher values pulling the mean up and the standard deviation (SD) of 1.23 and the coefficient of variation (CV) of 20.35% suggest a moderate level of variability within the data set. This implies that the observations are dispersed around the mean, with some degree of fluctuation. We can consider the mean values as the reference.

Performance of Amenities for Bicyclists (PAB)

As Calculation shown in Appendix K; The same application was repeated, and an in-depth analysis of the dataset was conducted, yielding the following results. In this iterative process, the application was once again employed to gather data, ensuring consistency and reliability in the dataset.

From the analysis of performance of amenities for bicyclists (PAB) mean value of 6.22 and the median value of 5.92 indicate a moderately positively skewed distribution, with the mean slightly higher than the median. This suggests that there may be some higher values pulling the mean up and standard deviation (SD) of 0.95 and the coefficient of variation (CV) of 15.28% suggest a moderate level of variability within the data set. This implies that the observations are dispersed around the mean, with some degree of fluctuation. Again, take the mean value as our references.

Performance of Accessibility for Bicyclists (PAFB)

An extensive examination of the dataset was carried out as calculation shown in Appendix K, resulting in the presentation of the subsequent findings. Through this iterative procedure, the application was redeployed to collect data, emphasizing the importance of maintaining consistency and reliability in the dataset.

Also apply the same techniques to Performance of Accessibility for Bicyclists (PAFB) we conclude that moderately positively skewed distribution with a moderate to high level of variability. While the mean and median are relatively close, indicating some consistency, there is notable spread around the mean. Mean value 6.66 set as the benchmark from our study.

5.3.4 Network connectivity

Evaluation of Comprehensive Network Coverage (ECNC)

As shown in Appendix K; do the comprehensively analyze the collected data and discern the intricate patterns within the dataset, it is imperative to conduct a thorough examination. This entails not only determining the dataset's behavior but also delving into its underlying dynamics.

To achieve this, calculating central tendencies becomes indispensable. By computing measures such as the mean, median, and mode, one can gain a deeper understanding of the dataset's central values and its distribution across different variables.

Performance of Bicycle Interconnectivity (PBI)

As shown in Appendix K; conduct a comprehensive analysis of the collected data and gain insights into the behaviour of the dataset, it is imperative to employ various statistical techniques. One essential step involves calculating the central tendencies, including measures such as the mean, median, and mode. These central tendency values serve as pivotal reference points, providing a concise summary of the dataset's central or representative values.

Performance of Infrastructure Standards (PIS)

As shown in Appendix K; examination of the gathered data and acquire a deep understanding of the dataset's dynamics, it is crucial to utilize diverse statistical methodologies. A key procedural component entails the computation of central tendencies, encompassing statistical metrics like the mean, median, and mode. These central tendency metrics function as crucial benchmarks, delivering a succinct overview of the core or representative values within the dataset.

Performance of Strategic Route Plan (PSRP)

As calculation shown in Appendix K; examination of the gathered data and uncover insights into the dataset's behaviour, employing diverse statistical methodologies is crucial. Among these methodologies, calculating central tendencies emerges as a fundamental step, encompassing metrics such as the mean, median, and mode. These central tendency metrics serve as pivotal anchors, succinctly summarizing the dataset's core or representative values.

Performance of connectivity to neighborhoods and communities (PCNC)

To undertake a thorough analysis of the gathered data and grasp the nuances of the dataset's behaviour, it's crucial to utilize a range of statistical methodologies. Among these methods, calculating central tendencies emerges as a pivotal aspect. Central tendency metrics such as the mean, median, and mode offer succinct summaries of the dataset's core values, guiding the analysis with clarity and precision. These metrics serve as essential reference points, facilitating a deeper understanding of the dataset's underlying trends and patterns. Network metrics such as Evaluation of Comprehensive Network Coverage (ECNC), Performance of Bicycle Interconnectivity (PBI), Performance of Infrastructure Standards (PIS), Performance of Strategic Route Plan (PSRP) and Performance of connectivity to neighbourhoods and communities (PCNC) data Patten similar which is data exhibits a somewhat skewed distribution with a moderate to elevated level of variation. Although the mean and median are fairly proximate, suggesting a degree of consistency. Select the mean value as benchmark from this study.

5.3.5 Safety & security

Performance of Separation of Bicycles (PSB)

In the context of the relevant query, we meticulously analysed the gathered data to discern the central tendencies and variables inherent within the dataset. Our objective was to delve into the performance of individual lanes, seeking to extract valuable insights that could inform decision-making processes. Below, we present a breakdown of lane-specific performance metrics and corresponding values. Select the mean value as benchmark from this study.

Performance of intersection safety (PIS)

Analysing intersection safety for bicyclists entails a comprehensive examination of core findings derived from the data. It is crucial to scrutinize strategic information that aids in conducting this analysis effectively. Below, we present the results obtained from this analysis for further review and interpretation. Select the mean value as benchmark from this study.

Performance of conflict reduction (PCR)

In conducting an in-depth analysis of confit reduction for bicyclists, we focus on the core foundations of this critical issue. We meticulously examine strategic information that aids in our analysis, delving into various factors that influence bicyclist safety at road. Below, we present the results obtained from this comprehensive analysis, shedding light on key findings and insights essential for enhancing confit reduction for bicyclists. Select the mean value as benchmark from this study.

Performance of traffic calming measures (PTCM)

The analysis of traffic calming measures safety for bicyclists is conducted with a focus on core foundational elements. Strategic information crucial for this analysis is examined to provide comprehensive insights. The results of this analysis are presented below for further examination and consideration. Select the mean value as benchmark from this study.

5.4 Summarized the benchmarks

To establish meaningful benchmarks for each metric, we start by analysing the central tendencies and variables within each data set. This thorough analysis allows us to determine standard values and variations that will serve as reference points.

The following table summarizes these benchmarks, providing a clear overview of the expected ranges and averages for each metric. This data-driven approach ensures that our benchmarks are both accurate and reflective of the underlying trends in the data.

Summary of metrics benchmark in Appendix L

5.5 Comparison the Metrics Sri Lankan City (Colombo)

In Colombo city, bicycle transportation has not yet been actively promoted. As a result, we are currently unable to gather quantitative data related to the bicycle network, such as the length of the network, parking data, shared bicycle usage statistics, and funding mechanisms. However, we have collected similar data from surveys, which provide insights into the satisfaction levels of end users.

To make meaningful comparisons between qualitative and quantitative data, we must consider suitable assumptions. This approach will help us bridge the gap created by the lack of quantitative data on the bicycle network. Through these assumptions, we can estimate the potential impacts and benefits of promoting bicycle transportation in Colombo, thereby making informed recommendations for future infrastructure development and policy initiatives.

Infrastructure: We assume that the benchmark values for metrics that cannot currently be measured in Colombo City are set at a performance score of 7. This assumption provides a standardized reference point, enabling us to evaluate and compare various aspects of bicycle transportation, even in the absence of specific local data. By using this assumed benchmark, we can better assess the potential effectiveness and impact of proposed improvements and initiatives in the city's bicycle network.

Table 40: Infrastructure metrics comparison

Metrics	Benchmark	Units	Converted Benchmark	Colombo
BND	2.49	Km/Km2	7	1.36
PDBN	3368.71	Km^3/ No of people	7	1.42
BLP	0.86	RII Value	8.6	1.56
TSPC	0.77	RII Value	7.7	1.53
IPC	0.78	RII Value	7.8	1.53
BPP	0.84	RII Value	8.4	1.67
SBP	0.82	RII Value	8.2	1.33
SBPR	7.85	Percentage	7.85	-
SBR	26.82	Million USD/ annum	26.82	-
SBRG	0.04	Percentage	0.04	-
SBER	5.45	Percentage	5.45	-

Regulatory environment: The infrastructure and speed-related regulations in developed cities are typically sufficient to create a safer and more convenient environment for bicycle transportation. Consequently, when converting these values to a performance score, we can assume that they achieve the maximum value, which is 10, and other score consider 7. This assumption reflects the high standards of safety and convenience found in well-developed urban areas, serving as an ideal benchmark for evaluating similar initiatives in other contexts.

Table 41: Regulatory environment metrics comparison

Metrics	Benchmark	Units	Converted	Colombo
BLWR	2, 3	m	10	0.56
BDS	30	Km/h	10	0.61
BRS	20	Km/h	10	1
BTR	20	m	10	1.06
BSSD	30	m	10	1.42
BPRR	22.5	Median vale of	7	1.47
PMLU	0.83	RII Value	0.83	1.5
BLPNR	3.91	Median Unit	7	1.86
BLPRL	2.465	Median number	7	1.5
RPP	33.4	Mean percentage	7	1.61
BPP	25.4	Mean percentage	7	1.19
SBSRF	2	USD	7	1.44
SBMSF	16.5	USD	7	1.78
TSBP	16%	Mean percentage	7	2.14

User convenience:

Table 42: User convince metrics comparison

Metrics	Benchmark	Colombo
PITB	6.03	2.25
PAB	6.22	1.78
PAFB	6.66	2

The benchmark data is already aligned with the scoring method, eliminating the need for any conversions. This allows us to directly compare the performance of various metrics in the Sri Lankan city of Colombo against these benchmarks. By using this direct comparison approach, we can accurately assess Colombo's performance in areas user convenience relative to established standards. This method ensures clarity and precision in our evaluation, facilitating more effective decision-making and planning for future improvements.

Network connectivity:

Table 43: Network connectivity metrics comparison

Metrics	Benchmark	Colombo
ECNC	6.93	1.69
PBI	6.76	1.39
PIS	6.39	1.69
PSRP	7.04	1.5
PCNC	6.68	1.69

The benchmark data has already been established using a scoring method, which means no further conversion is required. This allows us to directly compare the performance metrics of Colombo, Sri Lanka, against these benchmarks. By utilizing the same scoring system, to compare the Network connectivity metrics.

Safety & security:

Table 44: Safety & Security metrics comparison

Metrics	Benchmark	Colombo
PSB	6.4	1.78
PIS	6.81	1.64
PCR	6.82	1.78
PTCM	6.78	2.03

We have utilized benchmark data along with a scoring method, eliminating the need for any conversions. This approach allows us to directly compare the safety & security performance of various metrics in Colombo, Sri Lanka, against established benchmarks.

CHAPTER 6: CONCLUSION & RECOMMENDATION

The comprehensive analysis presented in this report underscores the critical importance of promoting micro-mobility solutions, particularly bicycle transportation, within urban environments like Colombo. Despite the current lack of bicycle-specific infrastructure and data in Colombo, the study effectively utilizes benchmarks from other micro-mobility-promoted cities to draw meaningful comparisons and insights. This approach highlights not only the potential benefits but also the urgency of implementing robust bicycle transportation systems.

The research reveals significant gaps in Colombo's bicycle infrastructure, regulatory environment, user convenience, network connectivity, and safety and security compared to established benchmarks. These findings highlight areas where targeted improvements are necessary to foster a more bicycle-friendly environment. The lack of adequate infrastructure and regulatory frameworks significantly hampers the adoption of bicycles as a viable mode of transportation, impacting overall user experience and safety.

The use of benchmark data and a standardized scoring method allows for a clear and precise comparison, making it evident that Colombo falls short in several key metrics. For instance, the city's scores in user convenience, network connectivity, and safety are considerably lower than those in more developed micro-mobility cities, pointing to specific areas needing immediate attention and enhancement. These gaps underline the need for a comprehensive strategy to develop and promote micro-mobility.

As our conclusion Colombo city far fall from the benchmark values that need the progressive improvement to achieve the required standard, this study recommends the 5 stages to achieve the micro mobility promoted city level performance.

6.1 Stage of development bicycle mobility in Colombo city

Stage 1: Start use the current infrastructure in effective manner (Benchmark rise to 3)

To enhance bicycle usage in Colombo city, the first step is to address the societal perception of bicycles as a "poor man's vehicle." This mindset needs to shift towards recognizing bicycles as a sustainable, healthy, and modern mode of transportation. Our study also said in promoted cities 25%of user use to go for school/ work, Efforts to educate the public can start with schools, where daily assemblies include talks on sustainability and the benefits of cycling. Similarly, workplaces can introduce cycling as a viable commuting option through awareness campaigns. Media and social media platforms play a critical role in promoting cycling culture, leveraging influencers and ambassadors to advocate for its benefits and normalize its use.

Colombo's existing cycling infrastructure faces challenges such as unauthorized motor traffic on bicycle pathways and vehicles parked illegally, causing accidents and inconveniences for cyclists. Strict enforcement of regulations is crucial to reclaim and maintain the safety and functionality of these pathways. Authorities must implement penalties for motor vehicles encroaching on bicycle lanes and ensure that pathways remain clear for cyclists.

Additionally, roadside parking along Colombo’s shoulders is a persistent issue, impacting both motor traffic and the potential for safe cycling routes. Implementing strict regulations to remove roadside parking and reallocating this space for demarcated bicycle pathways can greatly enhance safety and encourage more people to cycle.

In cities promoting micromobility, innovative solutions like constructing shared pathways over covered drains parallel to pedestrian walkways have been successful. Such pathways, designed with sufficient width and clear separation for pedestrians and cyclists, can create safer and more accessible routes in Colombo.

Signage is another fundamental factor in ensuring cyclist safety. Installing clear, visible signs along cycling routes can guide both cyclists and motorists, reducing conflicts and enhancing awareness.

Addressing the lack of secure bicycle parking is vital. Authorities should designate spaces for bicycle parking at key locations such as railway stations, workplaces, schools, and bus stands, making cycling a convenient and practical choice for daily commuters.

Stage 2: Policy and regulatory framework (Benchmark rise to 4)

The second stage focuses on introducing supportive policies and incentives to make cycling in Colombo more appealing and practical for the public.

One critical step is to introduce and strictly enforce cyclist-friendly traffic laws. These laws should include clear rules for sharing the road with cyclists, along with strict penalties for motorists who violate these regulations, such as encroaching on cycling lanes or endangering cyclists. Creating a legal framework that prioritizes the safety of cyclists sends a strong message about the city's commitment to sustainable transportation and helps build confidence among potential cyclists.

To encourage more people to take up cycling, financial incentives can play a transformative role. Offering tax benefits, subsidies, or discounts on bicycles and cycling gear will make the switch to cycling more affordable and attractive. These incentives can target different demographics, including students, employees, and families, further breaking the perception of cycling as a low-status mode of transport and highlighting its economic benefits.

Collaboration between government agencies, private developers, and local communities is vital for the success of this stage. Regular consultations with stakeholders can help identify challenges and tailor solutions to meet the city's specific needs.

Stage 3: Expanding Cycling Infrastructure and Support Facilities (Benchmark rise to 6)

The third stage focuses on expanding Colombo's cycling infrastructure by utilizing existing natural and urban spaces, creating dedicated pathways, and introducing essential support facilities. These improvements aim to enhance connectivity, convenience, and safety for cyclists.

Colombo's rivers, canals, and parks offer significant potential for developing scenic and functional cycling pathways. Creating pathways along these natural corridors can provide cyclists with safe, traffic-free routes while also enhancing the city's appeal as a sustainable and environmentally conscious urban center. Inspired by successful initiatives in micromobility-promoted cities, such pathways could be part of a "Park Connector" system, linking parks, waterways, and urban neighborhoods into a cohesive cycling network. This interconnected system would not only improve mobility but also encourage recreational cycling and active lifestyles.

In addition to leveraging natural spaces, dedicated cycling pathways should be integrated into the city's broader transportation network. These pathways can be established alongside highways, main roads, and arterial routes, ensuring that cyclists have safe and uninterrupted access to key destinations. Proper demarcation, safety barriers, and regular maintenance will be critical in ensuring the usability and safety of these routes.

To support cyclists on their journeys, it is essential to establish support stations at strategic locations. These stations should include basic facilities such as air pumps, tools for minor repairs, and water refill points. Partnerships with private companies, such as gas stations or convenience store chains, can make these stations more accessible and cost-effective. These businesses can co-brand the facilities, creating a win-win situation that benefits both cyclists and the participating companies.

By creating well-connected pathways, ensuring safe cycling routes along major roads, and facilitating convenient support stations, this stage aims to make cycling in Colombo more accessible and enjoyable. These enhancements will encourage more residents to adopt cycling as a practical, efficient, and sustainable mode of transport, further solidifying Colombo's position as a cyclist-friendly city.

Stage 4: Integrating Cycling with Public Transportation and Introducing Shared Bicycle Systems (benchmark rise to 8)

The fourth stage focuses on enhancing the integration of cycling with other modes of transportation and introducing modern shared bicycle systems. These initiatives aim to increase the convenience and accessibility of cycling, enabling it to serve as a practical solution for first- and last-mile connectivity.

To achieve seamless interconnectivity, dedicated cycling pathways should be developed to link major transportation hubs, such as train and bus interchanges. These pathways should provide safe and direct access to these destinations, supported by secure parking facilities for bicycles. By offering convenient connections, this approach will encourage more people to cycle to transit stations, increasing the overall use of sustainable transportation and reducing dependency on private vehicles.

The introduction of a shared bicycle system can significantly enhance cycling accessibility in Colombo. Studies from other micromobility-promoted cities reveal that up to 53% of people prefer shared bicycles for their convenience and affordability. A shared bicycle system would allow residents and visitors to rent bicycles for short trips, making cycling an easy and cost-effective option. Agreements with service providers and investors are crucial to establishing and maintaining this system. These partnerships can bring in expertise, technology, and funding, ensuring a successful rollout and operation.

To further support the shared bicycle system and improve the overall cycling experience, a dedicated mobile application should be developed. This app can provide real-time navigation, show the availability of shared bicycles at docking stations, and suggest safe and efficient routes for cyclists. By integrating these features, the app can simplify trip planning, enhance user convenience, and attract more people to the system.

As our study also majority of people use the bicycle for first and last millage, 41% use for 1-2Km ride. By creating strong interconnectivity with public transport, introducing shared bicycle services, and leveraging technology, this stage will expand cycling's reach and usability in Colombo. These improvements will encourage more people to adopt cycling as part of their daily commute, supporting the city's goals for sustainable and inclusive urban mobility.

Stage 5: Sustainable and Inclusive Cycling Culture (benchmark rise to 9)

The final stage focuses on fostering an inclusive cycling culture in Colombo while using data-driven strategies to refine and expand cycling initiatives. This approach ensures that cycling becomes a universally accessible and sustainable mode of transportation for all demographics.

To make cycling infrastructure truly inclusive, it is essential to design pathways and facilities that cater to children, seniors, and people with disabilities. Dedicated spaces for beginner cyclists, wider lanes for adaptive bicycles, and features like gentle ramps and tactile signage can ensure that cycling is safe and enjoyable for everyone. By prioritizing inclusivity, Colombo can position cycling as a mode of transport that transcends age, ability, and social barriers.

City-wide cycling events, marathons, and advocacy drives are powerful tools to normalize and celebrate cycling culture. Organizing regular events, such as "Cycling Sundays" or community rides, can bring people together and showcase the benefits of cycling.

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APPENDIX A

SUB-METRICS CLASSIFICATION

No	Infrastructure	Regulatory environment	User convenience	Network connectivity	Safety & security
1	Length of bicycle lane	Traffic laws and regulations	Information technology	Comprehensives network coverage	Separation from motor vehicle traffic
2	Type of bicycle lane	Land use regulations	Amenities	Interconnectivity with other modes of transportation	Intersection safety
3	Traffic Signal	City transportation planning	Accessibility	Consistent infrastructure standards	Conflict points
4	Intersection improvement	Funding mechanisms		Strategic route planning	Traffic calming measures
5	Parking	Public engagement		Connectivity to adjacent neighborhoods and communities	Bicycle-friendly infrastructure design
6	Shear bicycle program	Enforcement		User feedback and input	Education and awareness

APPENDIX B

SUMMARISE THE METRICS FOR STUDIES

Subjects	Metrics	Metrics identity
Bicycle infrastructure		
Length of bicycle network	Bicycle Network Density	BND
	Population Density Index Relative to Bicycle Network	PDBN
Type of lane & performance.	Bicycle Lane Performance	BLP
Bicycle traffic signal & crossing	Traffic Signal Performance for Cyclists	TSPC
Intersection improvement/ facilities for cyclist	Intersection Performance for Cyclists	IPC
Parking facilities for cyclist	Bicycle Parking Performance	BPP
Shear bicycle program	Share Bicycle Performance	SBP
	Share Bicycle Penetration Rate	SBPR
	Share Bicycle Revenue	SBR
	Share Bicycle Revenue Growth	SBRG
	Share Bicycle Expected User Ratio	SBER
Regulatory environment		
Traffic laws and regulations	Bicycle Lane Width Requirement	BLWR
	Bicycle Design Speed	BDS
	Bicycle Recommended Speed	BRS
	Bicycle Turning Radius	BTR
	Bicycle Stopping Sight Distances	BSSD
Land use regulations	Bicycle parking regulation requirement	BPRR
	Performance of Mixed Land Use	PMLU
City transportation planning	Bicycle Network Length per Number of Railway Stations	BLPNR
	Bicycle Length per Length of Railway Network	BLPRL
	Railway Population Percentage	RPP
	Bicycle Population Percentage	BPP

Funding mechanisms	Share Bike Single Ride Fee	SBSRF
	Share Bike Monthly Subscription Fee	SBMSF
	Tax for Share Bicycle Providers	TSBP
Public engagement	Engagement Performance for Bicycling	EPB
Enforcement	Bicycle Regulation Enforcement Performance	BREP
User convenience		
Information technology	performance of information technology for bicyclist	PITB
Amenities for cyclist	Performance of Amenities for Bicyclists	PAB
Accessibility	Performance of Accessibility for Bicyclists	PAFB
Network connectivity		
Comprehensives network coverage	Evaluation of Comprehensive Network Coverage	ECNC
Interconnectivity with other modes of transportation	Performance of Bicycle Interconnectivity	PBI
Consistent infrastructure standards	Performance of Infrastructure Standards	PIS
Strategic route planning	Performance of Strategic Route Plan	PSRP
Connectivity to adjacent neighbourhoods and communities	performance of connectivity to neighborhoods and communities	PCNC
Safety & security		
Separation from motor vehicle traffic	Performance of Separation of Bicycles	PSB
Intersection safety	Performance of intersection safety	PIS
Conflict points	performance of conflict reduction	PCR
Traffic calming measures	performance of traffic calming measures	PTCM

APPENDIX C

SUMMARY OF DATA COLLECTION METHODS

Subjects	**Metrics**	**Method of data collection**
	Bicycle infrastructure	
Length of bicycle network	Bicycle Network Density	Data from the published Articles, and/ or official government authority webpages
	Population Density Index Relative to Bicycle Network	Data from the published Articles, and/ or official government authority webpages
Type of lane & performance.	Bicycle Lane Performance	Case studies, and unstructured interview
Bicycle traffic signal & crossing	Traffic Signal Performance for Cyclists	Case studies, and unstructured interview
Intersection improvement/ facilities for cyclist	Intersection Performance for Cyclists	Case studies, and unstructured interview
Parking facilities for cyclist	Bicycle Parking Performance	Case studies, and unstructured interview
Shear bicycle program	Share Bicycle Performance	Case studies, and unstructured interview
	Share Bicycle Penetration Rate	Data from the published Articles, and/ or official government authority webpages
	Share Bicycle Revenue	Data from the published Articles, and/ or official government authority webpages
	Share Bicycle Revenue Growth	Data from the published Articles, and/ or official government authority webpages
	Share Bicycle Expected User Ratio	Data from the published Articles, and/ or official government authority webpages
	Regulatory environment	
Traffic laws and regulations	Bicycle Lane Width Requirement	Data from the published Articles, and/ or official government authority webpages
	Bicycle Design Speed	Data from the published Articles, and/ or official government authority webpages
	Bicycle Recommended Speed	Data from the published Articles, and/ or official government authority webpages

	Bicycle Turning Radius	Data from the published Articles, and/ or official government authority webpages
	Bicycle Stopping Sight Distances	Data from the published Articles, and/ or official government authority webpages
Land use regulations	Bicycle Parking in Residential Areas	Data from the published Articles, and/ or official government authority webpages
	Bicycle Parking in Shops	Data from the published Articles, and/ or official government authority webpages
	Bicycle Parking in Commercial Places	Data from the published Articles, and/ or official government authority webpages
	Bicycle Parking in Industrial Places	Data from the published Articles, and/ or official government authority webpages
	Bicycle Parking in Recreational Places	Data from the published Articles, and/ or official government authority webpages
	Performance of Mixed Land Use	Case studies, and unstructured interview
City transportation planning	Bicycle Network Length per Number of Railway Stations	Data from the published Articles, and/ or official government authority webpages
	Bicycle Length per Length of Railway Network	Data from the published Articles, and/ or official government authority webpages
	Railway Population Percentage	Data from the published Articles, and/ or official government authority webpages
	Bicycle Population Percentage	Data from the published Articles, and/ or official government authority webpages
Funding mechanisms	Share Bike Single Ride Fee	Data from the published Articles, and/ or official government authority webpages
	Share Bike Monthly Subscription Fee	Data from the published Articles, and/ or official government authority webpages
	Tax for Share Bicycle Providers	Data from the published Articles, and/ or official government authority webpages
Public engagement	Engagement Performance for Bicycling	questionnaire surveyor
Enforcement	Bicycle Regulation Enforcement Performance	questionnaire surveyor

User convenience		
Information technology	performance of information technology for bicyclist	questionnaire surveyor
Amenities for cyclist	Performance of Amenities for Bicyclists	questionnaire surveyor
Accessibility	Performance of Accessibility for Bicyclists	questionnaire surveyor
Network connectivity		
Comprehensives network coverage	Evaluation of Comprehensive Network Coverage	questionnaire surveyor
Interconnectivity with other modes of transportation	Performance of Bicycle Interconnectivity	questionnaire surveyor
Consistent infrastructure standards	Performance of Infrastructure Standards	questionnaire surveyor
Strategic route planning	Performance of Strategic Route Plan	questionnaire surveyor
Connectivity to adjacent neighbourhoods and communities	performance of connectivity to neighborhoods and communities	questionnaire surveyor
Safety & security		
Separation from motor vehicle traffic	Performance of Separation of Bicycles	questionnaire surveyor
Intersection safety	Performance of intersection safety	questionnaire surveyor
Conflict points	performance of conflict reduction	questionnaire surveyor
Traffic calming measures	performance of traffic calming measures	questionnaire surveyor

APPENDIX D

TYPE OF BICYCLE LANE AVAILABLE ON EACH CITIES

City	Type of bicycle lane on cities
Singapore	Shared pathway , On road bicycle lane , Park connectors, & Designated cycling path
Denmark – Aarhus	Bicycle Tracks, Bicycle Lanes , Green Routes , Shared Bicycle and Pedestrian Paths, & Bike-friendly Streets
Spain- Madtid	Segregated Bicycle Lanes, Buffered Bicycle Lanes, Contraflow Bicycle Lanes, Shared Bicycle and Pedestrian Paths, Bicycle Boulevards , & Bike Lanes on Urban Roads
France- Bordeaux	Separated Bicycle Lanes, Buffered Bicycle Lanes, Contraflow Bicycle Lanes, Shared Bicycle and Pedestrian Paths, Bicycle Priority Streets
Germany- Hamburg	Segregated Bicycle Lanes, Buffered Bicycle Lanes Contraflow Bicycle Lanes, Shared Bicycle and, Pedestrian Paths, Bicycle Priority Streets , Bicycle Highways
Netherland- Eindhovan	Segregated Bicycle Lanes, Buffered Bicycle Lanes Red Asphalt Bicycle Lanes, Two-Way Bicycle Lanes Shared Bicycle and Pedestrian Paths, Bicycle Streets
Sweden- Gothenburg	Segregated Bicycle Lanes, Buffered Bicycle Lanes Bicycle Paths, Shared Bicycle and Pedestrian Paths Bicycle Boulevards
Japan- Yokosuka	Shared Sidewalks, Bicycle Lanes, Segregated Bicycle Paths, Bicycle-Friendly Roads
Norway- Oslo	Segregated Bicycle Lanes, Buffered Bicycle Lanes Bicycle Paths, Bicycle Streets, Shared Bicycle and Pedestrian Paths, Green Lanes
USA- Oakland	Buffered Bicycle Lanes, Conventional Bicycle Lanes Protected Bicycle Lanes, Shared-Use Paths, Neighbourhood Greenways, Bike Lanes on Urban Roads

APPENDIX E

TYPE OF INTERSECTION AVAILABLE FOR CYCLIST IN EACH CITIES

City	Intersection improvement
Singapore	Bicycle boxes, Advance stop line, Bicycle turning box-, & Protected intersection
Denmark – Aarhus	Advanced Stop Lines and Boxes, Bicycle-Specific Signal Phases, Protected Bicycle Intersections, Roundabouts with Dedicated Cycling Infrastructure, & Bicycle-Priority Crossings
Spain- Madtid	Bicycle lane, Bike box, Protected Bicycle Intersections, Green paint marking, & Roundabouts
France- Bordeaux	Advanced Stop Lines , Protected Bicycle Intersections Roundabouts , Shared space and zone , Signage and wayfinding
Germany- Hamburg	Bicycle lane/ tracks , Advanced Stop Lines , Protected Bicycle Intersections, Roundabouts , Zebra crossing , Bicycle priority zone, Green paint marking, wayfinding
Netherland- Eindhovan	Protected Bicycle Intersections, Bike box, Roundabouts Bicycle priority zone, Separate bike crossing, Roundabout
Sweden- Gothenburg	Protected Bicycle Intersections, Bike box, Roundabouts Green paint marking, Traffic calming measures
Japan- Yokosuka	Protected Bicycle Intersections, Bike box, Roundabouts Green paint marking, Traffic calming measures, Shared space and zone
Norway- Oslo	Bicycle lane, Protected Bicycle Intersections, Bike box Roundabouts , Shared space and zone, Green paint marking
USA- Oakland	Bicycle lane, Protected Bicycle Intersections, Bike box,, Sharrows, Green paint marking, Wayfinding, Traffic calming measures

APPENDIX F

TYPE OF PARKING FACILITIES AVAILABLE EACH IN CITIES

City	Parking
Singapore	Public transportation parking, Park connector parking Residential parking, Commercial area parking Recreation area parking , Parking in public institution
Denmark – Aarhus	Public transportation parking, Bike shear station Cycle street and land parking, Parking in public institution, Recreation area parking
Spain-Madtid	BiciMAD bike shearing park, Public transportation parking, Public plaza and parks, Parking in public institution
France-Bordeaux	Bicycle tracks. , V^3 Bike shear parking, Tram & Bus stops parking, Cycle lane park, Parking in public institution
Germany-Hamburg	Cycle lane park, Parking in public institution Bicycle tracks, Train and bus station
Netherland-Eindhovan	Bicycle tracks, Train and bus station, Shear bike provides , Carryout the urban development project
Sweden-Gothenburg	Bicycle tracks, Public transportation integration Shear bike provides , Parking in public institution Carryout the urban development project
Japan-Yokosuka	Bicycle friendly roads: those roads include the parking facilities too, Train station, Shear bike provides Carryout the urban development project, Residential area
Norway-Oslo	Bicycle tracks, Public transportation integration Shear bike provides , Parking in public institution Carryout the urban development project
USA-Oakland	Bicycle tracks, Public transportation integration Shear bike provides , Parking in public institution Carryout the urban development project

APPENDIX G

FACILITIES SUPPORTED FOR SHEAR BICYCLE PROGRAM & SHARE BICYCLE PROVIDER NAME

City	Support facilities for shear bicycle program	Provider's
Singapore	Good bicycle path and lanes: safe designated lanes Park connectors: Npark arrangement with environmental friendly Park and ride facility: MRT station and bus interchanges Rental Kiosks Government supports & initiatives	oBike ofo Mobike SG bike Anywheel Grabcycle WhizBike
Denmark – Aarhus	Provide the good Citywide cycling infrastructure Aarhus Bycyklen program which is supportive for shear bicycle in cities. Offered the grate parking facilities in numerous places Cycle supper highways which is helped for long ride Bike rental shops	Aarhus Bycyklen Donkey republic Swapfiets Various local rental shops
Spain- Madtid	BiciMAD public bicycle shearing system Good cycling infrastructure CicloRutas designated route provide the comfortable and space for travel. Bicycle rental shops City initiatives and promoting action for cycle users.	BiciMAD Lime Donkey republic oBike Other local rental shops
France- Bordeaux	Vcub official shear bike program Transport Bordeaux metropole and other intergrated transportation systems. Local initiatives and promoting action	Vcub Lime Donkey republic Blablabike Other local rental shops
Germany- Hamburg	StadtRAD hamburg official bike sharing program Bicycle friendly lane and roads HVV- supportive Hamburg public transport system	StadtRAD hamburg Call a bike Lime Donkey republic

	City initiatives and promoting action for cycle users.	Next bike
Netherland- Eindhovan	OV-fiets official bike shear program Supportive local transport authorities Bicycle friendly lane and roads City initiatives and promoting action for cycle users.	OV-fiets Swapfiets Local shops City council resources
Sweden- Gothenburg	Styr & Stall official shear bike program Supportive public transport integration Bicycle friendly lane and roads City initiatives and promoting action for cycle users.	Styr & Stall Lime Donkey republic Local shops
Japan- Yokosuka	Extensive public transportation system Bicycle friendly culture Well maintained cycle lanes Local initiatives and promoting action	Local shops Hotel service for customers Local communities & universities arrangements Military based shear bicycle program
Norway- Oslo	Bysykkel official shear bike program Public transport integration Well maintained cycle lanes Local initiatives and promoting action	Bysykkel Lime Donkey republic Local shops
USA- Oakland	Ford GoBike official shear bike program Bicycle user friendly infrastructure Public transport integration Local initiatives and promoting action	Bay wheels Lime University own shear bike programs Local shops

APPENDIX H

KEY AGENCY'S AND AUTHORITIES INVOLVE THE BICYCLE NETWORK DEVELOPMENT

City	Primary Authority which influence the traffic regulation for bicycle
Singapore	Land transport authority
Denmark – Aarhus	Aarhus Municipality
Spain- Madtid	Madtid City council
France- Bordeaux	Metropolitan authority
Germany- Hamburg	Regional government of Hamburg
Netherland- Eindhovan	Eindhovan Municipality
Sweden- Gothenburg	Swedish Transport Administration
Japan- Yokosuka	Ministry of Land, Infrastructure, Transport and Tourism (MLIT)
Norway- Oslo	Norway, the national government
USA- Oakland	U.S., state transportation department

APPENDIX I

BICYCLE PARKING REQUIREMENT IN VARIOUS LOCATION

City	Residential developments	shops	Commercial place/ halls	Industrial place	Sports & recreations place
Singapore	1 parking place for every 4 dwelling units	15 parking	1 parking every 200m^2	1 parking every 200m^2	30 bicycle parking
Denmark – Aarhus	1.5 parking place for every 1 dwelling units	20 parking	8 parking every 500m^2	8 parking every 500m^2	40 bicycle parking
Spain-Madtid	1.5 parking place for every 1 dwelling units	25 parking	8 parking every 400m^2	8 parking every 400m^2	40 bicycle parking
France-Bordeaux	1.5 parking place for every 1 dwelling units	20 parking	6 parking every 300m^2	5 parking every 300m^2	30 bicycle parking
Germany-Hamburg	1.5 parking place for every 1 dwelling units	30 parking	6 parking every 300m^2	5 parking every 300m^2	30 bicycle parking
Netherland-Eindhovan	1.5 parking place for every 1 dwelling units	30 parking	3 parking every 200m^2	4 parking every 200m^2	50 bicycle parking
Sweden-Gothenburg	1.5 parking place for every 1 dwelling units	20 parking	4 parking every 500m^2	4 parking every 500m^2	30 bicycle parking
Japan-Yokosuka	1.0 parking place for every 1	20 parking	1 parking every 300m^2	1 parking every 250m^2	35 bicycle parking

	dwelling units				
Norway-Oslo	1.5 parking place for every 1 dwelling units	30 parking	2 parking every $100m^2$	2 parking every $100m^2$	25 bicycle parking
USA-Oakland	1 parking place for every 4 dwelling units	30 parking	1 parking every $200m^2$	1 parking every $200m^2$	30 bicycle parking

APPENDIX J

SCORING OUTCOME OF QUESTIONNAIRE IN COLOMBO SRI LANKA

Question	Total Score	Ave Score
1. How would you rate the sufficiency of the bicycle network density in Colombo city? This refers to the Total Bicycle Network Length (km) divided by the Total Land Area (kmÂ²).	49	1.36
2. How would you rate the Population Density Index Relative to the Bicycle Network in Colombo city? This involves assessing the Population Density divided by the Bicycle Network Density.	51	1.42
3. Based on your riding experience in Colombo city, how would you rate the performance of bicycle lanes?	56	1.56
4. How would you rate the support provided by traffic signals and crossings for bicycle users in Colombo city?	55	1.53
5. What is your rating for the bicycle-friendliness of intersections in Colombo city?	55	1.53
6. How would you rate the bicycle parking facilities based on your experience in Colombo city?	60	1.67
7. Please rate your experience with the performance of shared bicycles in Colombo city.	48	1.33
1. How satisfied are you with the bicycle lane width requirements as per regulations?	20	0.56
2. How satisfied are you with the regulations regarding bicycle design speed, as outlined in guidelines?	22	0.61
3. How satisfied are you with the recommended speed regulations for bicycles according to guidelines?	36	1.00
4. How satisfied are you with the bicycle turning radius as specified in guidelines?	38	1.06
5. How satisfied are you with the guidelines concerning bicycle stopping sight distance?	51	1.42
6. How satisfied are you with the requirements for bicycle parking as per regulations?	53	1.47
7. How satisfied are you with bicycle parking regulations in recreational areas?	54	1.50
8. How satisfied are you with the performance of mixed land usage?	67	1.86
9. Do you believe the ratio of railway network length to the number of stations is sufficient?	54	1.50
10. Do you believe the ratio of bicycle network length to railway network length is sufficient?	58	1.61
11. How satisfied are you with the single ride subscription for shared bicycles?	43	1.19
12. How satisfied are you with the monthly subscription for shared bicycles?	52	1.44

13. How effective do you find the government's engagement with the public regarding cycling initiatives?	64	1.78
14. How effectively do you think the government enforces cycling regulations?	77	2.14
1. How would you rate the support provided by information technology for cyclists?	81	2.25
2. How satisfied are you with the amenities provided for cyclists?	64	1.78
3. How would you rate the facilities provided to enhance accessibility for cyclists?	72	2.00
1. How would you evaluate the comprehensive network coverage along your regular bicycle routes?	61	1.69
2. What rating would you give for the performance of bicycle interconnectivity along your regular bicycle routes?	50	1.39
3. How would you assess the performance of infrastructure standards along your regular bicycle routes?	61	1.69
4. How would you evaluate the performance of the strategic route plan in your area for cyclists?	54	1.50
5. Rate the performance of connectivity to neighborhoods and communities within the network for cyclists.	61	1.69
1. How would you rate the performance of separating bicycles from other traffic in Colombo city?	64	1.78
2. How do you rate the performance of intersection safety measures in Colombo city?	59	1.64
3. Rate the overall performance of conflict reduction strategies in Colombo city?	64	1.78
4. How would you rate the effectiveness of traffic calming measures in Colombo city?	73	2.03

APPENDIX K

CALCULATION OF CENTRAL TENDENCIES AND VARIABLES OF METRICS

BND

Central tendencies, variables	
Mean	2.49
Median	1.52
SD	2.22
Variance	4.93
Min	0.59
Max	6.42
Range	5.83
Q1	0.83
Q3	4.21
CV	89.04
IQ	3.38

PDBN

Central tendencies, variables	
Mean	3368.71
Median	1300.75
SD	3966.99
Variance	15736978.60
Min	198.30
Max	11499.10
Range	11300.80
Q1	710.98
Q3	4412.08
CV	117.6
IQ	3701.10

BLP

Central tendencies, variables	
Mean	0.86
Median	0.90
SD	0.14
Variance	0.02
Min	0.64
Max	1.00
Range	0.36
Q1	0.73
Q3	0.95
CV	16.07
IQ	0.22

TSPC

Central tendencies, variables	
Mean	0.77
Median	0.74
SD	0.07
Variance	0.01
Min	0.68
Max	0.88
Range	0.20
Q1	0.73
Q3	0.84
CV	9.44
IQ	0.12

IPC

Central tendencies, variables	
Mean	0.78
Median	0.76
SD	0.07
Variance	0.01
Min	0.68
Max	0.86
Range	0.18
Q1	0.73
Q3	0.84
CV	8.83
IQ	0.12

BPP

Central tendencies, variables	
Mean	0.84
Median	0.88
SD	0.12
Variance	0.02
Min	0.64
Max	1.00
Range	0.36
Q1	0.75
Q3	0.94
CV	14.73
IQ	0.19

SBP

Central tendencies, variables	
Mean	0.82
Median	0.83
SD	0.04
Variance	0.00
Min	0.74
Max	0.86
Range	0.12
Q1	0.81
Q3	0.86
CV	4.79
IQ	0.05

SBPR

Central tendencies, variables	
Mean	7.85
Median	8.10
SD	2.86
Variance	8.20
Min	4.30
Max	12.40
Range	8.10
Q1	5.11
Q3	9.29
CV	36.49
IQ	4.18

PMLU

Central tendencies, variables	
Mean	0.83
Median	0.84
SD	0.10
Variance	0.01
Min	0.64
Max	0.96
Range	0.32
Q1	0.80
Q3	0.91
CV	11.95
IQ	0.11

TSBP

Central tendencies, variables	
Mean	0.16
Median	0.15
SD	0.07
Variance	0.01
Min	0.07
Max	0.28
Range	0.21
Q1	0.11
Q3	0.22
CV	44.99
IQ	0.11

BLPRL

Central tendencies	
Mean	3.601
Median	2.465
Min	0.73
Max	12.9
SD	3.54

BLPNR

Central tendencies	
Mean	5.585
Median	3.91
Min	1.46
Max	15.2
SD	5.01

EPB

Central tendencies, variables	
Mean	6.46
Median	6.10
SD	1.32
Variance	1.74
Min	5.05
Max	8.87
Range	3.82
Q1	5.48
Q3	7.28
CV	20.43
IQ	1.80

BREP

Central tendencies, variables	
Mean	5.33
Median	5.02
SD	0.79
Variance	0.63
Min	4.55
Max	6.77
Range	2.22
Q1	4.68
Q3	5.71
CV	14.90
IQ	1.03

PITB

Central tendencies, variables	
Mean	6.03
Median	5.47
SD	1.23
Variance	1.51
Min	5.26
Max	8.54
Range	3.28
Q1	5.31
Q3	5.79
CV	20.35
IQ	0.48

PAB

Central tendencies, variables	
Mean	6.22
Median	5.92
SD	0.95
Variance	0.90
Min	5.15
Max	7.38
Range	2.23
Q1	5.41
Q3	7.24
CV	15.28
IQ	1.84

PAFB

Central tendencies, variables	
Mean	6.66
Median	6.07
SD	1.68
Variance	2.81
Min	4.39
Max	9.11
Range	4.73
Q1	5.60
Q3	8.23
CV	25.15
IQ	2.63

ECNC

Central tendencies, variables	
Mean	6.93
Median	6.33
SD	1.49
Variance	2.23
Min	5.42
Max	9.10
Range	3.68
Q1	5.98
Q3	8.35
CV	21.54
IQ	2.37

PBI

Central tendencies, variables	
Mean	6.76
Median	6.25
SD	1.36
Variance	1.84
Min	5.18
Max	8.77
Range	3.58
Q1	6.19
Q3	7.96
CV	20.09
IQ	1.77

PIS

Central tendencies, variables	
Mean	6.39
Median	6.14
SD	1.85
Variance	3.42
Min	3.97
Max	8.80
Range	4.83
Q1	4.72
Q3	8.03
CV	28.95
IQ	3.31

PSRP

Central tendencies, variables	
Mean	7.04
Median	6.72
SD	1.35
Variance	1.82
Min	5.43
Max	9.00
Range	3.57
Q1	5.99
Q3	8.19
CV	19.16
IQ	2.20

PCNC

Central tendencies, variables	
Mean	6.68
Median	6.24
SD	1.93
Variance	3.74
Min	4.23
Max	9.30
Range	5.08
Q1	5.33
Q3	8.44
CV	28.95
IQ	3.11

PSB

Central tendencies, variables	
Mean	6.40
Median	6.36
SD	1.61
Variance	2.60
Min	4.48
Max	8.90
Range	4.42
Q1	4.90
Q3	7.59
CV	25.22
IQ	2.69

PIS

Central tendencies, variables	
Mean	6.81
Median	6.53
SD	1.61
Variance	2.60
Min	4.87
Max	8.98
Range	4.12
Q1	5.51
Q3	8.31
CV	23.70
IQ	2.80

PCR

Central tendencies, variables	
Mean	6.82
Median	6.54
SD	1.67
Variance	2.79
Min	4.64
Max	9.12
Range	4.48
Q1	5.63
Q3	8.30
CV	24.49
IQ	2.67

PTCM

Central tendencies, variables	
Mean	6.78
Median	6.52
SD	1.70
Variance	2.88
Min	4.72
Max	9.14
Range	4.42
Q1	5.56
Q3	8.29
CV	25.00
IQ	2.74

APPENDIX L

SUMMARY OF METRICS BENCHMARK

No	Metrics	Notification	Value	Units
Bicycle infrastructure				
1	Bicycle Network Density	BND	2.49	Km^{-1}
2	Population Density Index Relative to Bicycle Network	PDBN	3368.71	Km^3/ No of people
3	Bicycle Lane Performance	BLP	0.86	RII Value
4	Traffic Signal Performance for Cyclists	TSPC	0.77	RII Value
5	Intersection Performance for Cyclists	IPC	0.78	RII Value
6	Bicycle Parking Performance	BPP	0.84	RII Value
7	Share Bicycle Performance	SBP	0.82	RII Value
8	Share Bicycle Penetration Rate	SBPR	7.85	Percentage
9	Share Bicycle Revenue	SBR	26.82	Million USD/ annum
10	Share Bicycle Revenue Growth	SBRG	0.04	Percentage
11	Share Bicycle Expected User Ratio	SBER	5.45	Percentage
Regulatory environment				
1	Bicycle Lane Width Requirement	BLWR	2 & 3	m
2	Bicycle Design Speed	BDS	30	Km/h
3	Bicycle Recommended Speed	BRS	20	Km/h
4	Bicycle Turning Radius	BTR	20	m
5	Bicycle Stopping Sight Distances	BSSD	30	m
6	Bicycle parking regulation requirement	BPRR	22.5	Median vale of shops
7	Performance of Mixed Land Use	PMLU	0.83	RII Value
8	Bicycle Network Length per Number of Railway Stations	BLPNR	3.91	Median Unit meter
9	Bicycle Length per Length of Railway Network	BLPRL	2.465	Median number

10	Railway Population Percentage	RPP	33.4	Mean percentage
11	Bicycle Population Percentage	BPP	25.4	Mean percentage
12	Share Bike Single Ride Fee	SBSRF	2	USD
13	Share Bike Monthly Subscription Fee	SBMSF	16.5	USD
14	Tax for Share Bicycle Providers	TSBP	16%	Mean percentage
15	Engagement Performance for Bicycling	EPB	6.46	Mean score
16	Bicycle Regulation Enforcement Performance	BREP	5.33	Mean score
User convenience				
1	performance of information technology for bicyclist	PITB	6.03	Mean score
2	Performance of Amenities for Bicyclists	PAB	6.22	Mean score
3	Performance of Accessibility for Bicyclists	PAFB	6.66	Mean score
Network connectivity				
1	Evaluation of Comprehensive Network Coverage	ECNC	6.93	Mean score
2	Performance of Bicycle Interconnectivity	PBI	6.76	Mean score
3	Performance of Infrastructure Standards	PIS	6.39	Mean score
4	Performance of Strategic Route Plan	PSRP	7.04	Mean score
5	performance of connectivity to neighborhoods and communities	PCNC	6.68	Mean score
Safety & security				
1	Performance of Separation of Bicycles	PSB	6.40	Mean score
2	Performance of intersection safety	PIS	6.81	Mean score
3	performance of conflict reduction	PCR	6.82	Mean score
4	performance of traffic calming measures	PTCM	6.78	Mean score

A Research Study: Exploring Bicycle Network Metrics in Cities Promoting Cycling

Dear All;

I am Rasalingam Jhanaghiram, currently enrolled in the Master's program for Highway and Traffic Engineering at the University of Moratuwa. My research focuses on identifying metrics for assessing bicycle networks in cities that promote bicycling, with the aim of developing benchmarks applicable to other cities (Example: Colombo). To collect relevant data for these metrics, I require input from both users and the general public regarding their experiences.

This questionnaire is structured into five sections and should take approximately 30 minutes to complete. Your participation and cooperation are greatly appreciated.

Thank you for dedicating your time to this endeavor.

* Indicates required question

Section 1

Participants General information

1. Cities of your living *

Mark only one oval.

- Singapore
- Denmark – Aarhus
- Spain- Madtid
- France- Bordeaux
- Germany- Hamburg
- Netherland- Eindhovan
- Sweden- Gothenburg
- Japan- Tokyo
- Norway- Oslo
- USA- Oakland

2. Frequency of bicycle usage per week *

Mark only one oval.

- 5-7 days
- 3-4 days
- 2-3 days
- Less than 2 days
- No bicycle user.

3. Distance cover by bicycle *

Mark only one oval.

- 0-1Km
- 1-2Km
- 2-5Km
- More than 5Km

4. Purpose of the bicycle usage *

Mark only one oval.

- Ride to school/work
- Ride for shops/ recreation places
- Ride to other transportation interchanges
- Other

5. Type of bicycle use *

Mark only one oval.

- Own the bicycle
- Rental bicycle

"Public engagement and enforcement."

This section serves as a platform to collect insights and feedback from users regarding their firsthand experiences with public engagement initiatives and the enforcement of regulations pertaining to bicycle systems within urban environments. It aims to capture observations, opinions, and interactions individuals have encountered concerning the involvement of the public and the effectiveness of governmental enforcement practices in regulating and promoting bicycle usage and safety across cities.

6. 1. How satisfied are you with the availability of information on bicycle regulations in languages you are comfortable with? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10

7. 2. What is the rate of including language options for bicycle infrastructure and regulations in official communications? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

8. 3. Have you encountered any challenges in understanding or interpreting government communications related to bicycling due to language barriers? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

9. 4. How would you rate the clarity of language used in official communications about bicycle infrastructure and safety? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

10. 5. Rate that what extent do you feel that government communications about bicycling take into account cultural differences and nuances? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

11. 6. Rate of you notice any efforts by the government to incorporate cultural elements into bicycle-related campaigns or initiatives? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

12. 7. Rate for the bicycle infrastructure planning considers the diverse cultural needs and preferences of the community *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

13. 8. How important do you think cultural sensitivity is in promoting cycling as a mode of transportation in your community? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

14. 9. Rate public awareness of any official channels or mechanisms provided by the government for cyclists to provide feedback on bicycle infrastructure and regulations? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

15. 10. Rate your satisfaction with the responsiveness of government authorities to feedback and concerns raised by the cycling community? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

16. 11. Rate that how you personally utilized any feedback mechanisms to communicate with the government about bicycle-related issues? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

17. 12. Rate that effeteness of feedback mechanisms to better serve the needs of cyclists? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

18. 13. Rate that how effective do you think government-led education campaigns have been in promoting safe cycling practices? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

19. 14. Rate that how involve participation in any educational workshops or programs organized by the government to enhance cyclists' knowledge and skills? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

20. 15. What is the rating for awareness campaigns to educate the public about the benefits of cycling and bicycle safety? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

21. 16. What is the rating for the government to improve its educational efforts to better reach and engage the cycling community? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

22. 17. What is the rating for attending any government-organized cyclist events or activities in your community? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

23. 18. How would you rate the impact of cyclist events in fostering a sense of community among cyclists? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

24. 19. What is the rating for government-supported events to promote cycling and community engagement? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

25. 20. What is the rating for government-sponsored cyclist events be improved to better meet the needs and interests of the cycling community? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

26. 21. Rate it how frequently have you observed incidents involving cyclists in your local area over the past year? (less incident high score) *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

27. 22. If people witnessed incidents, how often were they reported to the relevant authorities? (more reporting rate high score) *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

28. 23. Rate of cyclists in your community follow traffic rules and regulations? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

29. 24. Rate it how often do you observe cyclists wearing helmets while riding? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

30. 25. Rate cyclists who receive citations for traffic violations are likely to repeat the same offenses? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

31. 26. Rate how satisfied are you with the response time of authorities to reported cyclist violations in your area? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

User convenience

This section has been specifically designated to compile user feedback regarding the role of information technology, amenities, and accessibility in supporting bicycle users. It aims to collect insights, opinions, and experiences from individuals regarding how these factors contribute to facilitating and enhancing the experience of cycling within urban environments.

32. 1. Rating the road signage for cyclists consistent in design and placement throughout the city? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

33. 2. How would you rate the uniformity of bicycle-related signage in different areas you cycle through? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

34. 3. Rating the road signs for cyclists easily visible to you while cycling? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

35. 4. Rating the placement of signage is effective in providing timely information to cyclists? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

36. 5. Rate for issues with the reflectivity of road signs, especially during night-time cycling? (less issue more score) *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

37. 6. Rate the road signs are adequately illuminated for clear visibility in low-light conditions? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

38. 7. Rate the satisfied of your with the overall performance of the cyclist mobile application? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

39. 8. Have you experienced any issues with the functionality of the app while cycling? (less issue more score) *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

40. 9. How confident are you in the accuracy of the route information provided by the mobile application? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

41. 10. Have you encountered any discrepancies in speed or distance measurements while using the app? (less issue more score) *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

42. 11. Do you feel that the data provided by the app is reliable for your cycling needs? *

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10
	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

43. 12. Are you concerned about the security of your personal data when using the cyclist mobile application? (app have more security give more score) *

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10
	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

44. 13. How well-informed do you feel about the measures taken by the app to protect your data? *

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10
	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

45. 14. How satisfied are you with the availability of water points along your cycling routes? *

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10
	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

46. 15. Are the existing water points conveniently located for cyclists, and do you find them easily accessible? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

47. 16. How would you rate the cleanliness and maintenance of the current water points for cyclists? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

48. 17. How frequently do you utilize rest areas during your cycling journeys? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

49. 18. Are the existing rest areas equipped with amenities that meet your needs for a comfortable break? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

50. 19. Do you think there is a sufficient number of rest areas along your typical cycling routes? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

51. 20. How important do you consider the availability of shelters for cyclists during adverse weather conditions? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

52. 21. Have you encountered situations where the lack of shelter negatively impacted your cycling experience?(less impact high score) *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

53. 22. Have you ever used bicycle repair stations along your cycling routes, and if so, how satisfied were you with the experience? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

54. 23. Are there locations where you believe additional bicycle repair stations would be particularly useful? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

55. 24. Are you generally aware of the presence of accessibility features, such as ramps and lifts, in public spaces and buildings? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

56. 25. Are these features easy to locate and use, or do you find them challenging to access? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

57. 26. Based on your experience, how effective are the ramps, lifts, and other accommodations in facilitating your movement in public spaces? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

58. 27. Do you find that accessibility features are consistently implemented across various public spaces, or do you encounter inconsistencies? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

59. 28. Are there channels or mechanisms in place for users to provide feedback on the accessibility of public spaces? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

60. 29. Can you identify specific challenges or difficulties you face related to mobility when navigating public spaces? (less challenges high score) *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

61. 30. How well-informed do you feel about the accessibility features in a new public space before visiting it for the first time? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

62. 31. Do you think there is a need for more awareness and training programs for the general public to understand and respect the needs of individuals with mobility impairments? (proactive awareness high score) *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

Network

This section is focused on conducting a thorough evaluation of the scoring system related to bicycle infrastructure networks. It involves assessing several key aspects, such as the breadth of network coverage across different areas, the level of integration with diverse modes of transportation, adherence to uniform infrastructure standards for consistency, strategic planning of routes to optimize usability and efficiency, and the degree of connectivity to neighboring communities and neighborhoods.

63. 1. How would you rate the overall connectivity of the bicycle network to employment centers, schools, and shopping areas in your area? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

64. 2. Rate the challenges or barriers when cycling to these destinations? (less challenges high score) *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

65. 3. How satisfied are you with the existing cycling infrastructure (bike lanes, paths, intersections) connecting to employment centers, schools, and shopping areas? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

66. 4. Rate the route where you believe improvements to cycling infrastructure are needed? (less improvement high score) *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

67. 5. How satisfied are you with the availability and quality of bicycle parking facilities at employment centers, schools, and shopping areas? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

68. 6. Rate how satisfied are you with the availability of bicycle parking facilities at these transportation hubs or interchanges? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

69. 7. Rate your usage of bicycle for the last mile of your commute to or from transportation hubs or interchanges? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

70. 8. Rate how well do you think the bicycle infrastructure facilitates last-mile connectivity at these locations? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

71. 9. How would you rate the overall connectivity of the bicycle network with other modes of transportation or interchanges in your area? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

72. 10. Rate how seamless is the integration between cycling and public transport in your experience? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

73. 11. Rate people involvement in any community engagement or advocacy efforts related to improving bicycle network connectivity in your city? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

74. 12. How would you rate the consistency of lane width across different bicycle paths and lanes within the city? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

75. 13. How would you describe the overall surface quality of bicycle paths and lanes in the city? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

76. 14. How well does the color coding help you identify and navigate through the bicycle network? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

77. 15. How satisfied are you with the overall maintenance conditions of bicycle infrastructure in the city? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

78. 16. Are there clear protocols and standards for regular maintenance and repairs of bicycle paths and lanes? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

79. 17. Are there visible signs of collaboration between different infrastructure projects to enhance overall connectivity? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

80. 18. How easy is it for you to access the bicycle network from your residence? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

81. 19. How comfortable do you feel using the existing bicycle lanes and paths? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

82. 20. How frequently do you use the bicycle network for commuting or recreational purposes? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

83. 21. Have you observed an increase in the number of cyclists since the implementation of the strategic plan? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

84. 22. Have you utilized any technology or apps that support cycling in the city? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

85. 23. How effective do you find technology in enhancing the safety and convenience of cycling? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

86. 24. How would you rate the connectivity of the bicycle network in your neighborhood to adjacent areas? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

87. 25. Have you been involved in any community initiatives or discussions related to bicycle network connectivity? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

88. 26. How satisfied are you with the level of community involvement in improving bicycle connectivity? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

89. 27. How satisfied are you with the bicycle network connectivity in your neighborhood? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

Safety & security

This section addresses the safety and security concerns of bicycle riders, encompassing various aspects such as separation from motor vehicle traffic, intersection safety, identification of conflict points, and the implementation of traffic calming measures. It explores strategies and interventions aimed at enhancing the safety of cyclists on roadways, including physical separation measures, intersection design improvements, identification and mitigation of potential conflict areas, and the implementation of traffic calming techniques to reduce vehicle speeds and improve overall road safety for bicyclists.

90. 1. Rate your satisfaction with our city's current infrastructure regarding bicycle pathways and separation from motor vehicle traffic? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

91. 2. Rate your experienced discomfort or felt unsafe while cycling due to proximity to motor vehicle traffic? (less discomfort high score) *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

92. 3. Rate the physical barrier separating bicycles from motor vehicles on shared roadways? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

93. 4. Rate how feel that separate pathways designated specifically for bicycles would enhance safety for cyclists? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

94. 5. Rate how satisfied are you with the current level of safety for cyclists in the city? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

95. 6. Rate your experienced discomfort or felt unsafe while navigating intersections on your bicycle? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

96. 7. Rate that dedicated bicycle traffic signals would improve safety for cyclists at intersections? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

97. 8. Rate that for encountered bike boxes (advanced stop lines for cyclists) at intersections in our city, do you find them effective in enhancing cyclist safety? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

98. 9. Rate it how important do you think clear signage and markings are at intersections to indicate the presence of bicycle-specific infrastructure? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

99. 10. Rate that implementing protected intersections and dedicated bicycle traffic signals would encourage more people to cycle in our city? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

100. 11. Rate that how satisfied are you with the current level of intersection safety for cyclists in our city? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

101. 12. Rate safety concerns or experienced conflicts while navigating interaction areas? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

102. 13. Rate observed any measures in our city aimed at enhancing visibility in interaction areas, such as improved lighting, clear signage, or road markings? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

103. 14. Rate the Satisfy the implemented to reduce conflicts and improve safety in interaction areas? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

104. 15. Rate how satisfied are you with the current visibility and safety measures in interaction areas in our city? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

105. 16. Rate that satisfy the technology could play in improving visibility and safety in interaction areas? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

106. 17. Rate that ever encountered safety concerns or felt at risk while cycling due to vehicle speeds in certain areas? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

107. 18. Rate about your aware of the concept of traffic calming measures, such as speed humps, roundabouts, or traffic circles, aimed at reducing vehicle speeds? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

108. 19. Rate that use of roundabouts or traffic circles as traffic calming measures to improve cyclist safety? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

109. 20. Rate the important do you think it is for city authorities to prioritize cyclist safety when implementing traffic calming measures? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

110. 21. Rate the implementation of traffic calming measures would encourage more people to cycle in our city? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

Finding the Bicycle Network Performance in Colombo, Sri Lankan City

Dear All;

I am
Rasalingam Jhanaghiram, a graduate student pursuing a Master's degree in Highway and Traffic Engineering at the University of Moratuwa. I am conducting a questionnaire to assess the current pros and cons of bicycle transportation in Colombo. To ensure the accuracy of my research, I am seeking input from both cyclists and the general public regarding their experiences in navigating the city's streets.

This
questionnaire is structured into Six sections and should take approximately 15 minutes to complete. Your participation and cooperation are greatly appreciated.

* Indicates required question

Section 1: **Infrastructure**

This section cover the bicycle infrastructure present situation in Colombo, Sri Lanka.

1. 1. How would you rate the sufficiency of the bicycle network density in Colombo city? This refers to the Total Bicycle Network Length (km) divided by the Total Land Area (km²). *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

2. 2. How would you rate the Population Density Index Relative to the Bicycle Network in Colombo city? This involves assessing the Population Density divided by the Bicycle Network Density. *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

3. 3. Based on your riding experience in Colombo city, how would you rate the performance of bicycle lanes? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

4. 4. How would you rate the support provided by traffic signals and crossings for bicycle users in Colombo city? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

5. 5. What is your rating for the bicycle-friendliness of intersections in Colombo city? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

6. 6. How would you rate the bicycle parking facilities based on your experience in Colombo city? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zero	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

7. 7. Please rate your experience with the performance of shared bicycles in Colombo city. *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zero	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

Section 2: **Regulatory environment**

This section cover the Regulatory environment related with bicycle network, and riding

8. 1. How satisfied are you with the bicycle lane width requirements as per regulations? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zero	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

9. 2. How satisfied are you with the regulations regarding bicycle design speed, as outlined in guidelines? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zero	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

10. 3. How satisfied are you with the recommended speed regulations for bicycles according to guidelines? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

11. 4. How satisfied are you with the bicycle turning radius as specified in guidelines? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

12. 5. How satisfied are you with the guidelines concerning bicycle stopping sight distance? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

13. 6. How satisfied are you with the requirements for bicycle parking as per regulations? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

14. 7. How satisfied are you with bicycle parking regulations in recreational areas? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

15. 8. How satisfied are you with the performance of mixed land usage? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

16. 9. Do you believe the ratio of railway network length to the number of stations is sufficient? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

17. 10. Do you believe the ratio of bicycle network length to railway network length is sufficient? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

18. 11. How satisfied are you with the single ride subscription for shared bicycles? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

19. 12. How satisfied are you with the monthly subscription for shared bicycles? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

20. 13. How effective do you find the government's engagement with the public regarding cycling initiatives? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

21. 14. How effectively do you think the government enforces cycling regulations? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

Section 3: **User convenience**

This section discussed about the user convenience of bicycle user

22. 1. How would you rate the support provided by information technology for cyclists? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

23. 2. How satisfied are you with the amenities provided for cyclists? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

24. 3. How would you rate the facilities provided to enhance accessibility for cyclists? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

Section 4: **Network connectivity**

This section cover the network connectivity especially in

neighborhoods

25. 1. How would you evaluate the comprehensive network coverage along your regular bicycle routes? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

26. 2. What rating would you give for the performance of bicycle interconnectivity along your regular bicycle routes? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

27. 3. How would you assess the performance of infrastructure standards along your regular bicycle routes? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

28. 4. How would you evaluate the performance of the strategic route plan in your area for cyclists? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

29. 5. Rate the performance of connectivity to neighborhoods and communities within the network for cyclists. *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

Section 5: **Safety & security**

this is cover the bicyclist and pedestrian safety and security performance

30. 1. How would you rate the performance of separating bicycles from other traffic in Colombo city? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

31. 2. How do you rate the performance of intersection safety measures in Colombo city? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

32. 3. Rate the overall performance of conflict reduction strategies in Colombo city? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

33. 4. How would you rate the effectiveness of traffic calming measures in Colombo city? *

Mark only one oval.

	0	1	2	3	4	5	6	7	8	9	10	
Zerc	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Max performance

Section 6: Other Feedback

This is section try to capture the feedback from participant

34. Please to write the feedback that may need the more attention & focus to improve the bicycle mode of transportation in Colombo city. *

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