INTEGRATION OF BICYCLE SHARING SYSTEM WITH BUS RAPID TRANSIT IN PESHAWAR

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My Loving Parents

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LIST OF SYMBOLS, ABBREVIATIONS AND ACRONYMS

BSS	Bicycle/Bike Sharing Systems
BRT	Bus Rapid Transit
OECD	Organization for Economic Cooperation and Development
KPK	Khyber Pakhtunkhwa
NATO	North Atlantic Treaty Organization
ITDP	Institute for Transportation and Development Policy
GIS	Geographic Information System
IISD	The International Institute for Sustainable Development
ITF	International Transport Forum
MUPs	Multiuse Paths
TOD	Transit-Oriented Development
FLM	First/Last Mile
PLUZ	planning, land use, and zoning
GPS	Global Positioning System
HCM	Hybrid Choice Model
MNR	Ministry of Natural Resources
UBC	University of British Columbia
GHG	Greenhouse Gases
PED	Price-Elasticity of Demand
PT	Public Transit

ABSTRACT

The synergistic integration of Bicycle Sharing Systems (BSS) with public transit stations has emerged as a prominent strategy to promote sustainable urban mobility, improve last-mile connectivity and foster environmentally friendly travel choices. This research investigates the feasibility and potential benefits of integrating BSS with Bus Rapid Transit (BRT) stations in Peshawar, Pakistan. The initial phase of this study involves a comprehensive stated preference survey to understand individuals' mode preferences and attitudes towards BSS. The survey facilitated the identification of optimal sites and design framework for bicycle stations. An inclusive spatial analysis was conducted using Geographic Information System (GIS) to pinpoint optimal location for BSS in close proximity to BRT stations. This analysis took into account critical factors such as population density, land use patterns, and accessibility to key destinations. The anticipated outcomes of this research include: enhanced last-mile connectivity, reduced traffic congestion and air pollution, increased physical activity with associated health benefits, and improved public transport access, thereby promoting social equity within the urban transport ecosystem. This research endeavors to identify key challenges that necessitate resolution to ensure seamless integration of BSS with BRT stations. This encompasses the provision of requisite infrastructure and amenities catering to BSS users, mitigating safety and security risks, and the assurance of universal accessibility. In conclusion, this research sets out the efficacy and sustainability of Peshawar’s urban transportation system, offering valuable insights for policymakers and urban transportation planners as they consider the integration of BSS with public transit networks.

Key Words: Public Transit; Bicycle Sharing Systems; Integration; Spatial Analysis; First-Last mile

CHAPTER 1: INTRODUCTION

1.1 Background

Sustainable urban development mobility has gained significant traction in recent years as cities worldwide face growing challenges associated with traffic congestion, air pollution, and limited accessibility to public transportation. In response to these issues, there has been a growing interest in promoting the integration of various modes of transport, intending to create seamless and efficient transportation networks. One key initiative that has gained momentum in urban centres is the integration of Bicycle Sharing Systems (BSS) with existing public transit stations. Sustainable transport originates in the broader framework of sustainability, defined as "development that meets present needs without compromising the ability of future generations to meet their needs." This definition underscores the imperative to balance immediate societal requirements while safeguarding environmental constraints for the well-being of future generations [1].

From an economic standpoint, the concept of sustainability assumes an integrated structure. This integration entails synchronizing environmental, spatial, economic, social, and institutional dimensions to form a unified entity. In this context, sustainable transport, alternatively known as sustainable transportation or green transport, emerges as a pivotal aspect. The nomenclature "green transport" is indicative of its emphasis on environmentally friendly practices within the realm of transportation. Sustainability encompasses the intricate interplay between environmental, economic, and social systems, which can either benefit or hinder one another across different spatial dimensions [2].

Sustainable transport, as defined by the Organization for Economic Cooperation and Development (OECD), is characterized by its commitment to safeguarding public health and ecosystems. The concept extends beyond focus focusing on resource depletion and air pollution, encompassing a broader spectrum that includes social and economic dimensions. In the narrow sense, sustainable transport addresses resource depletion and air pollution issues, acknowledging these as significant environmental threats. However, a comprehensive understanding transcends these challenges, recognizing that sustainable transport is not exclusively confined to ecological concerns.

In the broader sense, the evaluation of sustainable transport incorporates social and economic well-being. This holistic approach emphasizes the need for an integrated framework that considers environmental aspects and prioritizes social and economic dimensions. Furthermore, it underscores the importance of establishing an appropriate institutional framework to facilitate sustainable transport practices. To achieve sustainable transport, it is imperative to balance environmental, social, and economic considerations. This involves addressing current challenges and anticipating and preparing for the population's future needs. The OECD's definition underscores the necessity of responsible use of renewable and non-renewable resources in pursuing sustainable transport practices [3].

The introduction of bike-share programs has sparked a nuanced debate within the realm of urban transportation research. Scholars diverge on the role of bike-share in shaping urban transportation, with some contending that it fosters a healthier and more sustainable system by both directly and indirectly substituting motorized vehicles [4], [5] Conversely, an opposing viewpoint posits that bike-share exerts minimal influence on the existing transportation system, offering limited reductions in car usage and negligible synergy with public transit [6].To comprehensively evaluate the impact of bike-share, an essential focus lies in understanding its effects on public transit, considering the shared allocation of public resources between public bike-share and public transit systems.

Efficient integration rather than competition emerges as a pragmatic approach, particularly given the joint operation of public bike-share and public transit. Convey the "first-last mile" predicament of public transportation accessibility becomes paramount for planners, necessitating strategic placement of bike-share stations in areas with limited public transit networks [7]. Moreover, recent research indicates that bike-share can function as a sustainable alternative where public transit offers an inefficient travel route.

BSS is widely acknowledged as a transportation mode that is both environmentally sustainable and highly efficient globally and offers various advantages, including rapid journeys, positive health impacts, and cost-effective commuting. In urban transportation sustainability, prioritizing non-motorized modes, mainly promoting bicycles in developing countries, is deemed crucial. BSS operates as a public service, employing a short-term rental model between distinct docking stations, sparing users the burden of bicycle storage and maintenance costs. Commonly used for final-mile journeys in combination with other modes of transportation [8].

Integrating BSS with public transit has garnered attention from practitioners and researchers. Studies employing survey-based and data-driven analytical approaches have revealed insights. In San Francisco, bike-share tends to substitute e-hailing, alleviating urban traffic congestion and enhancing transit service reliability. Conversely, e-scooters are more likely to facilitate first/last-mile transit access [9]. Washington DC's study indicates that respondents in less-dense areas prefer combining transit with bike-share. Research using regression models suggests a positive correlation between bike-share trips and Metrorail ridership [10]. Spatial analyses underscore the significance of resident proportion, job density, and distance to the central business district on metro bike-share activities [11].

Shared mobility, particularly micro-mobility solutions like bike-sharing, is progressively gaining traction. These systems, evolving through four generations, hinge on optimal decision-making regarding station location, capacity, and bicycle redistribution for sustained success.

Peshawar is the capital city of Khyber Pakhtunkhwa (KPK) province and has a population of 4.26 million, according to the population survey in 2017 (Government of Pakistan, 2017). Peshawar city is a business hub and a gateway to Afghanistan, connecting Pakistan to Central Asia and Middle Eastern countries. This makes it a geo-strategically important city in Pakistan, connecting a route for the supplies of the North Atlantic Treaty Organization (NATO) [12]. Looking back to the past decade, Peshawar has faced its fair share of experience in rapid expansion and population increase, with a tremendous increase in private modes of transportation and private car ownership increasing by about 229% [13]. Due to this, it has experienced severe congestion, economic and environmental damage, and safety problems. To cope with this chaotic urban network system, Bus Rapid Transit (BRT), along with BSS, was introduced in Pakistan and year completed in 2020. BRT corridor is spread over a 26 km long distance with 31 stations coming along the way. The average distance between any two stations is 850 m, 15km distance is at-grade, flyovers take 8kms, and 3km section are covered by underpasses.Figure 1.1 shows below the network map of BRT Peshawar.

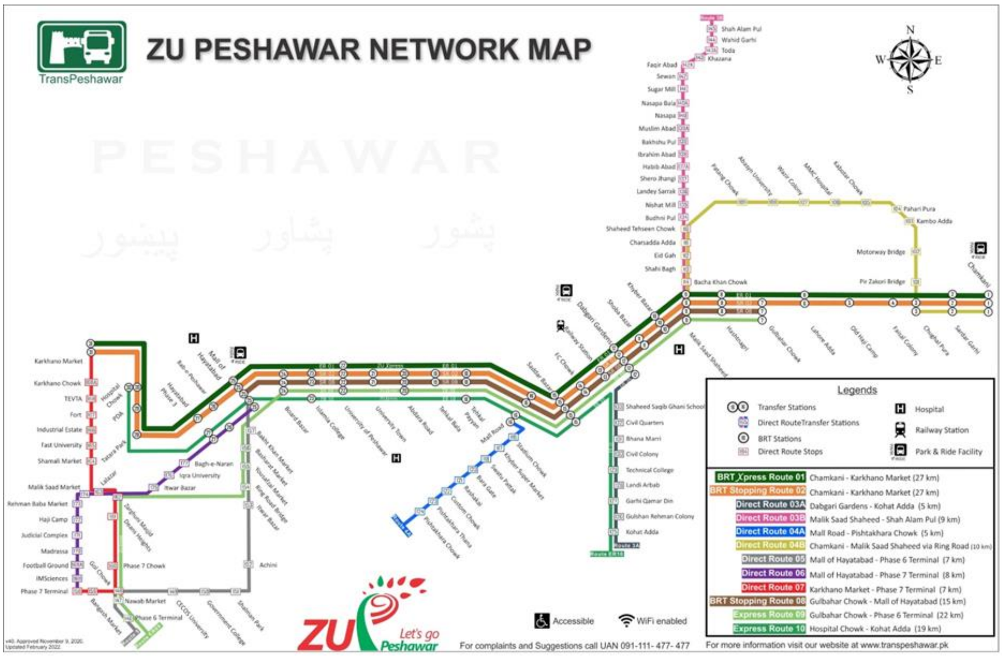

Figure 1.1: BRT Network map Peshawar (Trans Peshawar)

Peshawar has effectively promoted walking and cycling by reevaluating the city's transportation choices by implementing the Zu Peshawar system. The BRT main corridor has been developed with exclusive bicycle lanes in specific regions, ensuring a secure infrastructure for cyclists. Furthermore, individuals who commute to the station on their bicycles can take advantage of the bicycle parking facilities provided at each station. Moreover, the city has implemented the nations in augural bike-sharing program, encompassing 32 stations and 360 bicycles. This bike-sharing system links prominent educational institutions and residential neighbourhoods to the BRT system along the primary route. To enhance convenience, both kiosks and the Zu Mobile App offer up-to-date information on the whereabouts of available bicycles. Since the implementation of bike share, there has been a 6% increase in cycling trips, according to Trans Peshawar and the KPK Government. The design of the BRT system also incorporates spacious and readily accessible walkways, escalators, elevators, stairs, ramps, and pedestrian bridges, which have improved pedestrian safety. In a heavily congested area of the city, a 4 km multi-use pathway is being constructed for cyclists and pedestrians. The design includes significant stations spaced 800 meters apart, making future redevelopment projects accessible to the Bus Rapid Transit system within 400 meters. The city has also invested in improving drainage to prevent flooding and make the pathway more accessible. To promote transit-oriented development (TOD), efforts have been undertaken to establish three primary commercial hubs seamlessly integrated with the BRT stations [14].

1.2 Problem Statement

Peshawar, Pakistan, is facing significant urban mobility challenges characterized by traffic congestion, air pollution, and limited accessibility to public transportation. The Bus Rapid Transit (BRT) system, introduced to address these issues, has shown promise in improving public transit. Still, there remains a need to explore the commuter behaviour towards the spatial integration of BSS with BRT stations and innovative solutions for first and last-mile connectivity and sustainable urban transportation. This study aims to investigate the potential barriers of the commuter towards BSS, the integration attitude towards BSS with BRT Station of the commuter, and to address the first and last-mile connectivity using spatial analysis of a BSS with the existing BRT infrastructure in Peshawar to enhance the overall efficiency and accessibility of the public transportation system.

In identifying potential challenges and solutions to ensure seamless integration, it is essential to understand the preferences, needs, and behaviour of Peshawar commuters regarding using BSS integrated with BRT stations. This includes safety concerns, bicycle infrastructure, and the convenience of bicycle mode as a first- and last-mile means of transport. A detailed stated preference survey will be conducted. The objectives of the study above will be to know about the individual's preferences for various travel modes used as a First and Last mile, the potential barriers the Commuter faces in using the Bicycle mode, and their attitude towards BSS. How satisfied are passengers with the integration between the BSS and BRT stations?

Peshawar's BRT system covers extensive routes, but many commuters face challenges in accessing BRT stations from their homes or workplaces, a GIS-based spatial analysis will be conducted to identify potential locations for BSS stations around

BRT stations, considering factors such as population density, land use, and distance from key destinations. This study seeks to identify the extent of the last-mile connectivity gap and assess how a BSS can bridge this gap effectively using spatial analysis. The results will offer valuable perspectives on the practicality, advantages, and obstacles of integrating a BSS into Peshawar's Bus Rapid Transit system. Ultimately, this will contribute to the city's sustainable development and enhance urban mobility.

1.3 Research Objectives

The research endeavours to accomplish the following objectives:

- To identify the key challenges and barriers to implementing BSS integration in Peshawar.
- To recommend strategies for overcoming the challenges and promoting adopting BSS integration in Peshawar.
- Enhancing the accessibility and Last-mile connectivity of BRT Peshawar by performing spatial analysis using Bicycle mode.

1.4 Scope of Research Work

Pakistan, a rapidly urbanizing country, confronts many transportation challenges, including traffic congestion, air pollution, and the need for improved last-mile connectivity to the public transit network. As is well known, Pakistan Vision 2025 aims to create a compelling and integrated transportation network that will aid in the growth of a vibrant economy. Ensure transportation costs are decreased, mobility is safe, and the connection is adequate.

By integrating BSS with public transport stations, travellers will be able to conveniently reach their final destinations from the transit station, improving the last-mile connection. This can encourage using environmentally friendly transportation options while reducing reliance on personal automobiles. BSS may support equality for all and lower the obstacles to employment, education, and other possibilities caused by transportation by offering inexpensive and accessible transportation choices to those in low-income communities.

By offering an alternate method of transportation for short trips that would otherwise be performed by private automobiles, integrating BSS with public transit stations can reduce traffic congestion. This measure can potentially alleviate traffic congestion and decrease the total volume of vehicles on the road. Integrating BSS with public transit stations can aid in lowering greenhouse gas emissions and enhancing environmental sustainability by encouraging the use of sustainable ways of transportation, such as cycling.

By promoting sustainable mobility alternatives that are practical, easy to use, and affordable, integrating BSS with public transit stations can improve urban liveability. This could lead to more liveable and livelier urban areas. By offering incentives, BSS can encourage people to ride more frequently for quick journeys. Encouraging active commuting and discouraging people from sitting down can improve the public's health.

1.5 Overview of Study Approach

To attain the intended goals of the research, a detailed methodology was developed, which consists of the following tasks;

- A detailed literature review was conducted on BSS integration with public transit stations and its potential benefits.
- Identification of the potential Barriers faced by the commuter using Bicycle mode.
- Collect secondary data from the concerned departments and authorities to observe the trend using BSS.
- Collect primary data using a questionnaire and BRT user's experience.
- Sorting and interpretation of data i.e. Statistical analysis and Spatial analysis
- Preliminary findings in terms of potential barriers from both analysis
- Extraction of results from the analyzed data.
- Conclusion of study and provision of recommendations.

1.6 Thesis Structure/Organization

Chapter 1 provides a concise overview of the research conducted within this study, encompassing an introductory section, problem statement, objectives, a comprehensive study approach, and the research work's scope. It gives an overview of the problems for which this research study is being conducted. Chapter 2 provides a brief review of past research on the BSS as a Last Mile Connection to Transit. Its implementation, operations, monitoring, impact, and evaluation. This chapter also contains the current knowledge and trends in bicycle mode. Chapter 3 discusses the overall framework of the research process, including project and study area description, data collection processes and complete procedures for the analysis of the collected data. Chapter 4 consisted of a detailed analysis of the Data and Results, i.e., statistical and spatial analysis. Chapter 5 of the thesis report concludes the overall work carried out in the research process. It includes discussions, conclusions, recommendations, and limitations. Recommendations provide and help decision-makers decide how to implement such sustainable projects in the future. It also recommends that future work be done in the area of bicycle-sharing systems.

CHAPTER 2: LITERATURE REVIEW

2.1 General

Bicycle-sharing systems have gained immense popularity worldwide as a means of transportation. This method of shared bicycle usage is increasingly being embraced due to growing concerns regarding the environmental impact of fossil fuel-powered cars and the desire to revitalize pedestrian-friendly urban areas. Consequently, cities in both developed and developing countries are showing support for bicycle-sharing systems. Around five years ago, modern bicycle-sharing systems were introduced in Denver, Washington, D.C., and the Twin Cities, marking the beginning of this innovative transportation trend in the United States. These systems aim to alleviate traffic jams, reduce air pollution, and enhance the overall liveliness of city life. Presently, 119 cities in the United States have implemented bicycle-sharing systems. [15].

Bicycle-sharing systems have gained popularity among younger generations and hold the potential to stimulate improved design for public areas. These flexible systems eliminate the need for individuals to own bicycles, offering an alternative to automobiles for short-distance travel and enhancing the convenience of public transportation. Consequently, bicycle-sharing systems present an attractive solution to the First and Last-mile issues in transportation systems. Unlike public transportation, which often operates at a loss and relies on public subsidies, the value of bicycle-sharing systems lies primarily in their social benefits and contribution to agglomeration economies. However, the sustainability of bicycle-sharing systems has been compromised in certain cities due to their exclusion from public transportation networks and their separate operation from existing transit systems. To address this issue, it is imperative to conduct systematic studies on the impact of bicycle-sharing systems on urban transportation systems and approach their implementation from a comprehensive perspective. Efforts have been made to integrate bicycle sharing into public transit systems to enhance their effectiveness and efficiency [16]. In Helsinki, the Bicycle-sharing system is claimed to seamlessly connect with the metropolitan area's multimodal public transportation system. Additionally, users can pay for all their trip fares using a single smart card known as the Travel Card of Helsinki [Helsinki City, 2016].

As discussed earlier in Chapter 1, this thesis attempts to identify the potential barriers faced by commuters in integrating BSS with transit stations and provide strategies for overcoming them. Integrating bicycle sharing into public transit systems can yield advantages for users, transportation agencies, and the environment.

2.2 History of Bicycle Sharing System

In 1965, the Netherlands introduced the first bike-sharing system to solve the traffic problems prevalent in Amsterdam's city Centre. A local community organization implemented a white bicycle initiative, wherein numerous bicycles were made available throughout the inner city. These bicycles were consistently unlocked and distributed in various locations, enabling individuals to utilize them at their convenience without any limitations on time. Nevertheless, this strategy proved ineffective due to widespread incidents of bicycle theft and vandalism. In the 1990s, Copenhagen introduced a second generation of shared bikes that required a coin deposit. Unfortunately, this did not effectively resolve the problem of theft, as the anonymity of users and the absence of time limits resulted in excessively long rental periods. Despite the failures of the previous generations, third-generation bike-sharing programs have gained global popularity. These programs are characterized by system integration, such as intelligent cards integrated with public transit and technological advancements like transaction kiosks at docking stations. The Velib system in Paris, the Hangzhou Public Bicycle system in China, and the BIXI system in Montreal are notable instances of third-generation bike-sharing programs [17].

A novel form of bike-sharing system emerged in major Chinese cities in 2016. This system, characterized by private ownership and app-based dock less programs, swiftly gained traction and is now recognized as the fourth generation of bike-sharing systems, surpassing the previously acknowledged three generations. As per the Research Report on Bike-sharing Employment, dock less bike-sharing operators in China, notably MO Bike, the two leading operators, collectively possess approximately 16 million bicycles and handle an average of over 50 million orders daily [State

Information Centre, 2017]. Figure 2.1 presents a comprehensive timeline and overview of the evolution of bike-sharing systems.

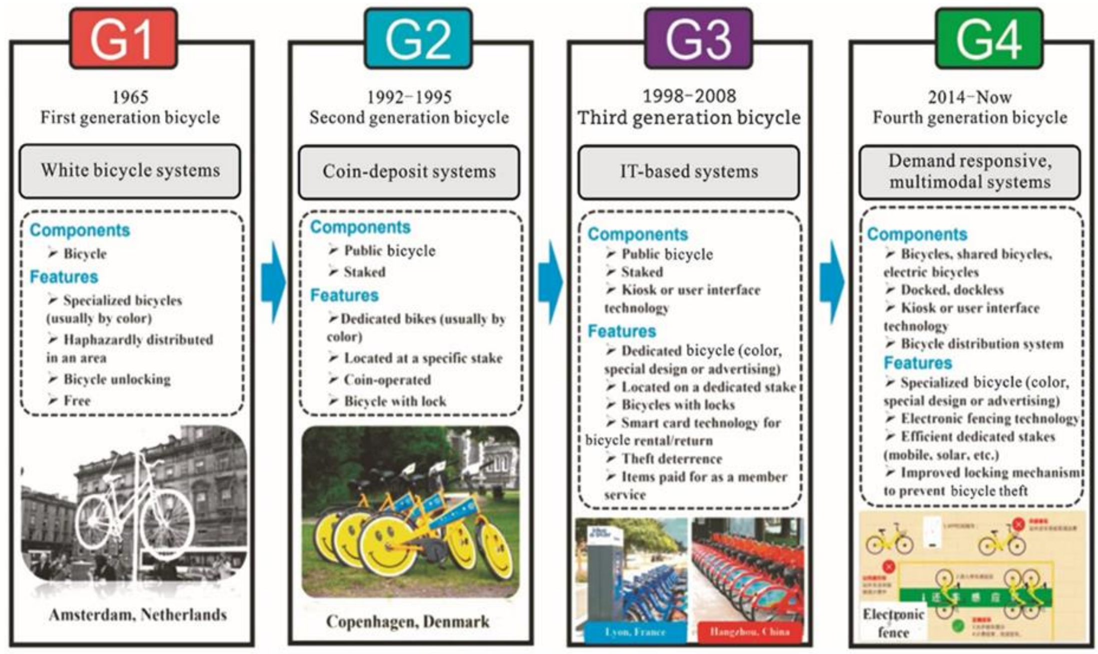

Figure 2.1: Different stages of development of global bicycle-sharing systems

2.3 Synthesis of Past Research

Micro mobility is a rapidly expanding and increasingly popular trend in urban transportation. It encompasses a wide range of small, human-powered vehicles like bicycles and newer electric-powered options such as e-scooters and e-bikes. These micro-vehicles can now be seen in numerous cities across the globe. In the past few years, there has been a notable increase in the emergence of diverse micro-vehicles designed to serve both communal and individual purposes, and the general population has widely accepted them. One notable example of the growth in micro mobility is the proliferation of bicycle-sharing systems worldwide. The number of bike-sharing programs has skyrocketed from 17 in 2005 to 2,900 in 2019 [18]. This expansion has been accompanied by the availability of electric bicycles and pedelecs, further diversifying the options for users. Additionally, the popularity of dock less bike-sharing has surged since 2010, initially starting in China and quickly spreading to other parts of the world [19].

Overall, the rise of micro-mobility has revolutionized urban transportation by offering convenient and sustainable alternatives to traditional modes of travel. The increasing availability and popularity of micro-vehicles demonstrate the positive reception and potential for further growth in this sector. The e-scooter provider in Europe has witnessed comparable progress, extending its operations to 10 nations in just one year after commencing its services in Sweden in 2018. Notably, the company has recorded an impressive count of over 16 million rides [20].

Micro mobility presents a potential solution to the transportation challenges faced by cities worldwide, offering the opportunity for significant shifts away from private motorized vehicles. The International Transport Forum (ITF) proposes defining micro-mobility based on the kinetic energy of vehicles. They define micro-mobility as using micro-vehicles weighing less than 350 kg (771 lb) and with a design speed below 45 km/h. This definition ensures that the kinetic energy of these vehicles remains limited to 27 kJ, which is much lower than that of a compact car at its maximum speed. This definition includes many vehicles, from human-powered options to electrically assisted ones, such as bicycles, e-bikes, kick scooters, skateboards, and four-wheeled electric micro-vehicles. It is important to note that this list is incomplete, and the micro-mobility concept continues to evolve. Consequently, the definition of micro-mobility remains broad, allowing for future developments and ensuring it is not restricted to a specific vehicle type or power source.

This approach enables the facilitation of regulations for newly introduced vehicles in the market, as well as the establishment of a comprehensive category that encompasses all micro-vehicles, regardless of their specific characteristics, such as the number of wheels or riding position. However, the task of regulating and implementing measures to effectively control the usage of these diverse micro-vehicles poses a significant challenge for planners and policymakers worldwide. To address this issue, the ITF proposes the categorization of micro-vehicles into four distinct types based on their top speed and mass. For further information regarding this classification and a comprehensive understanding of micro-vehicles, their types, and their classification, please refer to "Safe micro-mobility."[ITF-2020].

Public transit (PT) offers an extensive means of transportation for long distances; nevertheless, it fails to reach every nook and cranny of a city as efficiently as a car does. Consequently, the issue of the first and last mile arises frequently due to the restricted connectivity and adaptability of conventional public transit. Figure 2.2 shows the rough plan of an entire trip. The whole trip is divided into three segments: From origin A to transit station B is the first-mile trip, From B to C is the main trip where the commuter uses the public transport, and From C to D is the last-mile trip [21].

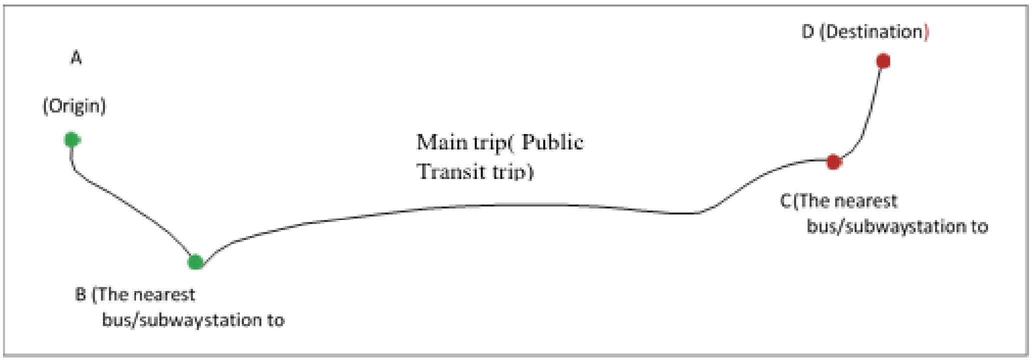

Figure 2.2: A rough route plan for the whole journey

Table 2.1: Literature study on integrating BSS with public transit

Authors	Integration type	Main Trip Mode	Country/City
William P. 2023	Multiuse paths	Rail	Japan
Shishir Mathur,2023	Walking	Metro	United States
Xingjian Xue,2022	Bicycle Share	Metro	China
Alejandro Builes,2022	Public Bicycle	Transit station	Medellín, Colombia
Renata ,2021	Bike sharing	Train	Poland
Bocker et al., 2020	multiple docking stations /BSS	Train/Metro	Oslo, Norway
Grosshuesch, 2020	e-scooters and bicycles	Public Transit	USA
Guo and He, 2020	Dockless BSS	Public Transit	China
Liu et al., 2020	BSS	Metro	Nanjing, China
Li et al., 2020	BSS/multiple docking stations	Public Transit	Xi’an, China

Tavassoli, 2020	BSS/multiple docking stations	PT	Iran

Table 2.1 shows the summary of the literature on how BSS integration was studied. Numerous research studies have concentrated on Chinese cities, which have made significant advancements in their sharing systems and successfully integrated them into their urban transportation networks. One possible explanation for this focus is the abundance of available data in these cities, where technology and ticketing systems have been seamlessly combined. Many of these studies have utilized smartcard data to identify integrated trip chains, such as the combination of bicycle sharing and metro usage within a single journey. On the other hand, some articles that lacked access to this type of data primarily examined the placement and accessibility of bicycle-sharing stations and their influence on individuals' choice of travel mode. William Rogers (2023) develops into the topic of integrating multiuse paths (MUPs) and bike share systems into public transit as a means to address the first/last mile (FLM) issue. The study's findings indicate that by incorporating MUPs and bike share systems into TOD strategies, the challenges associated with FLM travel can be effectively tackled, thereby enhancing the overall transit experience. The study employs survey questions to gain insights into people's behaviours and barriers concerning FLM travel patterns. It underscores the significance of overcoming obstacles in first-mile travel, particularly where driving is the predominant mode of transportation. Integrating bike share stations, transit stops, and MUPs is a crucial component in instilling confidence and surmounting FLM barriers in trips involving public transit [22]. Shishir Mathur's (2023) research examined the obstacles faced in the construction of TODs in the United States is provided. The author delves into the realm of planning, land use, and zoning (PLUZ) to identify the key challenges hindering TOD project progress. These challenges encompass a need for more supportive planning and zoning practices near transit stations, restrictions on density and diversity, and potential barriers that impede the successful implementation of TOD initiatives. The paper sheds light on the multifaceted issues that impede the development of transit-oriented infrastructure by conducting an extensive literature review and conducting country-wise surveys involving transit agencies and local governments. Addressing these barriers is underscored, as it is crucial for facilitating sustainable and efficient TOD in the United States [23]. The

study by Xue (2022) examines the various factors that influence individuals' selection of bicycle-sharing as a means of transportation. It delves into the complex interplay between user perception, psychological expectations, and loyalty and how these factors shape decision-making within the bicycle-sharing context. The main aim of this study is to contribute to a comprehensive understanding of the intricate decision-making process involved in choosing bicycle-sharing as a viable transportation option. To achieve this, the study likely utilizes both empirical data and theoretical frameworks to shed light on the nuances of user behavior within BSS [23].

Alejandro Builes-Jaramillo's (2022) study focuses on conducting a spatial-temporal analysis of the public bicycle-sharing system in Medellin, Colombia, using network analysis techniques. By utilizing advanced analytical methods, the study aims to explore the system's dynamics in terms of both time and space. The analysis will delve into various aspects, including station usage patterns, demand variations over time, and the overall connectivity of the bicycle-sharing network within Medellín's urban landscape. The findings of this study are expected to contribute to a deeper understanding of the operational dynamics of the system. This, in turn, will enable urban planners and policymakers to optimize resource allocation, improve infrastructure, and enhance the overall efficiency and sustainability of public bicycle sharing in Medellín. The application of spatial-temporal network analysis in an academic context is anticipated to reveal intricate patterns and interactions inherent in the complex urban environment. Consequently, it will provide valuable insights for sustainable transportation planning and research on urban mobility [24]. Renata Zochowska's (2021) study conducted by Żochowska et al., the authors examined a GIS-based technique that enables the evaluation of the spatial integration of bike-sharing stations in urban agglomerations. The research introduces a methodology that utilizes GIS tools to explore the spatial organization of bike-sharing stations, intending to assess the efficiency of their placement in urban settings. The analysis considers various factors, including accessibility and geographic distribution, to gauge the overall spatial integration of the bike-sharing system. The results of this study offer valuable insights for urban planners and policymakers, guiding optimizing bike-sharing station placement to improve accessibility and usability within urban areas [25]. Lars Böcker(2020) conducted a study that delved into integrating bike sharing with public transport in Oslo, Norway. The findings of this study reveal that the utilization of bike-sharing services is more common among men and younger individuals, particularly close to metro or rail stations. It is worth noting that the study highlights a positive squared age effect, indicating that age alone does not solely determine the likelihood of using bike-sharing services. The research also emphasizes the significance of spatiotemporal factors, contributing to bike-sharing patterns variations across different locations and times. Additionally, other studies suggest a potential bias towards privileged early adopters, such as individuals with higher education and income levels. Overall, this study came up with valuable intuition into the multifaceted aspects of bicycle sharing in conjunction with public transport, thereby offering crucial information for urban transportation planning and policy considerations [26]. Grosshuesch (2020) investigates the utilization of dockless shared bicycles and shared e-scooters as a means of transportation for first and last-mile travel within public transport networks. The study examines the regulatory frameworks and policies governing these micro-vehicles in US cities [27]. The other studies focus on multiple dockless bicycle-sharing systems [28] [29] [30].

Table 2.2: Key findings from the Literature on BSS integration with public transit.

Authors	Research Data	Key findings
Bocker, 2020	System Data	Bicycle-sharing trips within 200 m of a PT station.
Guo, 2020	System data – Dockless BSS	Trips within 100 meters of a PT station involving bicycle sharing
Li et al, 2020	Analysis of Spatial Data	Provision of BSS stations at origin, PT station & destination
Liu et al, 2020	System Data	Travel time of 10 minutes and in 300m buffer of each station
Tavassoli, 2020	Spatial data analysis	The analysis of public transit networks and catchment areas is done to determine their potential for different purposes.
Adnan, 2019	Field Data+ Questionnaire Survey	Respondents are inquired about their approach to integration
Fan et al, 2019	Questionnaire Survey	Respondents are asked about their integration approach or preferences

Hamidi, 2019	Geographic Data analysis	Parking lots and Stations within the vicinity of 250 m of PT
Lin et al, 2019	System Data	Required Buffer for in and out of BSS trips is approx. 50 m
Wu et al, 2019	System Data – Dockless BSS	Bicycle-sharing trips within 100 meters of a transit station entrance

System Data: refers to the data that has been recorded from smart cards and tickets in the respective metro ticketing machine system.

Table 2.2 shows several ways to study the integration of BSS with transit Stations. Examining the concept of integrated trip chains is a complex task that requires specific methodologies to identify and choose data on intermodal travel behavior; one must employ methods that effectively capture and analyse relevant information. Table 2.1 and Table 2.2 demonstrate various approaches to studying this integration. The most commonly used and relatively straightforward method involves conducting surveys to gather information on integration practices and preferences from respondents. For BSS, as shown in Table 2.2, data from bicycle-sharing companies, such as Global Positioning System (GPS) data on origin and destination locations, trip length, travel time, and user information, can be utilized. However, additional steps are necessary to identify trips that are in or out of public transit. Typically, in studies about dock less bicycle-sharing services, a common approach involves the selection of trips by establishing buffer radii around public transportation (PT) stations. Any micro-mobility sharing trips that commence or conclude within this designated buffer zone are categorized as inbound or outbound trips [31] [32]. The size of the buffer zone varies across studies, ranging from 50 m to 250 m [33]. Additional measures are typically implemented to eliminate journeys that are not part of a cohesive travel sequence. The most precise approach to this selection process entails leveraging intelligent card data, enabling the discernment of bicycle-sharing excursions and subway utilization for individual users via a unique user identity (ID) [34].

Table 2.3: Methodologies used to study the integration of BSS and public transit

Author's	**Methodologies**
Grosshuesch, 2020	The discussion is based on urban data, surveys, reports, and news articles.
Zuo et al., 2020	GIS analysis, Accessibility analysis, Equity analysis

Adnan et al., 2019	Using Hybrid Choice Model (HCM)
Fan et al., 2019	Using Multinomial logit model
Hamidi et al., 2019	Inequality analysis, Accessibility analysis
Lin et al., 2019	Spatial and regression analysis
Pritchard et al., 2019	Spatial data analysis
Weliwitiya et al., 2019	Analysis of Spatial and Survey Data

Table 2.3 presents the methodologies used in the past research and the data collection types that determine the integration of BSS and PT. The reviewed literature articles utilized various methodologies, with regression analyses and GIS-based spatial analyses being the most commonly used. Accessibility analyses were also frequently employed to investigate the impact of micro-mobility and PT integration on access to PT and services. Furthermore, several research studies have employed inequality indices and equity analyses to examine the societal consequences of integration. Qualitative studies were also reviewed, with direct stakeholder involvement through workshops and focus groups being a standard methodology. Other studies focused on conceptual analysis, policy reviews, national trends, and case studies. The diverse range of methodologies employed underscores the complexity of the subject and emphasizes the need for a comprehensive approach to studying and understanding the integration of micro-mobility and PT.

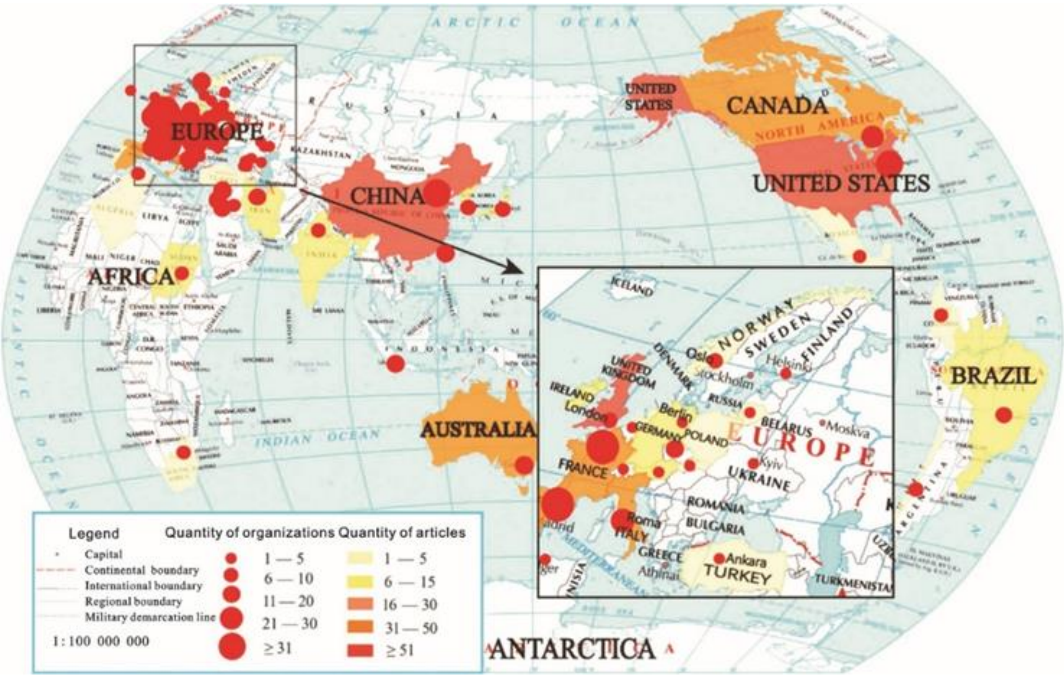

Figure 2.3: Regional Map of BSS literature (MNR, China)

Figure 2.3 shows the distribution of research studies by different nations and institutions. China and the United States are the top contributors, with 248 and 181 articles, respectively, making up 66.82% of the total. The central countries involved in BSS studies are East Asia, North America, Western Europe, and the Middle East. These regions share a common characteristic of having well-established BSS systems, as evidenced by research data from various sources such as Leon, London, BIXI in Montreal, City Bike in New York, and You Bike in Taiwan, China. In contrast, the regions of South America and Eastern Europe have published only 14 studies, highlighting a significant disparity in research output compared to the other areas. In the case of the subcontinent, the idea of BSS marks a new step towards sustainable mobility.

2.4 The current state of Knowledge of BSS in Pakistan

Bicycle-sharing systems have recently gained traction as a promising means of sustainable urban transportation in Pakistan. Although still in its early stages, various initiatives have been implemented, and the government is actively supporting further advancements in this area. With the increasing demand for environmentally friendly transportation alternatives, bicycle sharing has the potential to contribute to Pakistan's transportation landscape significantly.

In 2021, Peshawar became the first city to introduce a bike-sharing system into zones along the BRT Corridor, i.e. Zone-1 (University of Peshawar) and Zone-2 (Hayatabad area), and subsequently, other cities such as Islamabad and Lahore have followed suit by launching their programs. The Bicycle-sharing System in Peshawar will be discussed in the following section to provide a brief overview.

Zone-1 has a total of 17 Stations and covers the area of the University of Peshawar and Agriculture University, which shows that it is mostly an educational zone. **Islamia College Station** is linked with the central Corridor of BRT Peshawar.Figure 2.4 shows the Bicycle Sharing System which is operational in Zone-1.Table 2.4 below shows the capacity of Docking in each station of Zone-1.

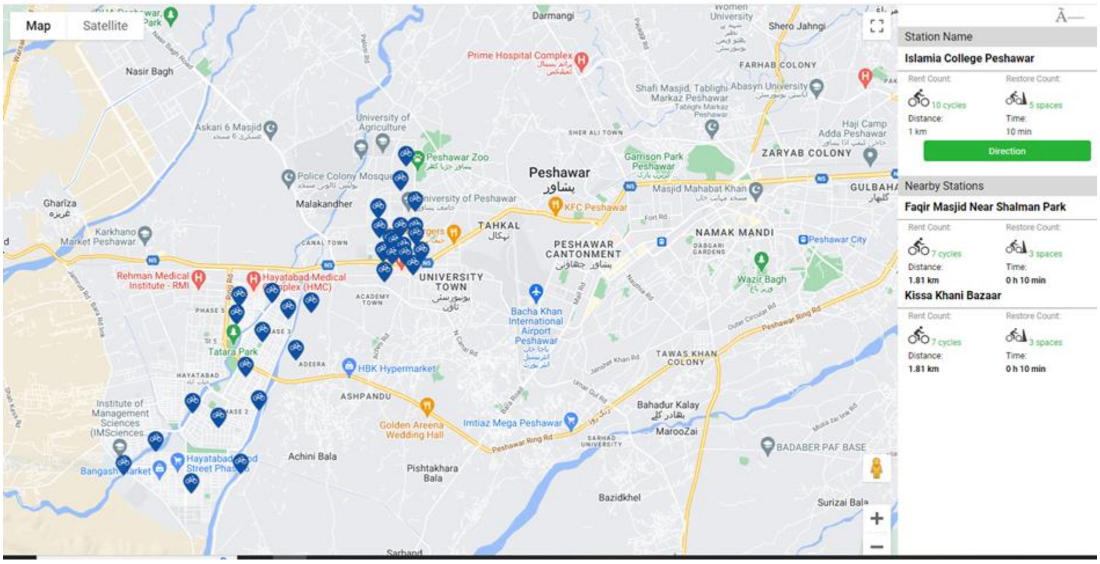

Figure 2.4: Operational map of Zone-1 (Google Earth)

Zone -2 has 15 Stations in total. It covers the Hayatabad area and is primarily a commercial zone. **Hospital Chowk** is linked to the main corridor of BRT Peshawar.Figure 2.5 shows the operational map of Bicycle Sharing System in Zone-2.Table 2.6 shows the capacity of Zone-2 for each Bicycle station.

Table 2.4: BSS Station Capacity of Zone-1

Serial No	Bicycle station name	Total Docks	Total Bicycle Deployed
1	Islamia College Peshawar	15	11
2	Khyber Medical College	22	14
3	Islamia Collegiate	23	15
4	Government Post Office	16	11
5	Islamia College Peshawar	18	12
6	University Gate	18	12
7	Institute of Management	18	12
8	Abdul Qadeer Khan	22	14
9	Qasim Hall Hostel	22	14
10	Student Teacher Café	15	11
11	Jinnah College Chowk	16	11
12	Peshawar University Hall	16	11
13	Lalazar Colony	16	11
14	Masjid-e-Wusta	14	9
15	Pakistan Forest Institute	14	9
16	Agriculture University	20	13
17	Nursery Chowk	14	9
	Total	**299**	**199**

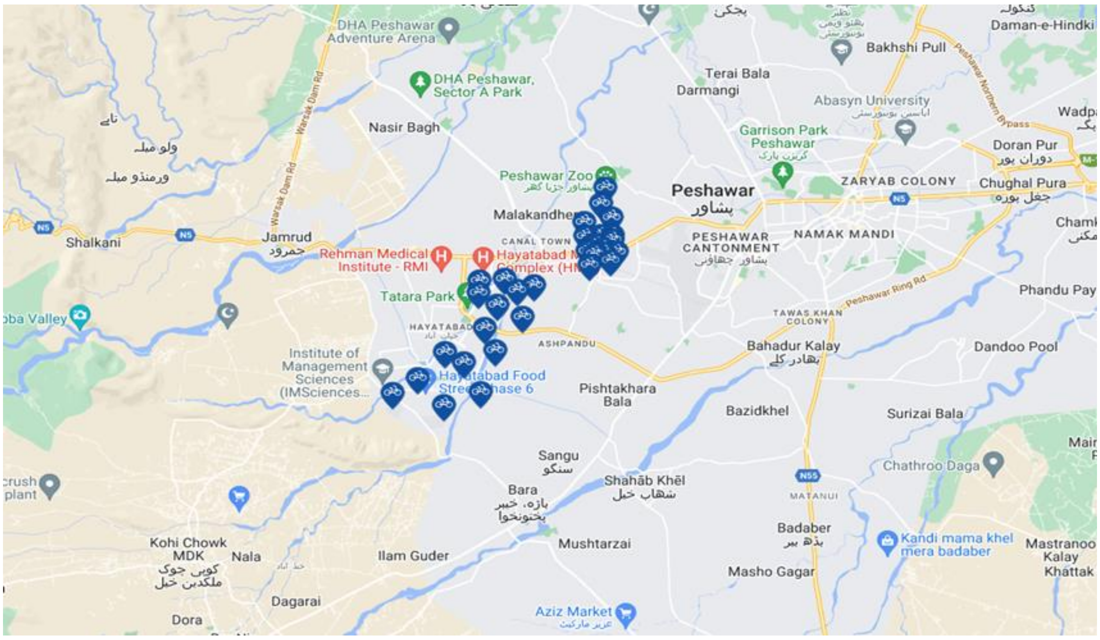

Figure 2.5: Operational map of Zone-2 (Google Earth)

Table 2.5: Key Aspects of Bicycle Sharing System Peshawar

SN	Items	Description
1	Bicycle Stations	32
2	Bicycles	360
3	Docks	540
4	Area	University of Peshawar and Hayat Abad
5	Fare Media	Zu Card and Mobile App

SN: Serial Number

Table 2.6: BSS Station Capacity of Zone-2

SN	Station	Total Docks	Total Bicycle Deployed
1	Hayatabad Medical Complex	16	11
2	Hospital Chowk	13	8
3	Hayatabad Depot	22	14
4	Peshawar Development Authority	16	11
5	Bab-E-Peshawar	11	7
6	Insaaf Market	15	11
7	Basharat Market	13	8
8	Bagh-E-Naran	16	11
9	Zahid Market	16	11
10	Lalazar Market	16	11
11	Ghani Bagh	16	11
12	Kernal Sher Khan Market	16	11

13	Faqir Masjid Near Shalman Park	15	11
14	Institute of Management Studies	22	14
15	Food Street	16	11
	Total	**239**	**161**

Figure 2.6: Zu Bicycles BRT Peshawar

2.5 Factors influencing bicycle integration with transit stations

These sections describe the main factors that influence the BSS integration with transit stations. The calibre of PT, the quality of cycling infrastructure, and the combination of these two elements are the main factors influencing bike transit adoption. Improving these aspects can positively impact the acceptance and usage of bike transit. Moreover, the characteristics of land use and the built environment also play a significant role, highlighting the importance of the local context in successfully implementing bike transit. Overall, the analysis demonstrates that bike transit has the potential to enhance the effectiveness of the current public transportation networks by extending their service area and improving accessibility. However, its impact on car usage has yet to be explicitly examined. The study finds that the combination of biking and transit presents a promising avenue for sustainable urban mobility and warrants further investigation. However, it also highlights the necessity for more thorough study methodologies and a particular emphasis on the kinds of travel behaviours that the bike-transit combination replaces [35]. The influencing factors were described as follows:

2.5.1 *Attributes of the journey and the standard of public transportation*

The successful implementation of bike transit relies on various factors, among which the access and egress components of the journey play a significant role and are extensively deliberated upon. The time and distance required to travel to and from bike-transit stations by bicycle significantly impact the likelihood of individuals choosing this mode of transportation. A study conducted In the Netherlands revealed that individuals residing within a 500-meter radius of a train station are 20% more inclined to take the train than those living 500-1000 meters away and 50% more inclined compared to those residing even farther away. Interestingly, these findings hold regardless of the specific access mode or egress utilized. Overall, bike transit is a preferred option for individuals within a range of access distances [36] within a range of 1 to 5 kilometres, we examined the distance people are willing to cycle. The proportion of cycling concerning the total travel distance significantly impacts the willingness to cycle [37]. In their study, Krygsman et al. (2004) discovered that the distance covered by cycling rises when the total travel distance reaches approximately 60 minutes, accounting for a minimum of 30-50% of the entire journey [38]. Shelat et al. (2018) reported that the average total distance of bike-transit trips in the Netherlands is 41 kilometres, indicating that cycling is more suitable for longer journeys. Nevertheless, cycling to transit may become less attractive compared to walking or utilizing alternative transportation methods when the access or total distance falls below a certain threshold [39].

The utilization and speed of public transportation also have a noteworthy impact on adopting bike-transit combinations. In The Hague, 9% of shared journeys involved a combination with slower modes such as buses or trams, whereas 46% completely replaced them. Even when utilized in conjunction, the average distance covered to reach tram stops in The Hague is roughly 1 kilometre, less than the 1–5-kilometre range for train stations, although it still exceeds walking distances by approximately 2-3 times [40].

2.5.2 *Land use and the nature of the built environment*

The urban context greatly influences the efficient integration of biking and public transportation. Lin et al.'s (2018) research examines the relationship between built environments and bicycle usage for accessing public transportation in Beijing, Taipei, and Tokyo. Despite similarities, the study finds that findings from one city may not apply to another. Overall, integrating different land uses positively affects the combination of bicycles and transit systems [41]. Nevertheless, research in China and Canada has indicated that bike-transit ridership is positively affected by population density and residential land density. In contrast, employment density has a detrimental effect [42]. Regarding population density, Hu et al. (2022) have discovered that the proximity of bike-transit integration to city centres yields negative consequences. Still, as the distance from these centres increases, the impact becomes positive. This implies that an ideal population density exists at which the highest advantages of bike-transit integration, particularly in terms of ridership, are achieved [43]. Furthermore, apart from land use, various attributes of the constructed surroundings exist that impact the effective amalgamation of cycling and public transport. One such example is the incline of the bicycle path, which has been discovered to exert an adverse effect on using bicycles to access public transportation [44].

2.5.3 *The level of interchange quality and available facilities*

Enhancing the quality of interchanges and amenities at stops or stations can alleviate the inconvenience traveller’s face during transfers. Although cyclists usually prefer to bring their bicycles on board, this practice can result in capacity problems and potential conflicts with other commuters. In most European and North American nations, bicycles are generally permitted on board, except during busy rush hours when public transportation is crowded. To tackle this issue, certain regions in North America have implemented front-mounted racks on buses. However, even these racks can become full during peak hours [45] [46].

An alternative solution when bringing bicycles onboard is not feasible is to use the bike as an access mode and park it before boarding. Bike parking plays a crucial role in integrating cycling with transit systems and is more cost-effective than allowing bikes onboard. Bike parking facilities at train stations significantly impact bike-transit integration, while bike lockers at bus stops are rarely used, suggesting that bike parking is more beneficial for high-speed transit and BRT systems [47].

The review of the Puncher et al. report has identified various factors that can impact the integration of bikes and transit through the provision of bike parking facilities. One crucial factor is the availability of an adequate number of parking spaces, particularly during peak hours. Studies have indicated that the significance of proper bicycle parking amenities is amplified in regions characterized by elevated levels of cycling and public transportation utilization. Additionally, the proximity of these facilities to public transport stops or stations is also crucial, as each additional minute of walking can negatively impact the likelihood of choosing bike transit. Payment requirements can also harm bike-transit integration. The presence of complimentary parking has been discovered to considerably enhance the probability of individuals opting for cycling to a train station. Moreover, providing covered amenities that shield commuters from unfavourable weather conditions has the potential to triple the likelihood of selecting bike transit as a preferred mode of travel. Safety and security are crucial elements, with bike-transit users preferring highly visible bike parking facilities. Secure bike cages have been shown to increase usage and encourage park-and-ride users to shift to the bicycle to access their station [46].

2.5.4 *Accessibility to Bicycle Sharing Station*

In general, integrating bikes and transit systems is more successful when bicycles are used as a first-mile solution. Numerous studies have suggested that this phenomenon occurs since most people find it more convenient to have a personal bicycle available at their residence rather than at their intended location. To bridge this gap, bike rental, and bike share programs have emerged as potential solutions. In their study, Stam et al. (2021) discovered that exclusively shared vehicles in the Netherlands would lead to a notable rise in bike usage at the intended location. It is worth noting that specific individuals may not have the privilege of owning a personal bicycle, even within the confines of their residence. In such situations, shared bikes can still be crucial in facilitating bike-transit integration. For instance, at a 10-minute walking distance, bikes accounted for 30% of transportation choices, while at a 15-minute walking distance, this figure rose to 70%. Bicycle trips can also be a more competitive option than bus trips, particularly during peak hours, as a feeder mode [47].

Kapuku et al. (2021) found that integrating bike-sharing and transit systems in Seoul, South Korea, resulted in more significant travel time savings than using buses or shared bikes separately. The study showed a significant improvement of 34% and 33% for the combined bike-sharing and transit approach and using shared bikes alone, respectively. Additionally, the potential for long waiting times associated with other feeder modes, such as buses, can further enhance the competitiveness of shared bikes [48].

2.5.5 *The availability and level of competition among choices*

In addition to the availability of bicycles, the competitiveness of other transportation options plays a crucial role in the successful promotion of bike transit. Failing to consider the competition from alternatives like cars can result in underestimating factors such as the value of time for potential users, leading to an overestimation of the bike-transit system's great potential, especially for those without cars. Additionally, when people see driving as the fastest and most convenient option, it makes bike transit even more appealing. The way to reach a station increases the likelihood of them choosing to drive instead of using bike transit [49].

To attract car owners to opt for bike transit, it is necessary to offer more substantial incentives regarding time savings and other aspects. Additionally, parking facilities at train stations and the chance to receive a ride from a family member or friend have been found. Negatively affect the adoption of bike-trans. However, cars are only one of the competitors in the bike-transit industry. Promoting cycling can lead individuals to choose bicycles for their entire journey, particularly for short distances, which can harm bike-transit uptake. In the city of Austin, USA, nearly half of the individuals utilizing shared bikes would have opted for public transportation if the option of shared bikes was not accessible. Likewise, around 28% of bike-share journeys in Chengdu, China substituted bus trips, while approximately 8% replaced subway trips [50].

Finally, Individuals' attitudes and perceptions towards various transportation modes also have an impact. Having a favourable outlook on bicycles and public transport, as well as being concerned about the environment, while having a negative view on car usage, can influence the decision to combine these modes of transport. This implies that promoting the integration of biking and public transit in urban areas that are primarily focused on cars and heavily reliant on them may pose more significant challenges compared to areas where cycling is already ingrained in the culture, and there is a well-developed public transport system [51].

2.5.6 *Sociodemographic characteristics*

Individuals' characteristics also impact their decision to choose bike transit as a form of transportation. Numerous studies indicate that men are more likely to combine cycling with public transit. Although age is also thought to be an important influence, the research about how it affects riding is not entirely consistent. While some research indicates that older people are less likely to use bike transit, other studies show that the chance of utilizing bike transit rises with age. A third group of studies indicates that people of all ages are less likely to use it [52].

Zhao et al. (2022) found that the relationship between income and bike-transit usage is also not straightforward. According to some research, bicycle combined with public transportation is favourably correlated with greater income, while others found that it has a negative impact [53]. Various studies have argued that individuals with higher levels of education tend to use bicycles in conjunction with public transportation [53].

2.5.7 *Trip purpose*

The circumstances surrounding a journey can have a significant impact, and this is particularly true for bike-transit trips. These types of trips are typically favoured by individuals who are travelling for practical reasons, such as commuting or education, as evidenced by various studies. As a result, there are two distinct peaks in bike-transit usage during the morning and evening rush hours, particularly on weekdays. One possible explanation for this trend is that individuals who frequently travel the same route are more comfortable with the bike-transit combination [54].

2.6 Benefits of bicycle sharing integration with transit stations

BSS with transit stations is expected to bring numerous advantages to commuters who frequently use public transport. These benefits are anticipated to fall into three categories: transportation, health, and environmental. The primary returns on investment in the integration of the bicycle system with public transit are projected to be in the realm of transportation benefits for the University of British Columbia (UBC) community, followed by improvements in health and the environment that will enhance the overall quality of life in the region. The six broad categories were discussed as follows:

2.6.1 *Transportation Benefits*

The integration of bicycle sharing with transit stations provides numerous transportation advantages, thereby enhancing the sustainability and effectiveness of urban mobility systems.

Integrating bicycle sharing with transit stations enhances intermodal connectivity, facilitating a smooth transition for commuters between cycling and public transit alternatives. The integration of bicycle-sharing with transit stations can effectively alleviate traffic congestion and the resulting air pollution by promoting the use of bicycles for short-distance trips. This strategy seeks to decrease the overall number of automobiles on the road, thereby minimizing traffic congestion and its associated emissions. By providing commuters with convenient access to bicycles at transit stations, individuals are encouraged to opt for this eco-friendly mode of transportation, decreasing traffic congestion and air pollution.

Bicycle sharing provides improved first—and last-mile connectivity, effectively filling the gaps between transit stations and final destinations, especially in regions with inadequate public transportation services. Figure 2.7 First-Last Mile connectivity improvement below shows the integration of BSS with Transit station in Austria, which address the last mile connection.

Figure 2.7 First-Last Mile connectivity improvement

2.6.2 *Health Benefits*

The relationship between public health and the built environment can either facilitate or hinder it, primarily through its influence on transportation choices. The transportation options available directly affect individuals' personal health and society's overall health. Environments that encourage walking, cycling, and other active modes of transportation positively impact the health of residents and society as a whole. This is because when walking and cycling are viable alternatives to driving, individuals have a more significant opportunity to engage in the recommended 30 minutes of moderate physical activity per day, as advised by the Centre for Disease Control (Centre for Disease Control and Prevention, 2009). The health benefits of engaging in half an hour of physical activity daily should not be underestimated, as it includes a significant reduction in the risk of developing heart disease, equivalent to the impact of not smoking. Even when divided into shorter episodes throughout the day, this level of physical activity can also lower the risk of developing diabetes, decrease blood pressure, and enhance functional capacity. Figure 2.8 summarizes the health benefits of Using Bicycle.

Figure 2.8: Health Benefits of BSS

2.6.3 *Environmental Benefits*

The consumption of energy and the release of greenhouse gases (GHGs) are greatly influenced by transportation, especially in large cities. As the demand for transportation continues to grow, the transportation sector's impact on overall energy consumption and GHG emissions becomes more pronounced. Nevertheless, bike sharing can significantly decrease energy usage and GHG emissions. To fully exploit the environmental advantages of bike sharing, it is imperative to thoroughly comprehend the transition from other transportation modes to bike sharing and assess the environmental repercussions of this transition. Existing research studies have used big data to determine the environmental benefits of bike-sharing systems. They analysed data from various sources and used geospatial methods to establish the connection between bike sharing and public transportation. The ecological impact of bike sharing was also measured. Two scenarios were examined to determine if the benefits of bike sharing are accurately represented when not considering its substitution for public transportation. The findings showed that 39% of bike-sharing trips replace bus trips, and 13.5% replace subway trips. This relationship is most noticeable in the city centre and during daytime hours. In areas with densely distributed public transit stations, bike sharing tends to substitute bus ridership and complement subway ridership primarily. The integration of bike share trips with the subway is the least common. The environmental impacts of bike sharing resulting from modal shifts were calculated in two scenarios based on the relationship between bike sharing and public transit. In the first scenario, only car trips and walking were considered as the modes being replaced by bike sharing. The study found that 66.1% of bike-share trips substituted other modes of transportation. It is important to note that if the substitution of bike sharing for public transit is not considered, the environmental benefits of bike sharing may be overestimated. However, bike-sharing services still have a significant role in reducing energy consumption and greenhouse gas emissions. Therefore, it is crucial to promote bike sharing as a standalone mode of transportation and in conjunction with public transportation. The findings of this research can provide significant knowledge to urban transportation planners and public transit policy experts while formulating forthcoming transportation planning choices. Whether bike-sharing journeys substitute private vehicles or public transportation, the outcomes of this study can be of great importance. Both scenarios result in substantial reductions in emissions and energy consumption. Consequently, policymakers are advised to encourage the utilization of bike-sharing services [55].Figure 2.10 depicts the summarization of the advantages using Bicycle mode as a sustainable transport option.

Figure 2.9: Environmental Benefits of BSS

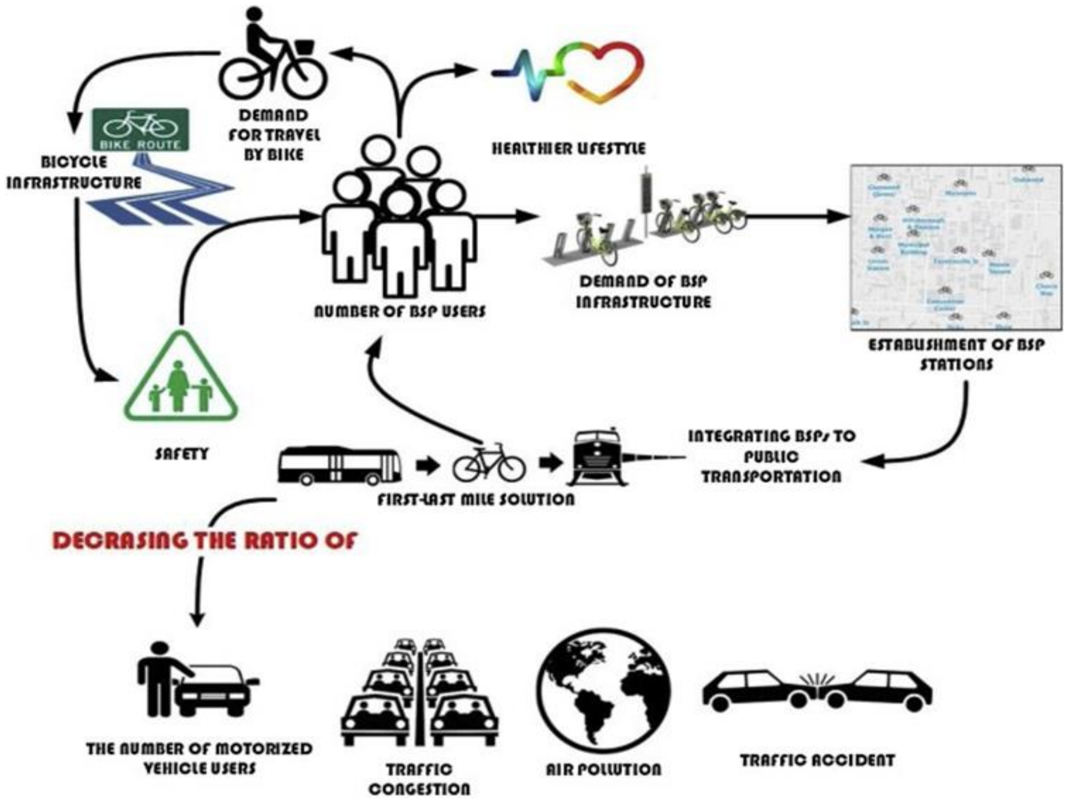

Figure 2.10: Summary of the Benefits

2.7 Potential barriers to bicycle integration mode with transit stations

Conducting a comprehensive analysis of existing literature on the challenges to bicycle integration with transit stations are related to planning, land use, and zoning that hinder the successful integration of different intermodal connectivity. Summarizes the different Levels of potential challenges are discussed as follows:

2.7.1 *Regional and Local Level Planning Barrier*

Shishir et al. (2023) emphasizes the importance of considering the effect of land uses around each station on the overall ridership of the transit system when planning at a system-wide scale. They argue that comprehensive planning, including regional and long-range considerations, is crucial for successfully implementing TOD tools like local zoning. Without such planning, TODs are likely to be developed sporadically within predominantly car-centric urban areas. Real estate developers also highlight the significance of sound planning in reducing uncertainties during the development process. Furthermore, they both emphasize the necessity of combining land use and transportation planning; Shishir goes one step further in emphasizing this point, citing ineffective coordination between transit agencies, local and regional land use agencies, and transportation planning agencies as a barrier to the implementation of transit-oriented developments (TODs) [56].

2.7.2 *Urban Design Level Barrier*

To ensure smooth transfers, it is essential to have bike-sharing stations conveniently situated near the entrances, exits, and bus stops of transit stations. The presence of a well-connected network of stations is of utmost importance to enhance accessibility and promote cycling as a complementary mode of transportation to public transit.

Providing secure and easily accessible parking spaces specifically designed for bicycles is crucial in mitigating the risks of theft and vandalism, thereby fostering a favourable environment for cyclists to utilize bike-sharing services. Illuminated and conveniently located parking zones not only enhance the overall safety and security for cyclists but also instil confidence and peace of mind.

Ensuring the safety of cyclists and bridging the gaps in infrastructure is of utmost importance when addressing the issue at hand. To safeguard cyclists from potential traffic hazards, it is imperative to establish secure and exclusive cycling lanes that seamlessly connect transit stations with the neighbouring communities

Efforts to raise public consciousness and educate individuals can effectively advocate for the advantages and proper conduct associated with cycling, thereby fostering the utilization of multiple modes of transportation [57].

2.7.3 *Zoning Level Barrier*

The integration of bike-sharing systems with transit stations can be impeded to a great extent by zoning regulations.

There needs to be more zoning regulations for mixed-use development to ensure the formation of lively and cyclist-friendly communities near transportation hubs, utilization diminishing the chance of bike-sharing. Implementing mixed-use zoning can foster cycling as a convenient and easily accessible means of transportation.

The absence of zoning regulations that enforce or encourage the integration of bicycle-friendly infrastructure, such as designated bike lanes and safe parking facilities, can harm cycling and impede the successful integration of bike-sharing programs. By incorporating mandatory bicycle-friendly infrastructure requirements into zoning codes, it is possible to establish a more interconnected and accommodating environment for cyclists

The absence of effective coordination between zoning authorities and transportation planners can result in the development of unaligned infrastructure, thereby posing challenges in seamlessly integrating bike-sharing systems with transit stations. By fostering collaborative endeavours between zoning and transportation departments, it is possible to ensure that zoning regulations are conducive to successfully integrating bike-sharing and public transit [58].

2.7.4 *Economics and Financial Level Barriers*

Economic and financial barriers pose significant challenges to the development of TODs. These barriers, include a weak economy and real estate market, limited financing options, inflexible loan underwriting standards that discourage the integration of different land uses and affordable housing, and the need for extensive parking facilities. Additionally, the construction costs and associated risks are exceptionally high for TODs located in inner cities or already urbanized areas of the United States. These areas often require infrastructure upgrades and environmental remediation, further escalating the expenses and uncertainties involved in the development process. Consequently, there is a considerable risk of significant revisions or cancellations for these TOD projects. Moreover, the scarcity of vacant, developable land and the challenges associated with assembling land parcels further exacerbate the risks and costs. The initial capital investment required for TODs is substantial, and the project gestation period tends to be prolonged. Furthermore, the need for dedicated public funds for TOD planning and construction adds to the hurdle’s developers face.

Traditional lenders are often reluctant to finance TODs incorporating mixed land uses, and the uncertain market demand for these developments in the United States further complicates the situation. This is primarily because TODs, especially those with mixed-use components, are a relatively new real estate product in many localities [59].

2.7.5 *Organizational Level Barrier*

The literature emphasizes a notable obstacle within organizations and institutions: the need for more effective coordination and collaboration among different stakeholders. These stakeholders encompass local governments, transit agencies, and developers. The lack of coordination can be attributed to various factors, including the competition between local governments for new development and funding, the absence of a regional agency responsible for land use and transportation planning, unclear interaction guidelines, and the absence of a designated project leader. Furthermore, stakeholders may need to share crucial information regarding the structuring of joint development agreements, cost reduction strategies, profit maximization techniques, and the potential advantages and disadvantages of collaborative endeavours [60] [61].

2.7.6 *Policy Level Barriers*

According to Nathen et al. (2017), the lack of consensus on the objectives of TODs often leads to conflicting policies. The question arises whether TODs should prioritize maximizing ridership or lease revenues or focus on creating vibrant urban spaces. This lack of agreement results in a cohesive policy environment where transit agencies and local governments need help to establish a shared vision for TOD. Another policy ambiguity they highlighted they highlighted was the conflict between the concept of a node and a place. Transit agencies may perceive a station as a functional node that efficiently feeds riders into their transit systems. On the other hand, planners may view a station as a desirable place that contributes to the overall urban environment. This perspective disparity can lead to conflicting requirements, such as transit agencies demanding ample parking at stations, which contradicts planners' vision of creating vibrant, walkable, and bike able station areas [62].

Lea Ravens Bergen et al. (2018) further explore that the absence of state-level policies specifically addressing TODs poses a significant barrier. State-level policies have the potential to significantly impact the financing of station-area planning and infrastructure enhancements, fostering collaboration among state agencies, encouraging regional planning efforts, facilitating partnerships between the public and private sectors, implementing pilot programs for transit-oriented development (TOD), and mitigating regulatory and legislative barriers that hinder TOD-supportive land use. The lack of clear state-level policies may have deterred some transit agencies from implementing TODs; ultimately, the success of TODs relies on the presence of state-level policies that align with regional and local visions and policies, particularly in terms of land use-transportation coordination and urban sustainability [63].

CHAPTER 3: RESEARCH METHODOLOGY

This Chapter exemplifies the various methodologies employed to gather the necessary data for the execution of this research and the application of the techniques. Two distinct forms of data, primary and secondary data, are essential to carry out the study. Consequently, the subsequent paragraphs outline the approaches to acquiring primary and secondary data.

3.1 Introduction of Research Methodology

A research methodology functions as a guiding framework that outlines the nature of research endeavours, offers instructions on how to proceed, establishes criteria for measuring progress, and defines what constitutes success. It is a systematic approach to collecting data and information to achieve the objectives. The methodology plays a pivotal role in effectively accomplishing the tasks.

3.2 Research Design

The research conducted in this study is a combination of statistical and spatial analysis, which is based on field surveys and practices carried out in both developed and developing countries. The data for this research has been collected from primary and secondary sources. To present the findings and outcomes related to the BSS integration with BRT Peshawar, residents' opinions and surveys were utilized.

This study encompasses various stages, including identifying the research problem, formulation of objectives, literature review from both developed and developing countries, and the local context. A questionnaire was designed to align with the research objectives, facilitating the collection of primary and secondary data. This data was then processed and analysed to derive meaningful insights.

Valuable insights were obtained through the analysis, which led to the formulation of conclusions and recommendations. A research design framework was prepared, as depicted in section 3.11.

The research method employed for this study was a hybrid approach, combining descriptive and exploratory methods to gather, study, and analyse the data. Exploratory research was conducted in the form of a Questionnaire drafted in Urdu and English to gather information on the various aspects of BSS integration and BRT Peshawar, including the demographic conditions of the Commuter, Trip Purpose travel time, etc.

3.3 Chi-Square Test

Before an experiment is conducted, a researcher must develop a hypothesis that declares a testable potential explanation for some outcome of interest. However, when a hypothesis is created, a null hypothesis must come. A null hypothesis is a statement that makes the hypothesis null and void. For example, suppose the hypothesis says that there is a relation between the potential barriers to using the bicycle mode and sociodemographic characteristics of the commuter. In that case, the null hypothesis must state that there is no relation between the potential barrier using bicycle mode and sociodemographic characteristics.

Statistical significance is a way of mathematically determining whether the probability of something happening was due to chance or due to the effect of some variable. Because statistical significance measures the likelihood of an occurrence being genuine, its symbol is the lowercase letter p. At some point way back in the history of statistics; it was mutually agreed upon that an occurrence with a probability of 1 in 20 would be unlikely to occur by pure chance and was therefore statistically significant. Since one divided by 20 is 0.05, it is statistically significant if the p-value is 0.5. This point is where the chi-square test definition comes into play. The chi-square test is a statistical method of calculating whether variations in data are due to one of the tested variables or chance. The calculation of the Chi-Square statistic is relatively straight-forward and intuitive. Equation (3.1)shows the mathematical expression of Chi-square test.

$$X^{2} = \sum \frac{(fo - fe)^2}{fe} \qquad (3.1)$$

where f_o = the observed frequency (the observed counts in the cells)

and f_e = the expected frequency if NO relationship existed between the variables

As depicted in the formula, the Chi-Square statistic is based on the difference between what is observed in the data and what would be expected if there was indeed no relationship between the variables.

The Chi-Square Test of Independence is commonly used to test the Statistical independence or association between two categorical variables. However, the Chi-Square Test of Independence can only compare categorical variables. It cannot make comparisons between continuous variables or between categorical and continuous variables. Additionally, the Chi-Square Test of Independence only assesses associations between categorical variables and cannot provide any inferences about causation. The Statistical analysis approach is shown in Figure 3.1 below.

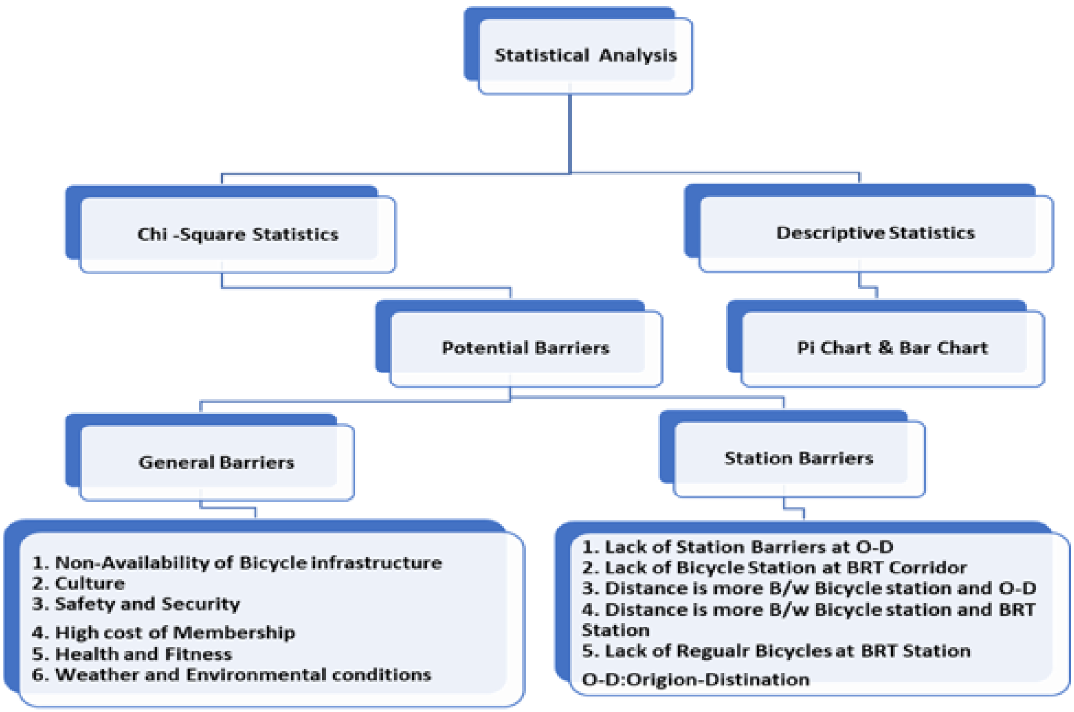

Figure 3.1: Overview of the Statistical Approach

3.4 Accessibility Analysis Using Gravity Model

The accessibility measure based on gravity assumes that as distance or travel time increases, the interaction or accessibility between different locations decreases. In contrast to the cumulative opportunities measure, which employs a discrete distance or travel time measure, gravity utilizes a continuous measure known as the "distance decay function" to discount accessibility as travel time or distance from a specific location increase. The general formula for the gravity-based accessibility measure is as follows. The simple generalized mathematical expression for gravity model as shown in Equation (3.2)

$$A_i = \sum_j^n \frac{Oj}{(tij)^{\alpha}} \qquad (3.2)$$

The accessibility measure for location "i" is denoted as Ai, while the travel time or distance between locations i and j is represented by t_{ij}. The number of opportunities at location "j" is denoted as O_j. The distance decay parameter is defined by α. A higher value of α indicates a faster decay in the attraction to the desired destination or a quicker reduction in accessibility.

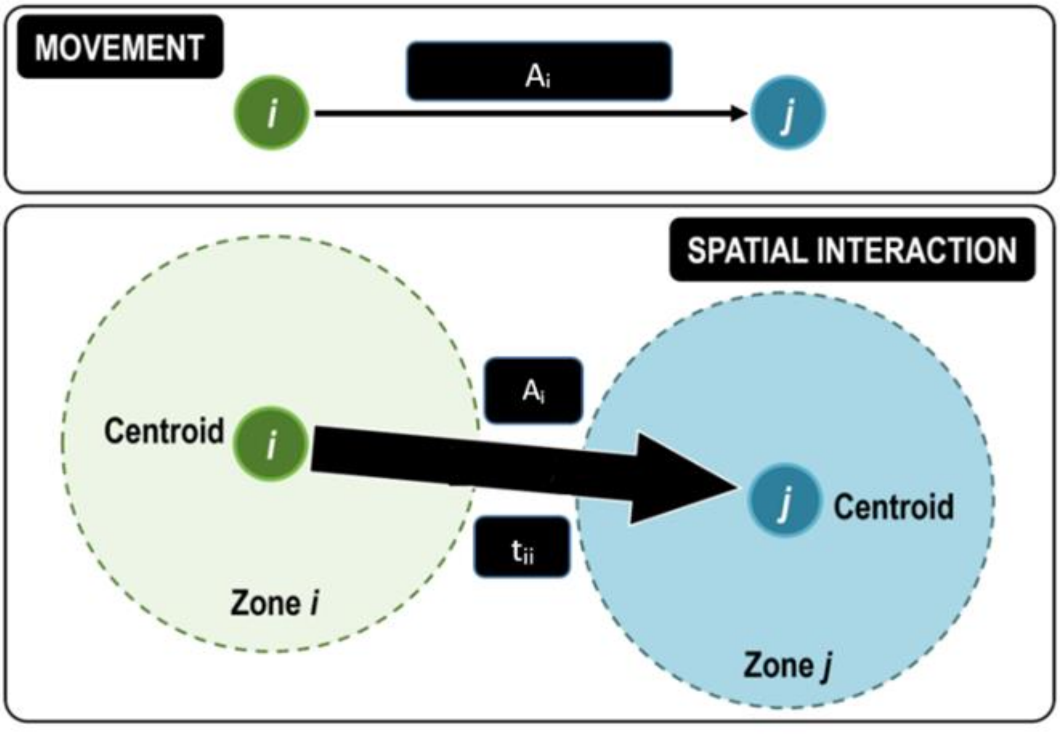

Figure 3.2: Gravity Model Depiction

Figure 3.2 represents the Gravity model in which "i" shows any nearest BRT Station along the BRT Corridor While "j" is any University or Recreational Facility along the BRT route, and "t_{ij}" is the travel time from any nearest BRT Station to the

University or recreational facility. Recreational facilities in the context of this study include parks, museums, historical places, jogging trails, etc. While the green spaces in the maps mean public parks, street verges, cemeteries, and sports grounds.

3.5 Spatial Analysis and Density Maps

The spatial analysis involves systematically examining the spatial arrangement, distribution, interconnections, and tendencies exhibited by geographical data. They are using techniques such as mapping, statistics, modelling, and visualization. With this process, you can answer questions such as where trips originate and terminate, how transport networks affect travel demand and performance, how spatial factors like land use or population density affect travel behaviour and preferences, and how transport policies and interventions like pricing or infrastructure impact spatial outcomes.

To apply spatial analysis to transport planning, one must collect spatial data representing the transport system and its context. These data can be vector or raster; vector data consists of discrete points, lines, and polygons that define the location and shape of geographic features, while raster data are continuous grids of cells storing numeric values. Spatial data sources for transport planning include census and survey data, transport network data, transport demand data, transport performance data, and remote sensing and GPS data. Census and survey data provide socio-demographic information and travel behaviour of individuals and households; transport network data describe the physical and operational characteristics of the transport infrastructure and services; transport demand data measure the volume and pattern of trips and movements by different modes; transport performance data indicate the level of service and quality of the transport system; and remote sensing and GPS data capture the spatial and temporal dynamics of the transport system. Decision-makers can utilize the consolidated version of this spatial data to make informed choices in response to the requirements. One practical application is using spatial analysis in urban traffic management, which empowers authorities to address the development of resilient cities proactively.

In this study, we have collected the data in the form of a questionnaire regarding the Trip purpose using Bicycle mode, Potential Barriers faced by the commuters, Prefer First and Last mile mode comparison of Walking and Bicycle mode along the BRT

Corridor over each BRT Station by distributing the equal number of the questionnaire. For the generation of Density maps of the parameters above we define the indexes for each station, geocode the stations, and assign the index to their respective station. The spatial approach is shown in the Figure 3.3 .

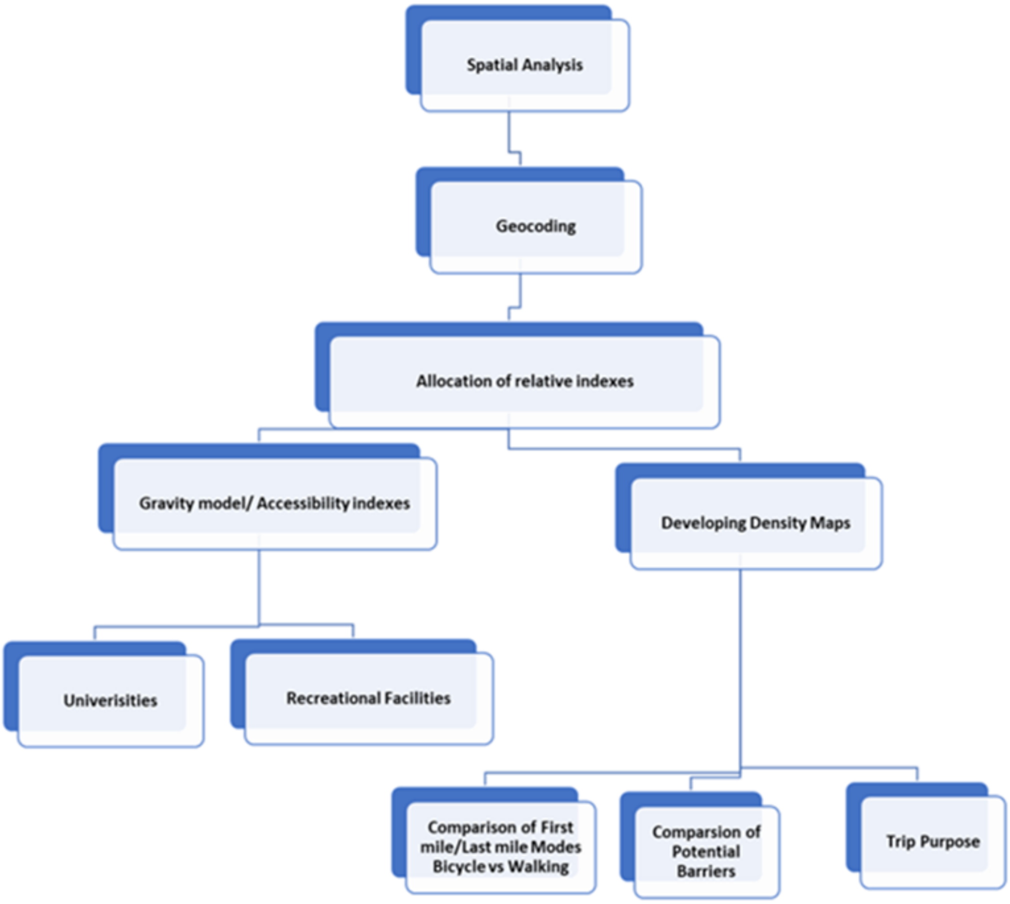

Figure 3.3: Overview of the Spatial Approach

3.6 Selection of Case Study

The case study area selection should meet specific criteria, such as accessibility, cost-effectiveness, and relevance to the project. For our project on Spatial Integration of Bicycle BSS to Public Transit Stations, we have chosen "Peshawar BRT" as the case study area. Peshawar BRT was the first BRT system in Pakistan that launched the BSS in the country, and we know land use, commuters' driver behaviour etc

3.7 The Literature Review

The literature review is paramount in any research endeavour as it elucidates the relationship between the proposed study and prior research. Moreover, it serves to validate the chosen methodology for conducting the research.

For this particular research, a thorough literature review has been conducted, focusing on prominent planning issues in developed and developing countries. The literature predominantly comprises articles, newspapers, and case studies. An extensive literature review has been undertaken at two stages: initially, before finalizing the research topic, and subsequently, after the topic selection. A literature review was conducted during the first stage to reach a well-informed conclusion regarding the research topic. In the subsequent stage, the literature review focused on existing research related to the chosen topic. Both national and international studies were consulted to gather ample data concerning prevailing planning problems at the regional, city, and even national levels.

3.8 Methods of Collection of Data

The selection of data collection methods is of utmost importance in guaranteeing the significance and success of research. These methods directly influence the outcomes obtained and the conclusions drawn, making them indispensable tools for evaluating and analysing different phenomena within research theory. The utilization of practical techniques for data collection is crucial for quantifying intricate research processes and inferences, identifying both observable and hidden factors, and ultimately producing meaningful and noteworthy results. Consequently, meticulous consideration should be given to the development and execution of precise measurement techniques to capture the complexities of the research subject accurately.

3.8.1 *Collection of Primary Data*

Primary data is information gathered firsthand in the field and has not been subjected to any statistical analysis. It is widely regarded as the most precise and up-to-date form of data, offering valuable insights for research purposes. Even with this, collecting primary data can be both time-consuming and expensive compared to utilizing secondary data sources. The collection of primary data becomes particularly crucial when the existing secondary data is outdated or when there are doubts regarding the reliability and accuracy of the information provided. In such instances, primary data is gathered to bridge gaps and guarantee a more comprehensive and dependable dataset for analysis.

For this particular research, the primary data was collected by conducting the questionnaire survey i.e., filed survey, as well as online among the BRT commuters along all the BRT Peshawar stations.

3.8.2 *Collection of Secondary Data*

Among the various approaches, secondary data collection stands out. It encompasses information that has been previously amassed, structured, or subjected to statistical analysis. For this particular research, we have visited and put a request letter for the provision of Ridership Data of BRT Buses and Bicycles to see which trend it follows

The initial action undertaken was the implementation of a desktop survey. Utilizing contemporary technology, the internet was a valuable tool for gathering comprehensive data regarding prominent planning issues. Various web links and sites were meticulously explored to acquire relevant information. The primary objective was to identify a suitable case study that offered cost-effective accessibility and the potential to amass a wealth of knowledge.

Not everything can be found on the internet. The library was also consulted to gather information about the methodology, i.e., statistical analysis and Spatial Analysis. Various books and other resources were explored to gain insights into the nature of the proposed methodology. Additionally, numerous articles and previously conducted research theses were examined to obtain relevant and accurate information.

3.9 Sample Size

As was aforementioned the survey was conducted online as well in the field. The questionnaire was distributed during the morning Peak hour and evening peak hour at every station and targeted the permanent users. The total number of responses was 945, of which 250 responses were recorded online, and 695 were collected through a field survey.99 responses were excluded as an outlier. Hence the total sample size is 846.Figure 3.4 below shows the overall approach used for this research.

3.10 Flow Chart of Research Methodology

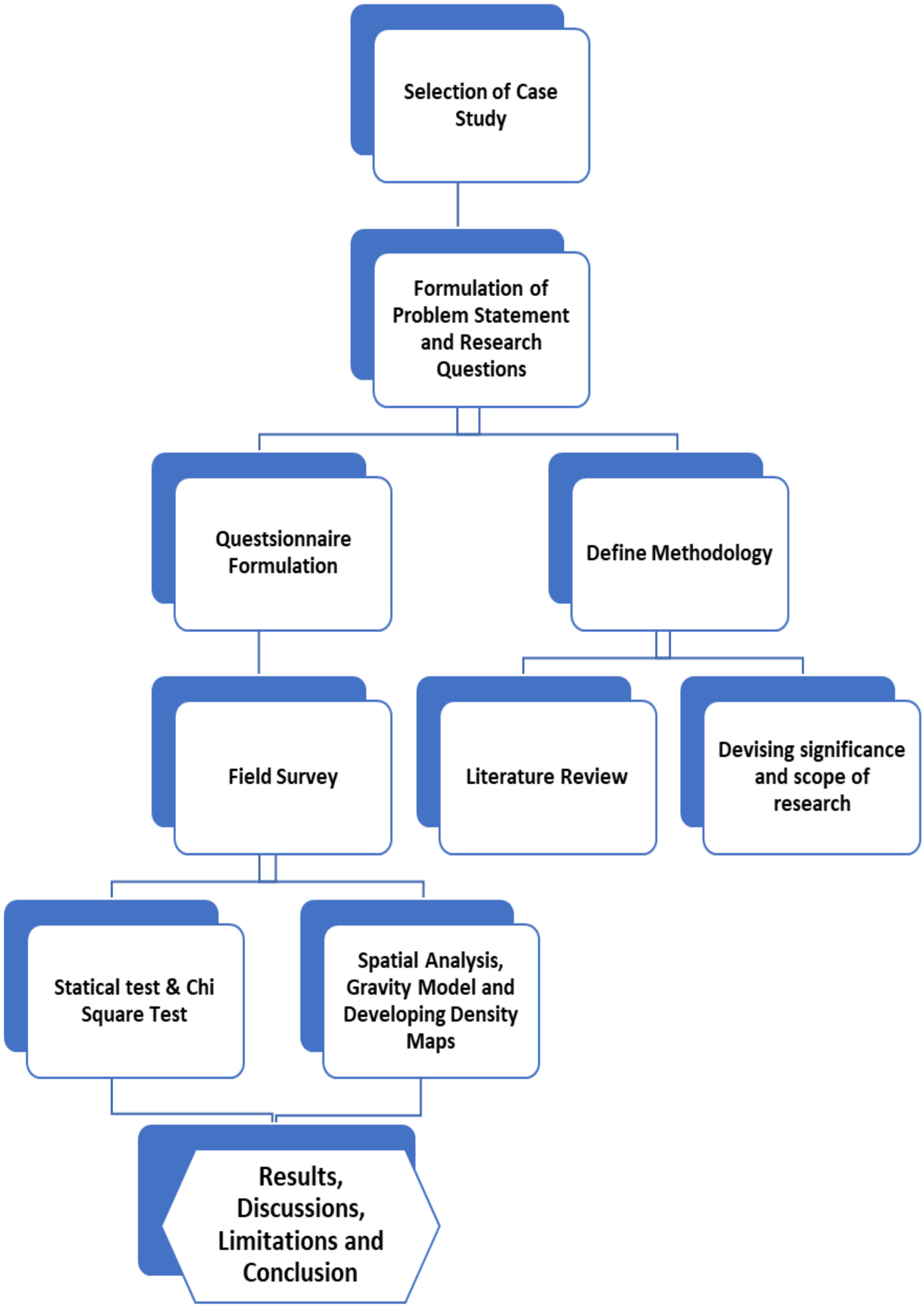

Figure 3.4:Overview of Methodology Approach

CHAPTER 4: ANALYSIS AND RESULTS

This Chapter contains the analysis of the data which have been collected in the field using the proposed methodology discussed in Chapter 3 of this report. The data were analysed statistically using the Chi-square test as well as spatial analysis developing the density maps over each station of BRT using different travel characteristics related to Bicycle sharing mode.

4.1 Statistical Analysis and Chi-square Test

4.1.1 *Descriptive Statistics*

Table 4.1: Descriptive Analysis

Variable	Characteristics	Frequency	Percentage
Gender	Male	479	56.62
	Female	363	42.91
Age group	18–24 Years	607	71.75
	25-34 Years	180	21.28
	35-44 Years	42	4.96
	45-54 Years	12	1.42
Level of Education	Nursery school to 8th grade	19	2.25
	Matriculation	56	6.62
	Higher Secondary	258	30.50
	Bachelor	411	48.58
	Postgraduate	102	12.06
Monthly household income (Rupees)	Less than 34,999	203	24.00
	35,000-59,999	189	22.34
	60,000-99,999	132	15.60
	100,000-149,999	60	7.09
	More than 150,000	52	6.15
	Prefer not to answer	210	24.82
Employment status/Occupation	Govt Employee	103	12.17
	Private Employee	119	14.07
	Own Business	42	4.96
	Retired	16	1.89
	Student	498	58.87
	Other	67	7.92
Trip Purpose Using Bicycle Mode	Workplace	81	9.57
	Grocery Stores/services	86	10.17
	Schools/College/University	135	15.96
	Recreational facilities	65	7.68
	BRT stops and stations	85	10.05

	Other neighborhood destinations.	49	5.79
	I Never use the Bicycle	457	54.02
Weekly Usage of the Bicycle Mode	0 to 1 day	567	67.02
	2 to 3 days	154	18.20
	4 to 5 days	95	11.23
	6 to 7 days	30	3.55
Preferred Travel Distance Using Bicycle	Less than 1km	297	35.11
	1 -2 km	224	26.48
	3-4 km	170	20.09
	5-6 km	108	12.77
	More than 6km	47	5.56
Preferred travel time Using a Bicycle	0 to 10 Minutes	247	29.20
	11-20 Minutes	266	31.44
	21-30 Minutes	248	29.31
	More than 30 Minutes	85	10.05
Bicycle Usage due to Weather condition	The threat of rain	181	21.39
	Heavy rain	376	44.44
	Drizzle	101	11.94
	Steady rain	143	16.90
	Fog	181	21.39
	Cold weather	181	21.39
	Hot weather	309	36.52
Potential Barriers affecting the User’s perception towards the bicycle-sharing system/Obstructions	Health and Fitness	161	19.03
	Weather and Environmental Conditions	151	17.85
	Culture	220	24.00
	Safety and Security	162	19.15
	Non-availability of adequate Bicycle infrastructure facility	206	26.35
	High Cost of Membership	134	15.84
	Bicycle Stations are too far	114	13.48
	Not enough stations close to BRT stations	149	17.61
Current First-mile mode Choice to BRT Access	By Private Vehicle (Rickshaw, Taxi, etc.)	233	27.54
	By Bicycle	123	14.54
	By Walking	418	49.41
	By own Vehicle	72	8.51
Prefer First-mile mode Choice to BRT Access	By Private Vehicle (Rickshaw, Taxi,	147	17.38
	By Bicycle	288	34.04
	By Walking	324	38.30
	By own Vehicle	87	10.28
	I never take the BRT Bus	40	4.73
Last mile mode Choice from BRT	Walk	447	52.84
	By Bicycle	109	12.88
	By own Vehicle	67	7.92
	By Private Vehicle (Rickshaw, Taxi,	183	21.63
Station Level Barriers	Not enough Bicycle stations at my Origin-Destination	214	25.30
	Not enough Bicycle stations at BRT bus stations	181	21.39
	Distance: BRT Bicycle stations are too far away from my Origin-Destination	204	24.11

	Distance: BRT Bicycle stations are too far away from BRT Bus stations	168	19.86
	Not enough regular Bicycles at BRT Stations	102	12.06
	Nothing prevents me	151	17.85
	Other	84	9.93
Attitude towards integration of BSS and BRT	Strongly agree	391	46.22
	Somewhat agree	200	23.64
	Neutral	202	23.88
	Somewhat disagree	34	4.02
	Strongly disagree	19	2.25
Attitude towards Using BSS after the improvements of Bicycle infrastructure	Strongly agree	430	50.83
	Somewhat agree	195	23.05
	Neutral	179	21.16
	Somewhat disagree	27	3.19
	Strongly disagree	15	1.77
Preferred Payment Method	By Cash	218	25.77
	By Card	403	47.64
	By Mobile App	119	14.07
	Single Payment for both BRT Bus and Bicycle (integrated payment system)	106	12.53

The data is collected in the form of a distribution of questions among the BRT Users along each station to know their trend using the Bicycle mode integrated with the BRT corridor. The Questionnaire contains three/3 sections; i.e. Sociodemographic characteristics of the commuters, Attitude towards Bicycle sharing System and Attitude towards integration of BSS with BRT as shown in Table 4.1.

The demographic profile includes Gender, Age, Highest Education Level obtained, Employment status and household income. Upon descriptive analysis of the demographic section, we found the frequencies and Percentages of the categories mentioned above. If we look at gender, the ratio is 43% for females and 57% for males. Considering age, 71% of the respondents were between the ages of 18-24 years from whom the data was collected, similarly less than 22% were at the age of 25-34 years old and almost 5% of respondents were at the age of 35-44 years old. As we can see, most of the respondents were between 18-24 years old. The reason behind this was that most of the data was collected from the young age group as they showed more inclination towards bicycle mode due to health and fitness. Likewise, if we look at the education status, almost 50% of the respondents have an education level of Bachelor while 30% have an education in Higher Secondary; the reason behind this was that most have an education level to collaborate resourcefully, so a proportion of them was higher.

If we compare the monthly household income, 24% of respondents have an income less than 35,000, 22% have an income in the range of 35,000-60,000, and 25% of respondents do not want to show their income. The reason that most of the questionnaires were distributed to low-income level commuters of the BRT is that low-income people don't have access to their cars, so they may use public transport more than those of the higher-income level. Similarly, considering the employment status more than 50 % were respondents a student. i.e., 59%, while 14% and 12% were private and govt employees, respectively. The reason is that students are more willing to use the bicycle as a transportation mode due to cost-effectiveness and health fitness.

Section 2 of the questionnaire shows the Bicycle culture in Peshawar, people's trip purpose using bicycle mode, weekly usage frequency of bicycle mode, their preferred travel distance, travel time, Bicycle usage during weather effects in hot weather, rain, etc. Potential barriers they are facing while riding on a bicycle. If we look at the trip purpose, 54% of people never use a bicycle, which is a matter of concern. That is why such a sustainable mode of transport is ignored in their daily commute. It may be due to improper bicycle infrastructure and the lack of awareness of the benefits of bicycle mode. While the rest of the percentage is not more significant. i.e., 16% of people use it for educational access to institutes, 10% for going to workplaces, 10% for daily necessities of the home like groceries etc., 10 % for access to BRT stations, and 8% for recreational purposes. It also further shows a need to explore the bicycle mode more in the study area. Likewise, the weekly usage frequency of Bicycle mode was also shallow. i.e., 67 % of the respondents use bicycle mode no more than a day in a week. While 18% and 11% of the respondents use it a maximum of 3 days and five days respectively, in a week. for the sake of future planning of BSS, the respondents have inquired regarding the preferred travel time and distance.35% of respondents prefer to travel a distance of less than 1km range using bicycle mode, while 26% of respondents want to travel a distance of 1-2 km, and 20% respondents want to travel less than 4km. likewise almost 30% respond to travel on bicycle mode for 30 minutes while 10% having travel time of more than 30 minutes. The collection of such data will provide some information in the future about Bicycle Station Location Bicycle infrastructure, etc. Considering the weather conditions, 44% of the respondents were not using the bicycle during heavy rain and 36% due to hot weather, while the percentage of using the bicycle mode due to cold weather was almost the same. i.e. 21%. The reason that most of the respondents don’t ride bicycles in heavy rain is safety issues like slipping the bicycle; heavy rain reduces the visibility of the rider, while in the hot season, it can cause problems health-related like dehydration, etc.

Considering the potential barriers affecting the thinking. In comparison, security perception towards the bicycle-sharing system, 26% of respondents consider the non-availability of adequate bicycle infrastructure facilities as the potential barrier, while culture is 24%, and safety and security are 19%. The reason may be that respondents observed that there were no dedicated lanes for bicycles to accommodate aggressive driver behaviour in the study area.

Section 3 of the questionnaire shows the attitude of the respondents towards integrating BSS and BRT; it includes first and last-mile mode choices for access to BRT stations, barriers they were facing at BRT stations, and preferred mode of payment for a bicycle trip. From the table, we can see that in the current situation, almost 50% of respondents use the walk to get access to BRT stations, while less than 15% use Bicycle mode similarly more than 50% of respondents use walk mode as the last mile journey after getting off from BRT. Likewise, 25% of respondents don’t find bicycle stations at their origin and destination spots.46% strongly agree to integrate the Bicycle mode with BRT, while a meagre percentage. i.e. 2.25%, which did not agree with the integration. Similarly, 47% of respondents prefer to use a card for bicycles on our trips.

4.1.2 *Potential Barriers*

Table 4.2: sociodemographic Characteristics vs. Potential barriers

Sociodemographic Characteristic’s	**Potential Barriers**	***p*-value**
Gender	Health and Fitness	**0.000**
	Weather and Environmental Conditions	**0.049**
	Culture	**0.000**
	Safety and Security	0.530
	Non-availability of adequate Bicycle infrastructure facility	0.173
	High Cost of Membership	**0.037**
Age	Health and Fitness	0.216
	Weather and Environmental Conditions	0.729
	Culture	0.217
	Safety and Security	**0.001**

	Non-availability of adequate Bicycle infrastructure facility	**0.040**
	High Cost of Membership	0.993
Education Level	Health and Fitness	0.873
	Weather and Environmental Conditions	0.282
	Culture	**0.000**
	Safety and Security	**0.001**
	Non-availability of adequate Bicycle infrastructure facility	**0.003**
	High Cost of Membership	0.261
Monthly Household income	Health and Fitness	**0.033**
	Weather and Environmental Conditions	**0.001**
	Culture	0.119
	Safety and Security	**0.020**
	Non-availability of adequate Bicycle infrastructure facility	**0.000**
	High Cost of Membership	**0.000**
Employment Status	Health and Fitness	**0.028**
	Weather and Environmental Conditions	0.320
	Culture	**0.059**
	Safety and Security	**0.050**
	Non-availability of adequate Bicycle infrastructure facility	**0.023**
	High Cost of Membership	0.273

Note: Bold values indicate a value of 0.05 or less.

Table 4.2 presents the results of a Chi-Square test to compare the distribution of potential barriers facing commuters across different sociodemographic groups. The sociodemographic characteristics included in the table are gender, age, education level, monthly household income, and Employment Status. General barriers included in the table are health and fitness, weather and environmental conditions, culture, safety and security, the non-availability of adequate bicycle infrastructure facilities, and the high cost of membership.

Colum 3 of Table 4.2 shows statistically significant differences in the distribution of General barriers across different sociodemographic groups. For example, Females are more likely to report experiencing barriers related to weather and environmental conditions, safety and security, and non-availability of adequate bicycle infrastructure facilities. People with lower education levels are more likely to report experiencing barriers related to health and fitness, weather and environmental conditions, and non-availability of adequate bicycle infrastructure facilities. People with lower monthly household incomes are more likely to report experiencing barriers related to safety and security and the high membership cost.

These findings suggest that potential barriers to commuting vary depending on sociodemographic characteristics. This information can be used to develop targeted interventions to help commuters overcome these barriers and commute more safely and conveniently. The Potential Barriers were assigned an IDs for better visualization in graphs as shown in Table 4.3.

Table 4.3: Potential Barriers IDs

Potential Barriers	IDs
Health and Fitness	1
Weather and Environmental Conditions	2
Culture	3
Safety & Security	4
Non-availability of adequate Bicycle infrastructure facility	5
High Cost of Membership	6

For example, interventions that focus on helping Females find safe and accessible places to bike or help people with lower education levels improve their safety awareness might be particularly beneficial. Interventions that focus on helping people with lower monthly household incomes afford the cost of a bicycle, or public transportation might also be helpful.

i. Gender Vs. Potential Barriers

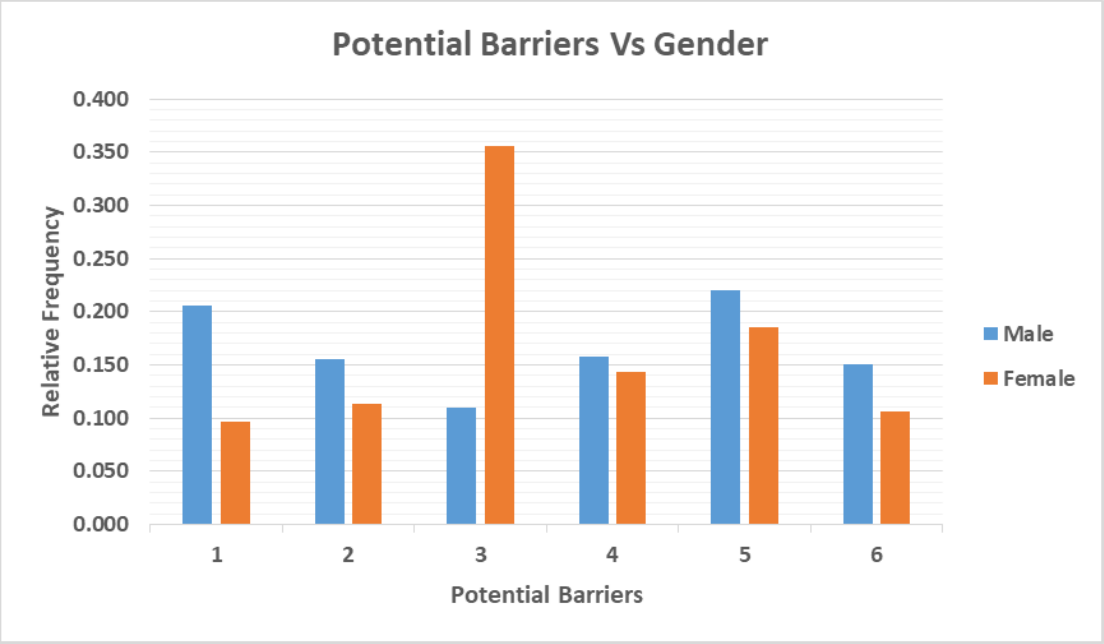

Figure 4.1: Gender vs. Potential Barriers

Figure 4.1 depicts the relative frequency of potential barriers experienced by both males and females while using bicycle mode. The results show that females are more likely to experience barriers than males, with the highest percentage of females experiencing barriers in safety and security, culture, and weather and environmental conditions.

These findings have implications for policymakers and Green Mobility organizations. Governments can invest in safe Cycling infrastructure, and cycling organizations can work to promote cycling as a safe and inclusive activity for women. This could involve developing educational programs, providing cycling safety training, and creating cycling groups and events specifically for females.

Age Group vs. Potential Barriers

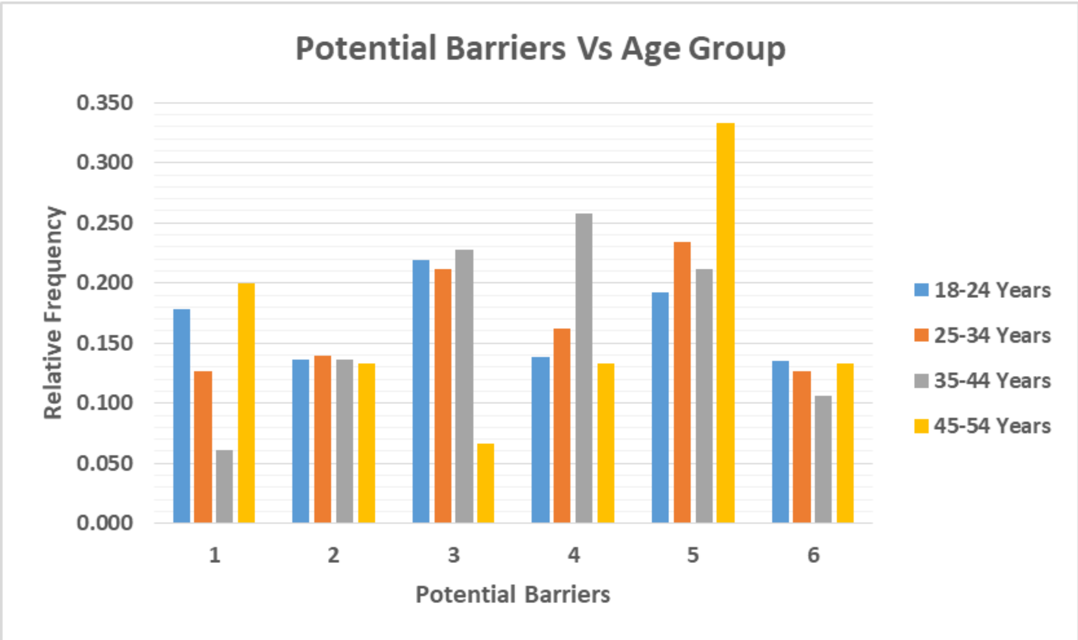

Figure 4.2: Age Group vs. Potential Barriers

Figure 4.2 shows the percentage of people in each age group who report experiencing different potential barriers in using the Bicycle Sharing System. The graph shows that people in all age groups report experiencing some potential barriers to using the bicycle-sharing system. However, there are some notable differences between age groups. For example, young adults (18-24 years old) are more likely to report that health and fitness barriers are a problem for them, while older adults (45-54 years old) are more likely to report that weather and environmental factors, safety and security, and high cost of membership are barriers.

This information can be used to develop interventions that help people overcome the barriers they face and be more physically active. For example, programs focusing on helping young adults improve their health and fitness might be particularly beneficial. Programs that provide safe and accessible places to be active for older adults might also be helpful. Overall, this graph gives a valuable overview of the potential barriers to physical activity that people of different ages face.

ii. Education Level vs. Potential Barriers

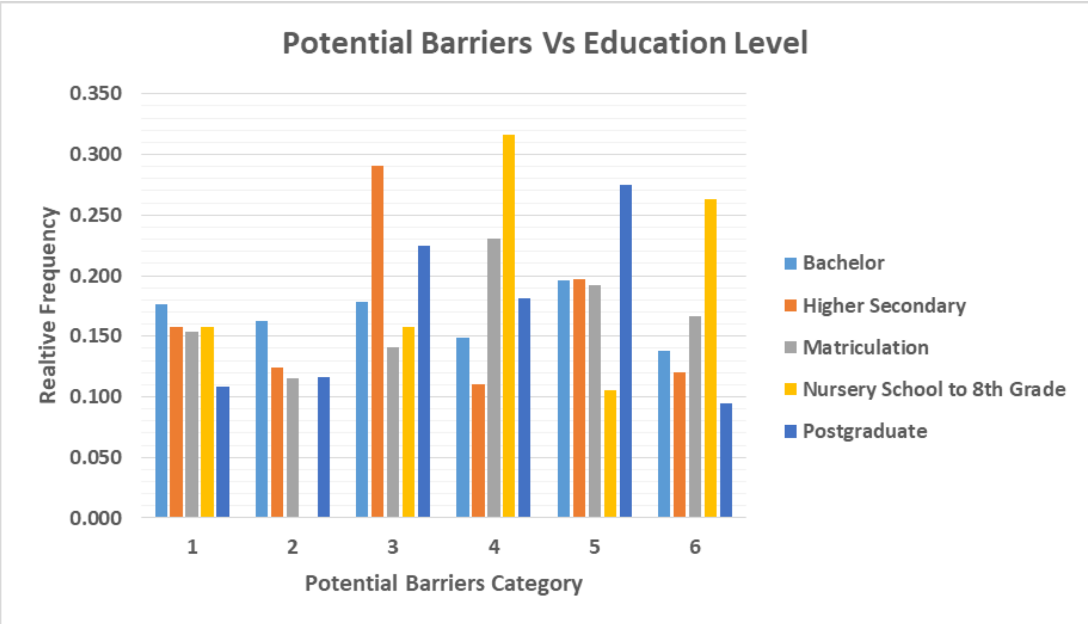

Figure 4.3: Education Level vs. Potential Barriers

Figure 4.3 shows the percentage of people in different education levels who report experiencing potential barriers to using Bicycle Mode. The graph shows that people with higher education levels are less likely to report experiencing all possible barriers. This suggests that education may play a role in helping people overcome the obstacles they face and be more physically active.

iii. Monthly Household income Vs. Potential Barriers

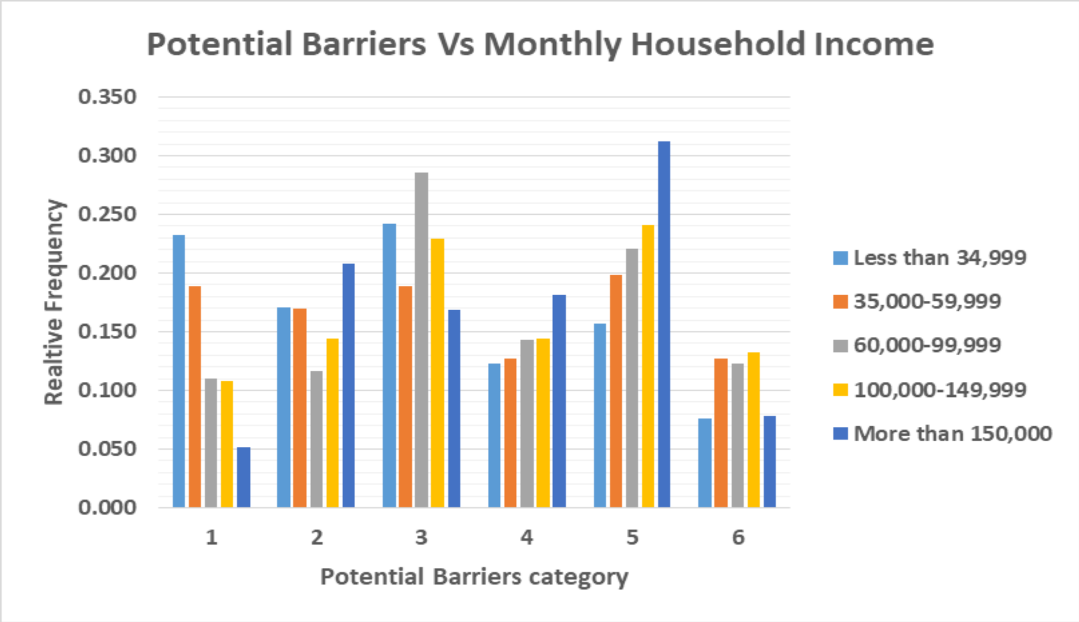

Figure 4.4: Monthly Household Income vs. Potential Barriers

Figure 4.4 shows the bar chart presenting the percentage of people in different monthly household income brackets who report experiencing different potential barriers using the Bicycle mode.

However, there are some notable differences between income brackets. For example, people in lower income brackets are more likely to report the high cost of membership and health and fitness barriers. People in higher income Levels are more likely to report safety and security barriers and the non-availability of adequate facilities as barriers.

This information can be used to develop targeted interventions to help people overcome the barriers they face. For example, interventions that focus on helping people at lower income levels by providing extra incentives. Interventions focus on helping people in higher income levels overcome safety and security concerns.

iv. Employment Status Vs. Potential Barriers

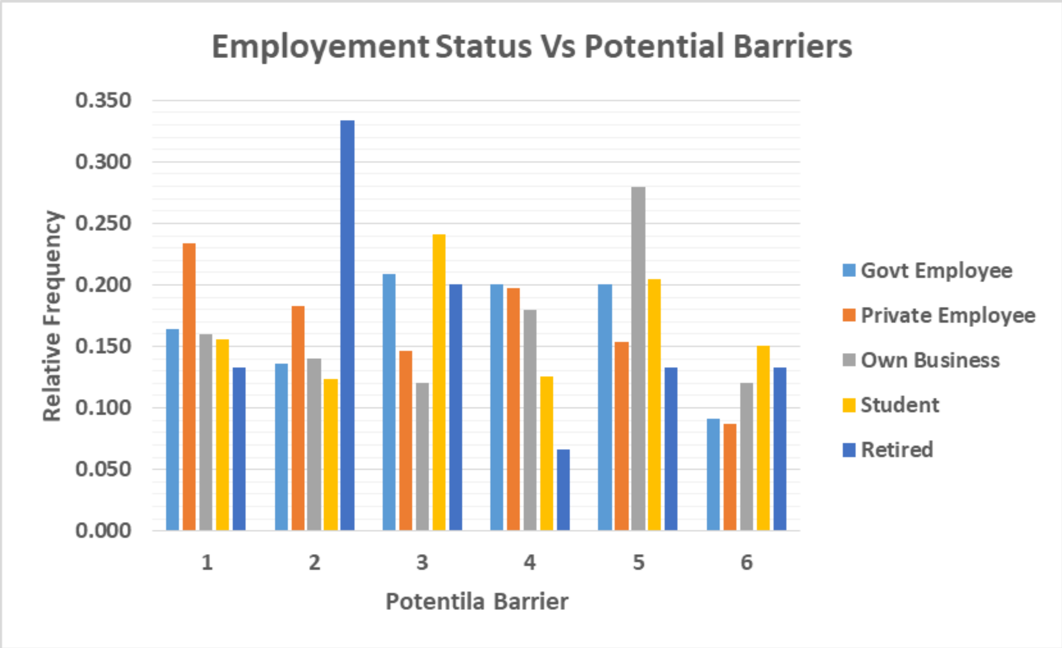

Figure 4.5: Employment Status vs. Potential Barriers

Figure 4.5 shows a bar chart that presents the percentage of people in different employment statuses who report experiencing different potential barriers in using Bicycle mode. However, there are some notable differences between employment statuses. For example, students are more likely to report that weather and environmental factors, safety and security, and high membership costs are barriers. Retired people are more likely to report that health and fitness barriers are problematic. This information can be used to develop interventions that help people overcome the barriers they face and be more physically active. For example, programs focusing on assisting students to find safe and accessible places to be active might be particularly beneficial.

Table 4.4: sociodemographic Characteristics vs. Station Level barriers

Sociodemographic Characteristic's	Station Level Barriers Category	*p*-value
Gender	Not enough Bicycle stations at my Origin-Destination	***0.002***
	Not enough Bicycle stations at BRT bus stations	***0.032***
	Distance: BRT Bicycle stations are too far away from my Origin-Destination	***0.058***
	Distance: BRT Bicycle stations are too far away from BRT Bus stations	***0.042***
	Not enough regular Bicycles at BRT Stations	*0.671*
	Nothing prevents me	*0.344*

Age Group	Not enough Bicycle stations at my Origin-Destination	***0.027***
	Not enough Bicycle stations at BRT bus stations	***0.000***
	Distance: BRT Bicycle stations are too far away from my Origin-Destination	*0.217*
	Distance: BRT Bicycle stations are too far away from BRT Bus stations	***0.046***
	Not enough regular Bicycles at BRT Stations	***0.005***
	Nothing prevents me	*0.617*
Education Level	Not enough Bicycle stations at my Origin-Destination	***0.048***
	Not enough Bicycle stations at BRT bus stations	***0.003***
	Distance: BRT Bicycle stations are too far away from my Origin-Destination	***0.024***
	Distance: BRT Bicycle stations are too far away from BRT Bus stations	*0.892*
	Not enough regular Bicycles at BRT Stations	*0.795*
	Nothing prevents me	*0.299*
Monthly Household Income	Not enough Bicycle stations at my Origin-Destination	***0.006***
	Not enough Bicycle stations at BRT bus stations	***0.022***
	Distance: BRT Bicycle stations are too far away from my Origin-Destination	***0.018***
	Distance: BRT Bicycle stations are too far away from BRT Bus stations	***0.053***
	Not enough regular Bicycles at BRT Stations	***0.035***
	Nothing prevents me	***0.000***
Employment Status	Not enough Bicycle stations at my Origin-Destination	***0.004***
	Not enough Bicycle stations at BRT bus stations	***0.025***
	Distance: BRT Bicycle stations are too far away from my Origin-Destination	0.644
	Distance: BRT Bicycle stations are too far away from BRT Bus stations	0.335
	Not enough regular Bicycles at BRT Stations	0.945
	Nothing prevents me	0.157

Table 4.4 presents the Chi-Square test results to compare the distribution of potential barriers facing commuters related to Bicycle stations across different sociodemographic groups. The table shows statistically significant differences in the distribution of the potential obstacles across different sociodemographic groups.

BSS is one of the intelligent transportation systems that includes bicycle rental stations and smart bikes. For all systems except for free-floating BSS, potential passengers need the bicycles available at the station to rent bikes and the empty bright parking unit to place the rented bike. Access to the nearest station is preferably required in both pick-up and return activities. Therefore, the stations should be deployed in the closest possible locations to reach their maximum coverage and the most significant number of people who wish to rent a bike. The proximity of BSS stations to each other and the cyclist's position increases bike-sharing demand. The decision processes, such as the determination of optimum station location, addition/subtraction of new stations, or increase/decrease in station capacities of BSS station, are the necessary interventions during network planning.

These studies provide valuable insights into the relationship between sociodemographic characteristics and station-level barriers. This information can be used to develop more effective policies and interventions to promote cycling as a safe and sustainable mode of transportation and First/Last mile connection.

4.1.3 *Attitude Survey*

Table 4.5: Attitude towards Integration of BSS with BRT Station

Explanatory Variable	**Categories**	**%age**	***p-value***
Gender	Male	56.62	***0.012***
	Female	42.91	
Age Group	18-24 Years	71.75	**0.015**
	25-34 Years	21.28	
	35-44 Years	4.96	
Education Level	Matriculation	6.62	***0.000***
	Higher Secondary	30.50	
	Bachelor	48.58	
	Postgraduate	12.06	
Monthly Household Income	Less than 34,999	24.00	***0.001***
	35,000-59,999	22.34	
	60,000-99,999	15.60	
	100,000-149,999	7.09	
Employment Status	Govt Employee	12.17	***0.010***
	Private Employee	14.07	
	Own Business	4.96	
	Student	58.87	

Table 4.5 shows attitudes toward the integration of bicycle-sharing systems with BRT stations based on the participant's age group, gender, education level, monthly

household income, and employment status. The p-values in the table indicate that the attitudes towards integrating bicycle-sharing systems with BRT stations are statistically significant for all the factors listed.

This information is helpful for policymakers and practitioners who are developing and implementing bicycle-sharing systems. By understanding the factors associated with attitudes towards integrating bicycle-sharing systems with BRT stations, they can develop programs and initiatives that are more likely to be successful. For example, they may want to target their programs and initiatives to specific groups of people, such as young people or people with lower incomes. They may also want to focus on developing programs and initiatives that address the particular concerns of different groups of people. For example, they may want to create programs that provide training on bicycle-sharing systems or address safety concerns.

v. Gender

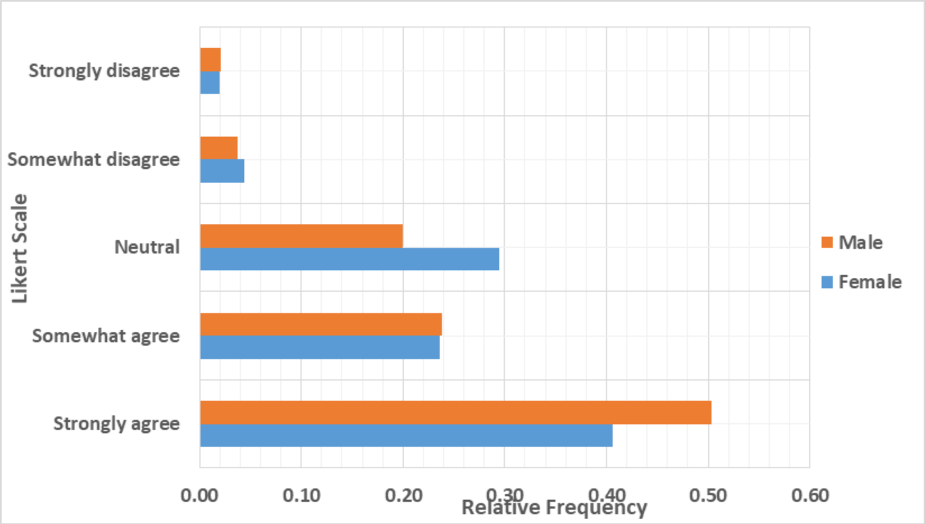

Figure 4.6: Gender vs. Attitude towards Integration

Figure 4.6 shows the relative frequency of attitudes towards integrating bicycle-sharing systems with transit stations by gender, using a Likert scale. It can be observed from the graph that both gender categories have shown strong support for the integration of the bicycle-sharing System with transit stations.

vi. Age Group

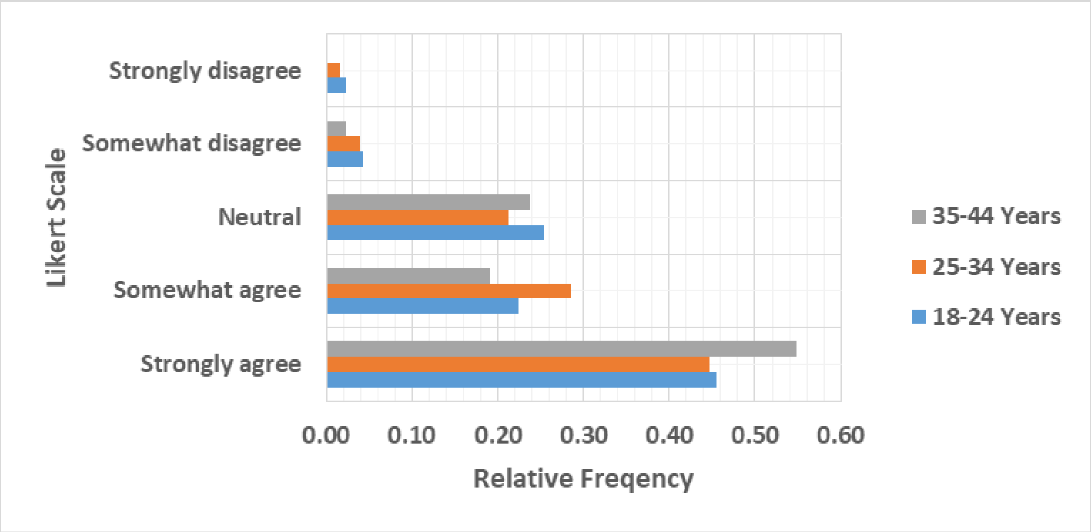

Figure 4.7: Age Group vs. Attitude towards Integration

Figure 4.7 shows the different age categories of people's attitudes toward the integration of bicycle-sharing systems with transit stations. The graph shows that people of all ages are more likely to support integrating bicycle-sharing systems with transit stations. However, there is a slight age gradient, with younger people more likely to agree with the integration strongly.

The youngest age group (18-24 years old) is the most likely to strongly agree with integrating bicycle-sharing systems with transit stations. This may be because young people are more likely to be interested in sustainable transportation options and are more likely to use bicycles for transportation. So, Governments should invest in bicycle-sharing systems to make them more accessible and affordable for people of all ages. Policymakers and Practitioners can help to make bicycle-sharing systems a more integral part of the transportation system and benefit people of all ages. Also Using the Chi-square statistics shows that there is a significant association at a 5% significance level between Age Group and Attitude towards integration.

vii. Education Level

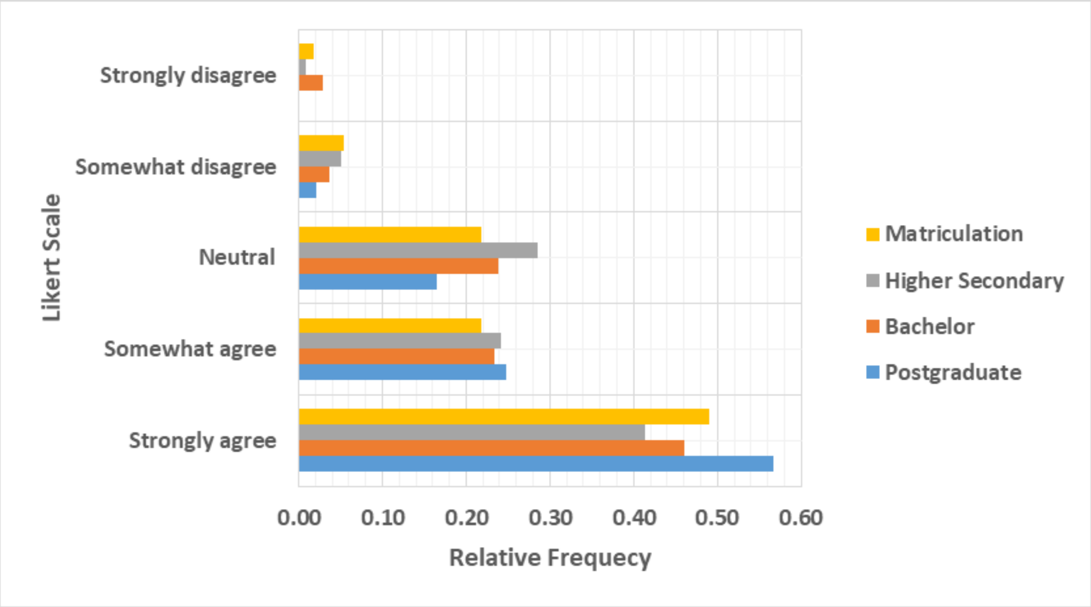

Figure 4.8: Education Level. Vs. Attitude towards Integration

Figure 4.8 represents the people's attitudes towards integrating bicycle-sharing systems with transit stations, stratified by education level. The figure shows a positive relationship between education level and attitude towards integration. Respondents with higher education levels were more likely to strongly agree with integrating bicycle-sharing systems with transit stations.

This suggests that people with higher education levels are more likely to see the benefits of integrating bicycle-sharing systems with transit stations. They may be more aware of the environmental and health benefits of cycling and more likely to value the convenience of being able to use a bicycle to connect to public transportation.

Another possibility is that people with higher education levels are likelier to have the skills and knowledge to use bicycle-sharing systems effectively. They may be more familiar with how to use the systems and more likely to know how to find safe and convenient places to ride a bicycle.

The findings of this study have several implications for policymakers and practitioners. First, it suggests that there is a need to promote the use of bicycle-sharing systems to people with lower education levels. This could be done through education campaigns, targeted marketing, and making bicycle-sharing systems more affordable and accessible.

Second, the findings suggest that policymakers and practitioners should consider the needs of people with different education levels when designing and implementing bicycle-sharing systems. For example, they may need to provide additional education and support to people with lower education levels on how to use bicycle-sharing systems safely and effectively.

By taking these steps, policymakers and practitioners can help to make bicycle-sharing systems more accessible and beneficial to people of all education levels. Also, using the Chi-square statistics shows a significant association at a 5% significance level between Education Level and Attitude towards integration.

viii. Monthly Household Income

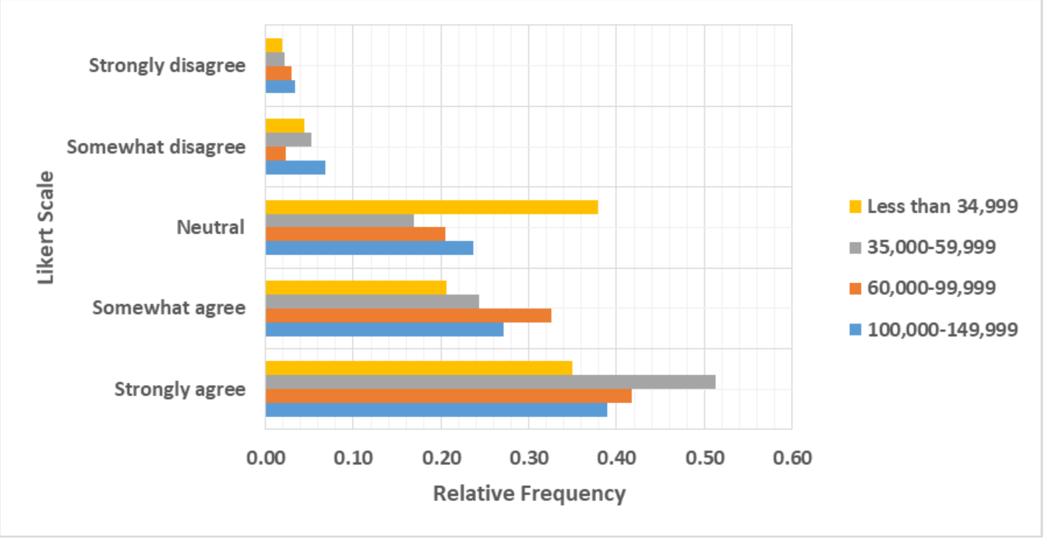

Figure 4.9: Income Level vs. Attitude towards Integration

Figure 4.9 shows the relationship between monthly household income and attitude towards integrating bicycle-sharing systems with transit stations. There is a positive relationship between monthly household income and attitude towards integration. Respondents with higher monthly household incomes were more likely to strongly agree with integrating bicycle-sharing systems with transit stations.

This suggests that higher-income people are more likely to see the benefits of integrating bicycle-sharing systems with transit stations. They may be more aware of the environmental and health benefits of cycling, and they may be more likely to value the convenience of using a bicycle to connect to public transportation. There are many potential explanations for this relationship. One possibility is that higher-income people are more likely to live in areas with good bicycle infrastructure and access to public transportation. This makes it more convenient for them to use bicycle-sharing systems to connect to their destinations.

The findings of this study have some implications for policymakers and practitioners. First, it suggests that there is a need to promote the use of bicycle-sharing systems to people with lower incomes. Second, policymakers should consider the needs of people with different incomes when designing and implementing bicycle-sharing systems. For example, they may need to provide additional financial assistance to lower-income people to help them afford bicycle-sharing systems. And also using the Chi-square statistics, it shows that there is a significant association at a 5% significance level between Monthly Household Income and Attitude towards integration.

ix. Employment Status

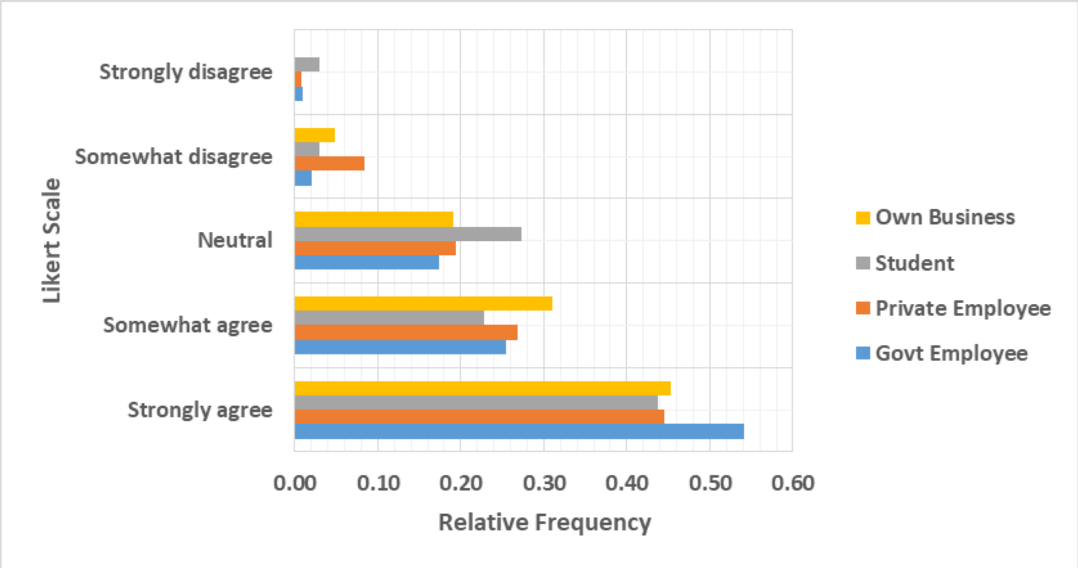

Figure 4.10: Employment Status vs. Attitude towards Integration

Figure 4.10 represents the people's attitudes towards integrating bicycle-sharing systems with transit stations, stratified by employment status. It can be observed from the graph that there is a positive relationship between employment status and attitude towards integration. This suggests that employed people are more likely to perceive the benefits of integrating bicycle-sharing systems with transit stations, such as the convenience of using a bicycle to connect to public transportation for their commute, the environmental and health benefits of cycling, and the potential to reduce traffic congestion and improve air quality.

The findings suggest that policymakers and practitioners should consider the needs of people with different employment statuses when designing and implementing bicycle-sharing systems. By taking these steps, policymakers and practitioners can help to make bicycle-sharing systems more accessible and beneficial to people of all employment statuses. Using the Chi-square statistics, there is a significant association at a 5% significance level between employment status and Attitude towards integration.

Table 4.6: Attitude towards Bicycle Usage

Explanatory Variable	**Categories**	**%age**	***p-value***
Gender	Male	56.62	***0.000***
	Female	42.91	
Age Group	18-24 Years	71.75	***0.032***
	25-34 Years	21.28	
	35-44 Years	4.96	
Education Level	Matriculation	6.62	***0.049***
	Higher Secondary	30.50	
	Bachelor	48.58	
	Postgraduate	12.06	
Monthly Household Income	Less than 34,999	24.00	***0.025***
	35,000-59,999	22.34	
	60,000-99,999	15.60	
	100,000-149,999	7.09	
	More than 150,000	6.15	
	Prefer not to answer	24.82	
Employment Status	Govt Employee	12.17	***0.052***
	Private Employee	14.07	
	Own Business	4.96	
	Student	58.87	

Table 4.6 shows the attitude /expected increase in bicycle mode usage after improving the bicycle infrastructure system in Peshawar. The Sociodemographic characteristics show a statistically significant association with the frequency of Bicycle mode.

Overall, the table suggests that improving the bicycle infrastructure system is likely to have a positive impact on bicycle usage. However, the effect is likely greater among certain groups of people, such as males, young people, people with higher levels of education, people with lower incomes, and students.

The findings of this study suggest that policymakers and practitioners should focus on improving the bicycle infrastructure system for the groups most likely to be affected by these improvements. These include males, young people, people with higher levels of education, people with lower incomes, and students.

x. Gender

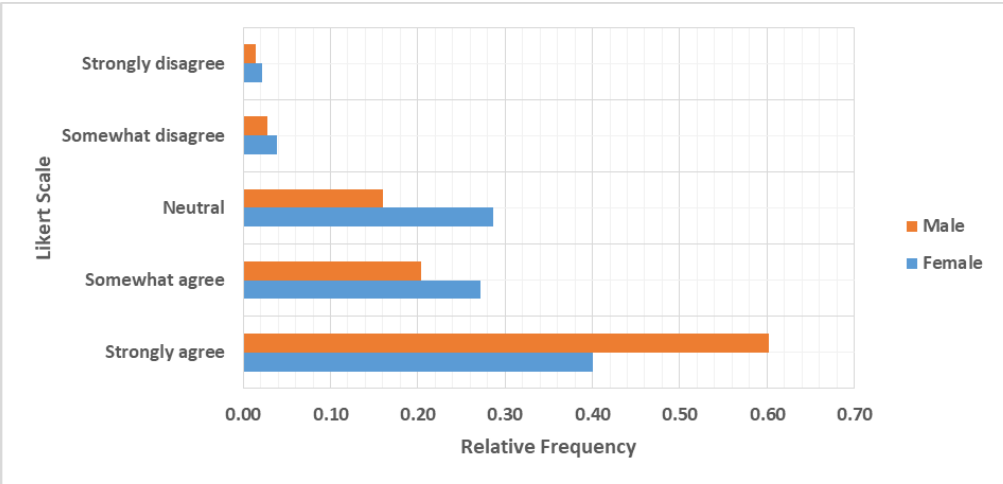

Figure 4.11: Gender vs. Attitude towards Bicycle Usage

Figure 4.11 shows the relative frequency of attitudes towards the bicycle-sharing systems infrastructure by gender, using a Likert scale. It can be observed from the graph that both genders, i.e. male and female, strongly agree to use the bicycle mode for different trip purposes when the required infrastructure is provided for bicycles like separate Bicycle Lane, etc.

Age Group

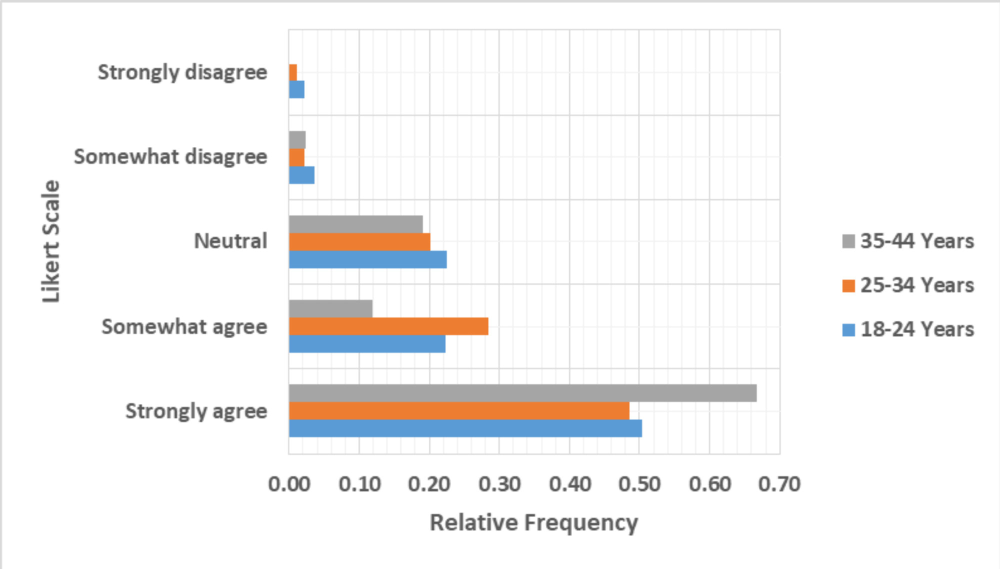

Figure 4.12: Age Group vs. Attitude towards Bicycle Usage

Figure 4.12 shows the different age categories of people's attitudes towards the Bicycle infrastructure. The graph shows that people of all ages are more likely to be supportive when Bicycle infrastructure is provided in Using Bicycle mode.

xi. Education Level

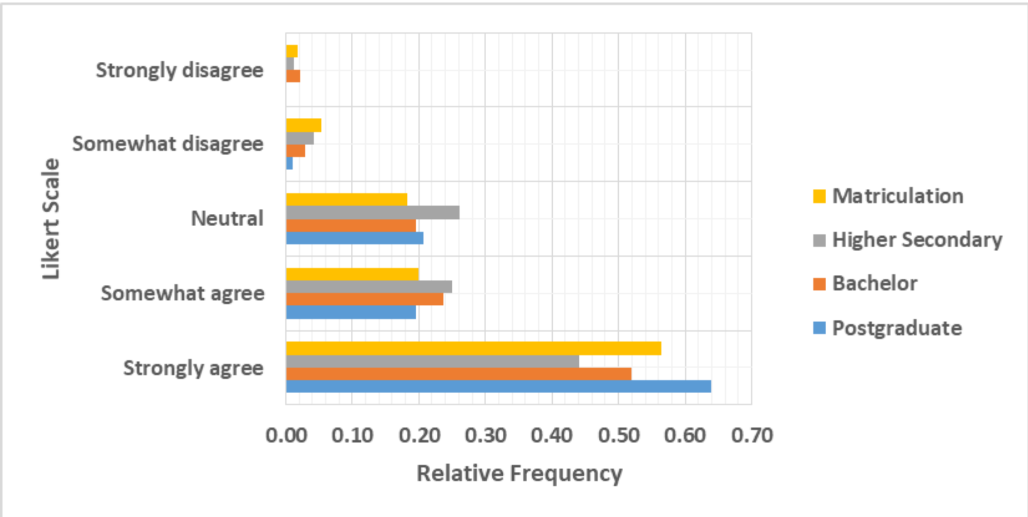

Figure 4.13: Education Level. Vs. Attitude towards Bicycle Usage

Figure 4.13 represents the people's attitudes towards the bicycle infrastructure with transit stations, stratified by education level. The figure shows a positive relationship between education level and attitude towards Bicycle infrastructure.

xii. Household Income

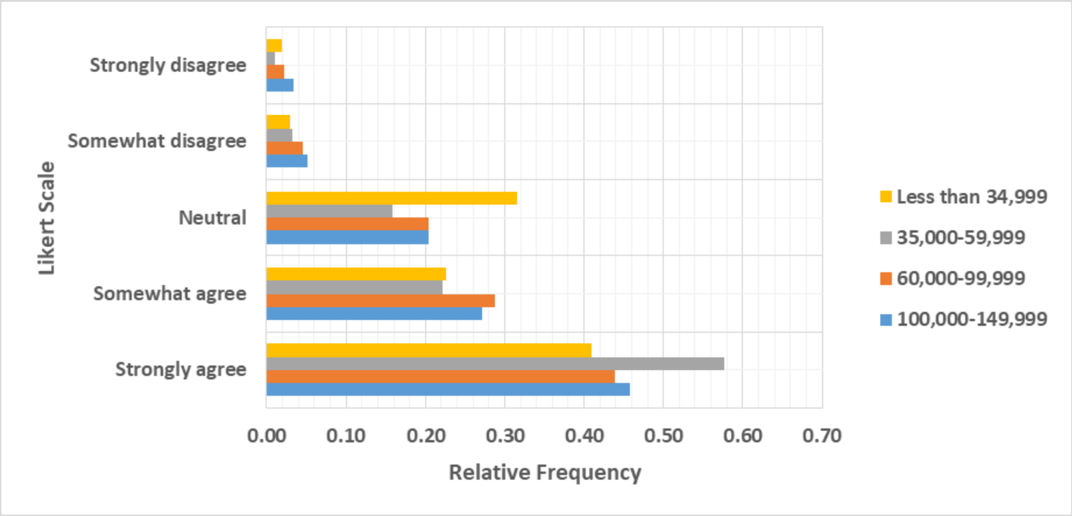

Figure 4.14: Income Level vs. Attitude towards Bicycle Usage

Figure 4.14 shows the relationship between monthly household income and attitude towards using bicycle-sharing systems with transit stations. A positive relationship exists between monthly household income and attitude towards the Bicycle infrastructure system.

xiii. Employment Status

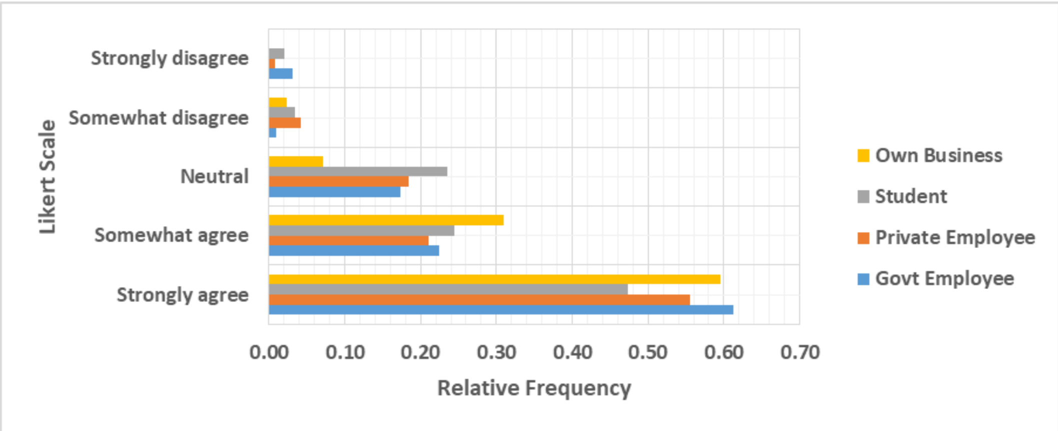

Figure 4.15: Employment status vs. Attitude towards Bicycle Usage

Figure 4.15 represents people's attitudes towards using bicycle-sharing systems after improving Bicycle infrastructure. The graph shows a positive relationship between employment status and attitude towards Bicycle infrastructure.

4.2 Spatial Analysis and Density Maps

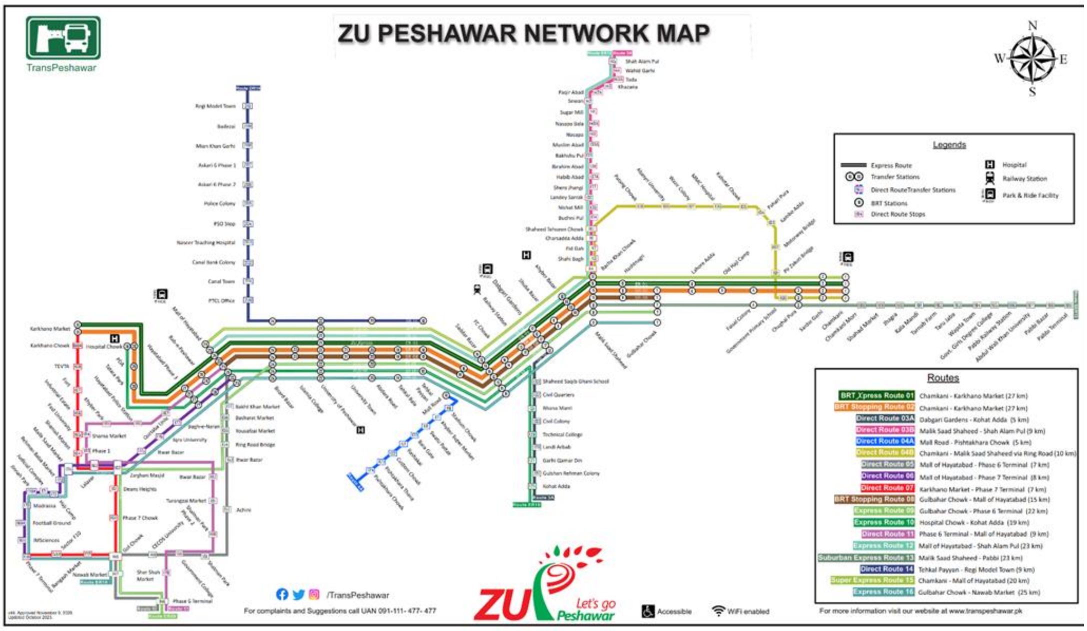

Figure 4.16: BRT Corridor with Station IDs

Table 4.7: Station IDs and Coordinates

Station Name	IDs	Y Coordinates	X Coordinates
Chamkani	1	34.02047004	71.64249103
Sardar Garhi	2	34.0188218	71.63988062
Chughal Pura	3	34.01747816	71.62928663
Faisal Colony	4	34.01663184	71.61470747
Old Haji Camp	5	34.01628257	71.60741186
Lahore Adda	6	34.01592943	71.59994286
Gulbahar Chowk	7	34.01543029	71.59224454
Hashtnagri	8	34.01500162	71.58121011
Malik Saad Shaheed	9	34.01457012	71.57206433
Khyber Bazar	10	34.01043079	71.56655158
Shoba Bazar	11	34.00787273	71.56190729
Dabgari Gardens	12	34.00578962	71.55768018
Railway Station	13	34.00252476	71.54966666
FC Chowk	14	33.99906397	71.54442393
Saddar Bazar	15	33.99509947	71.53839127
Mall Road	16	33.99839175	71.53344254
Tehkal Payyan	18	34.00823675	71.51917741
Tehkal Bala	19	34.00691569	71.50915792
Abdara Road	20	34.00290875	71.50139294
University Town	21	33.9993611	71.49467129
University of Peshawar	22	33.99774238	71.48728717
Islamia College	23	33.99819928	71.47837534

Board Bazar	24	33.99806744	71.47133658
Mall of Hayatabad	25	33.99220714	71.46142518
Bab-e-Peshawar	26	33.98745744	71.45234322
Hayatabad Phase	27	33.98357602	71.44759864
Tatara Park	28	33.98364756	71.4427945
PDA	29	33.98785159	71.44298881
Hospital Chowk	30	33.99319957	71.44341028
Karkhano Market	31	33.99921482	71.42669488

4.2.1 *First Mile Modes Comparison: Bicycle vs. Walking*

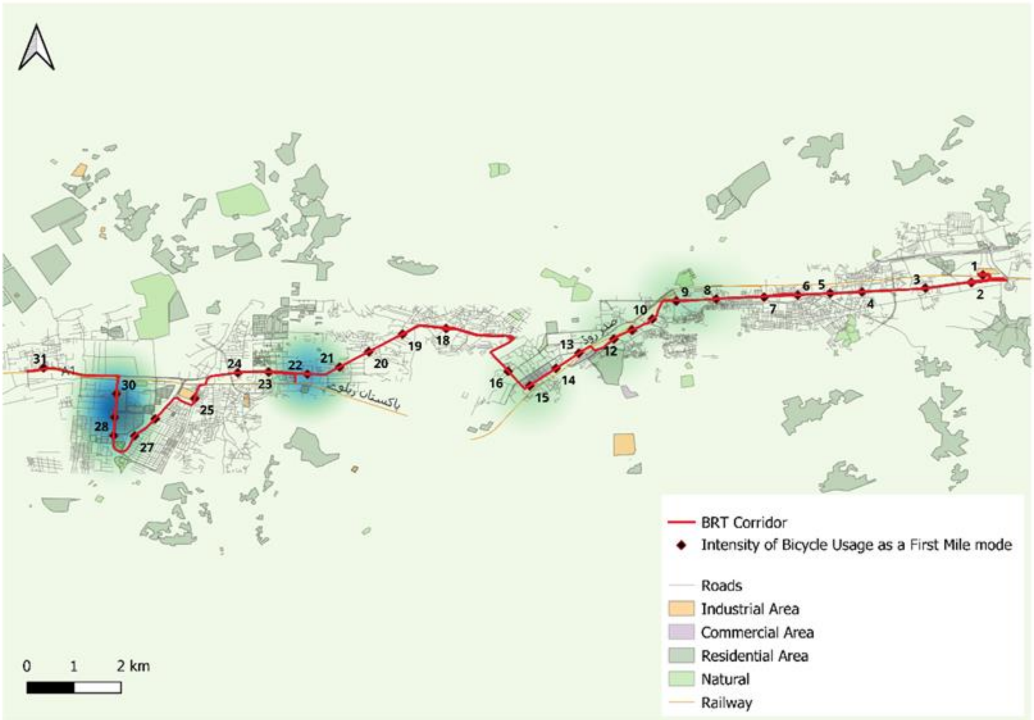

Figure 4.17: Usage of Bicycle mode as a First Mile option at BRT Corridor

Table 4.8:BRT stations with maximum bicycle usage for first-mile mode

Station IDs	Station Name
22	University of Peshawar
28	Tatara Park
29	PDA
30	Hospital Chowk

Figure 4.17 visually represents the initial step taken toward the origin (Station) in terms of Bicycle mode intensity. The map shows that specific locations, namely the University of Peshawar, Tatara Park, PDA, and Hospital Chowk, exhibit higher intensity in terms of bicycle usage as shown in the Table 4.8. This can be attributed to

the fact that these locations are already connected to the BRT corridor, making it convenient for people to access the BRT stations using bicycles. However, it is essential to note that the remaining stations do not have a BSS. This lack of infrastructure poses a barrier for commuters who wish to utilize bicycles as a mode of transportation. To enhance BRT ridership and promote sustainable transportation options, it is crucial to establish BSS stations along the BRT corridor.

By implementing BSS stations, individuals in these zones will have access to bicycles, making it easier for them to reach the BRT stations. This will not only encourage more people to use bicycles as a mode of transportation but also contribute towards a sustainable future by reducing the reliance on private vehicles and addressing the barriers commuters face in terms of bicycle infrastructure.

Overall, establishing BSS stations along the BRT corridor is a necessary step towards promoting sustainable transportation and enhancing BRT ridership. It will provide individuals in the remaining stations with a convenient and eco-friendly option for accessing the BRT system, ultimately contributing towards a more sustainable and efficient transportation network.

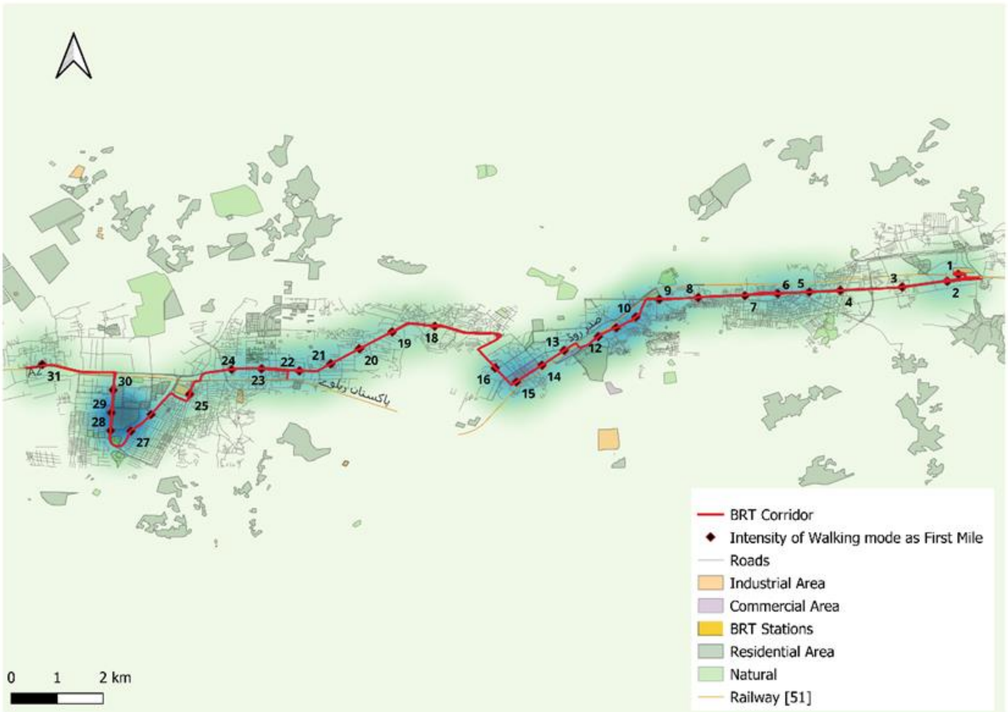

Figure 4.18: Intensity of walking mode as a First Mile option at BRT Corridor

Figure 4.18 demonstrates that a significant number of stations consistently had a higher index for the First-mile mode as walking. This finding can be attributed to several factors, primarily the convenience and cost-effectiveness of walking compared to Bicycling. Walking is a mode of transportation that requires no additional equipment or expenses. It is a natural and accessible form of movement requiring no special skills or training. This makes it an attractive option for individuals who want to save money on transportation costs or who do not own a bicycle. Furthermore, some BRT stations have limited bicycle parking facilities. These parking spaces may be either complete or inconveniently situated, making it difficult for cyclists to find a secure spot to park their bikes. This inconvenience and uncertainty can be avoided by choosing to walk instead. By walking, individuals can bypass the hassle of searching for a parking spot and the potential risk of their bicycles being stolen or damaged. Another factor contributing to the promotion of walking over cycling is the distance between the BRT station and the final destination. The distance is often relatively short, making walking a more time-efficient option. Walking can often be faster than cycling for short distances, especially in congested urban areas where traffic and road conditions can slow down Bicyclists.

Safety concerns also play a role in the preference for walking over Bicyclists. Some individuals may perceive walking as a safer mode of transportation than cycling, particularly in areas with heavy traffic or inadequate cycling infrastructure. Pedestrians are generally more visible to drivers and have designated spaces, such as sidewalks, while cyclists may have to share the road with vehicles, increasing the risk of accidents.

In conclusion, the majority of stations consistently had a higher index for the last-mile mode of walking due to the convenience and cost-effectiveness of walking compared to cycling. Limited bicycle parking at BRT stations, shorter distances, and safety concerns also contribute to promoting walking as the preferred mode of transportation.

4.2.2 *Last Mile Mode Comparison: Bicycle vs. Walking*

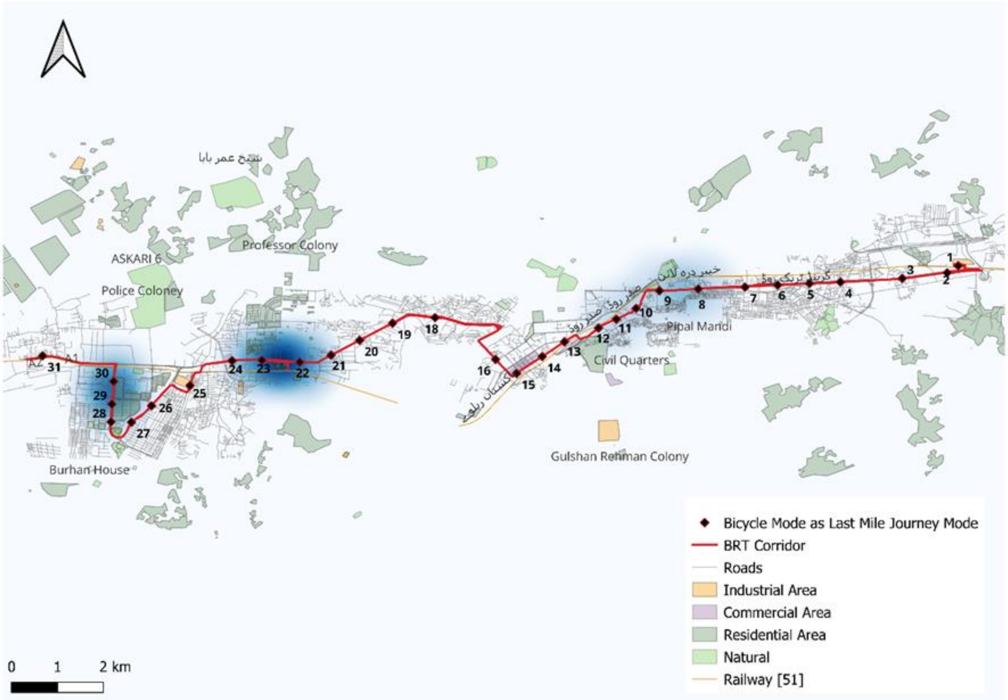

Figure 4.19: Usage of Bicycle mode as a Last Mile option at BRT Corridor

Table 4.9:BRT stations with maximum bicycle usage for last-mile mode

Station IDs	Station Name
8	Hasthnagri
22	University of Peshawar
23	Islamia College
29	PDA
30	Hospital Chowk

Figure 4.19 shows the Final step after getting out from BRT towards the Destination regarding Bicycle mode intensity. Specific locations, like Hasthnagri, University of Peshawar, Tatara Park, PDA, and Hospital Chowk, have higher bicycle usage due to their connectivity to the BRT corridor as shown in Table 4.9. However, other stations lack BSS infrastructure, making it challenging for commuters in those areas to use bicycles. BSS stations should be established along the BRT corridor to address this issue and promote sustainable transportation. This will make it easier for individuals in those areas to access their destination and contribute to a sustainable future by reducing reliance on private vehicles. Establishing BSS stations is crucial for enhancing BRT ridership and creating a more sustainable and efficient transportation network.

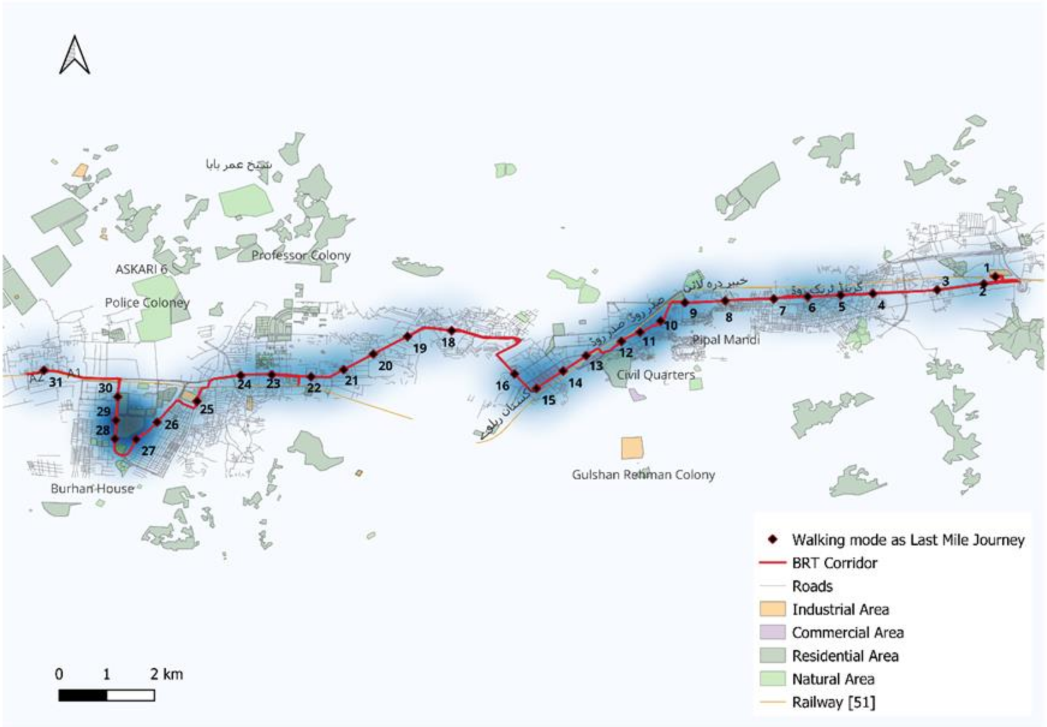

Figure 4.20: Intensity of walking mode as a Last Mile option at BRT Corridor

Figure 4.20 clearly shows that many stations consistently had a higher index for the Last mile mode as walking. This can be attributed to various factors, such as the convenience and cost-effectiveness of walking compared to cycling. Walking requires no additional equipment or expenses, making it an attractive option for those looking to save money or who do not own a bicycle. Additionally, some BRT stations have limited bicycle parking facilities, making it difficult for cyclists to find a secure spot to park their bikes. This inconvenience can be avoided by choosing to walk instead. Furthermore, the distance between the BRT station and the final destination is often short, making walking a more time-efficient option. Safety concerns also contribute to the preference for walking over cycling, as pedestrians are generally more visible to drivers and have designated spaces like sidewalks.

4.2.3 *Comparison of Potential Barriers Facing by Commuters*

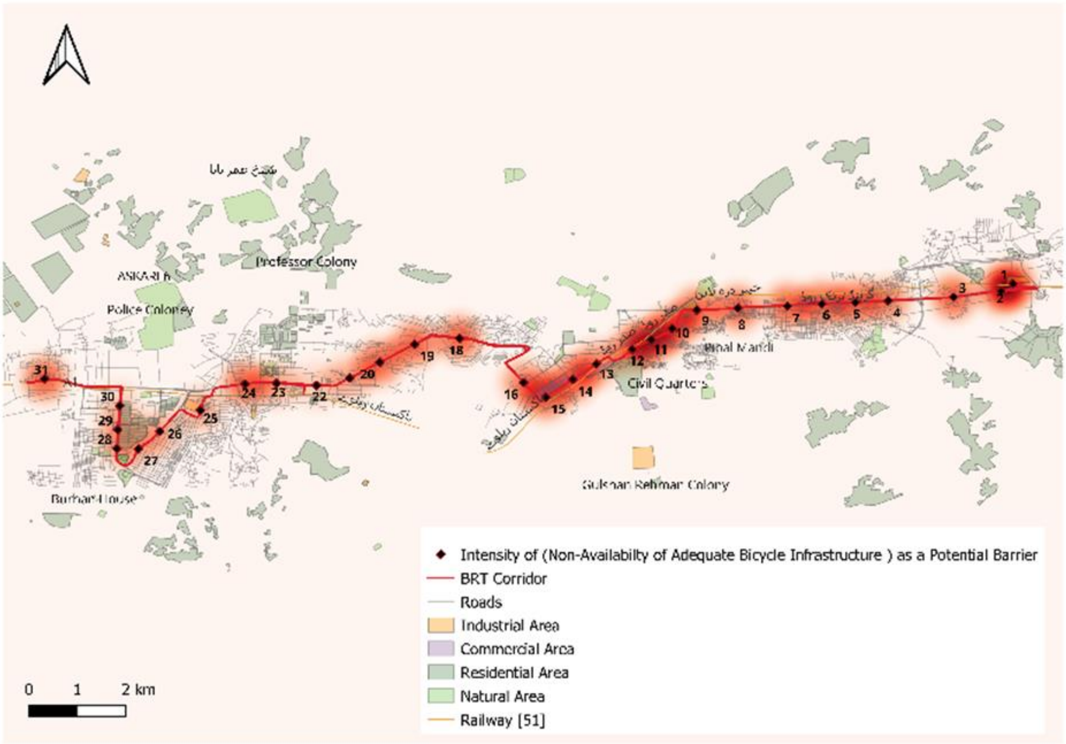

Figure 4.21: Non-Availability bicycle Infrastructure at BRT Stations

Figure 4.21 illustrates the consistent intensity range of the Potential Barrier (Non-Availability of adequate Bicycle infrastructure facility) throughout the BRT corridor, as depicted on the map. This consistency may be attributed to the absence of protected bicycle lanes and safety concerns. In general, the lack of sufficient bicycle infrastructure can result in a negative experience for Bicycle Commuters, diminishing the safety, convenience, and appeal of cycling compared to other transportation modes. Consequently, this can discourage individuals from choosing bicycles, even if they are interested, ultimately impeding the potential benefits for health, the environment, and urban liveability. To address this issue, local authorities and policymakers should prioritize the provision of separated bicycle lanes, ensure proper road maintenance, and actively promote the development of a well-connected network of bicycle lanes with minimal gaps and clear signage. These measures will enhance the convenience of bicycling for both commuting and leisure activities.

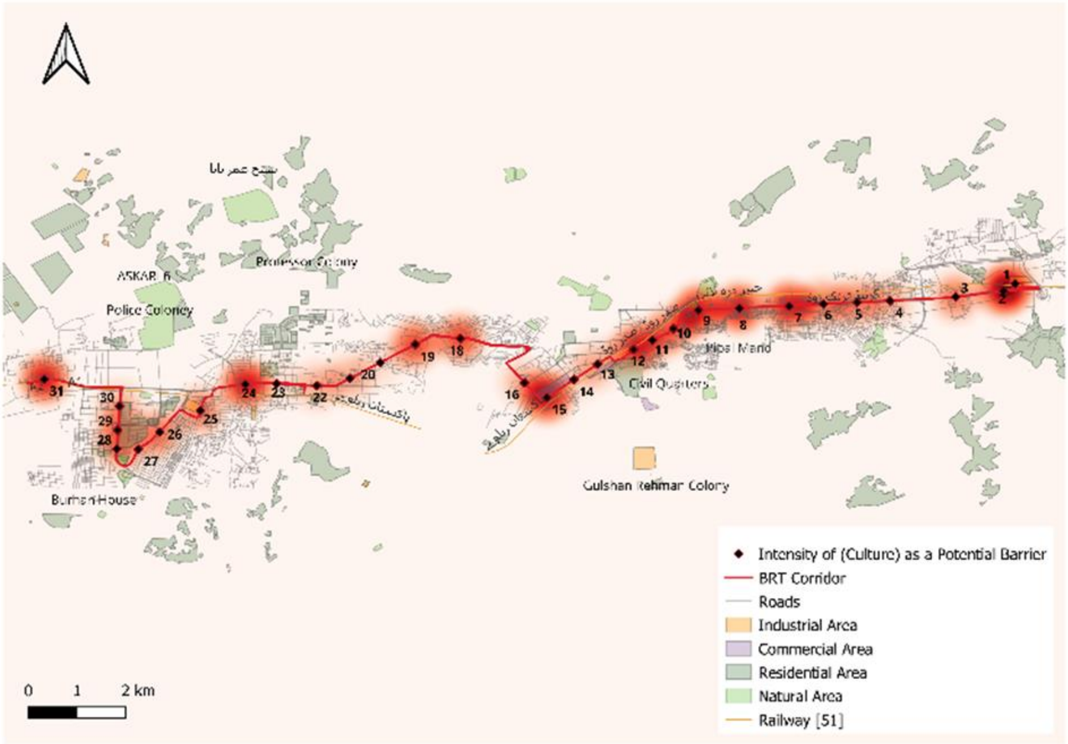

Figure 4.22: Culture as a Potential Barrier in Using BSS

Figure 4.22 shows that commuters perceive culture as a significant obstacle throughout the BRT Corridor. Certain cultures perceive Bicycles as a recreational pursuit rather than a viable means of transportation, resulting in inadequate infrastructure and support for cycling in urban areas. Additionally, there may be social norms in specific regions that associate Bicycling with lower status, discouraging individuals from choosing bicycles as a mode of transport. To address these barriers effectively, it is crucial to promote Bicycling as a practical mode of transportation and establish safe and easily accessible Bicycling infrastructure, including bicycle lanes and secure parking facilities, to enhance the appeal and feasibility of Bicycling.

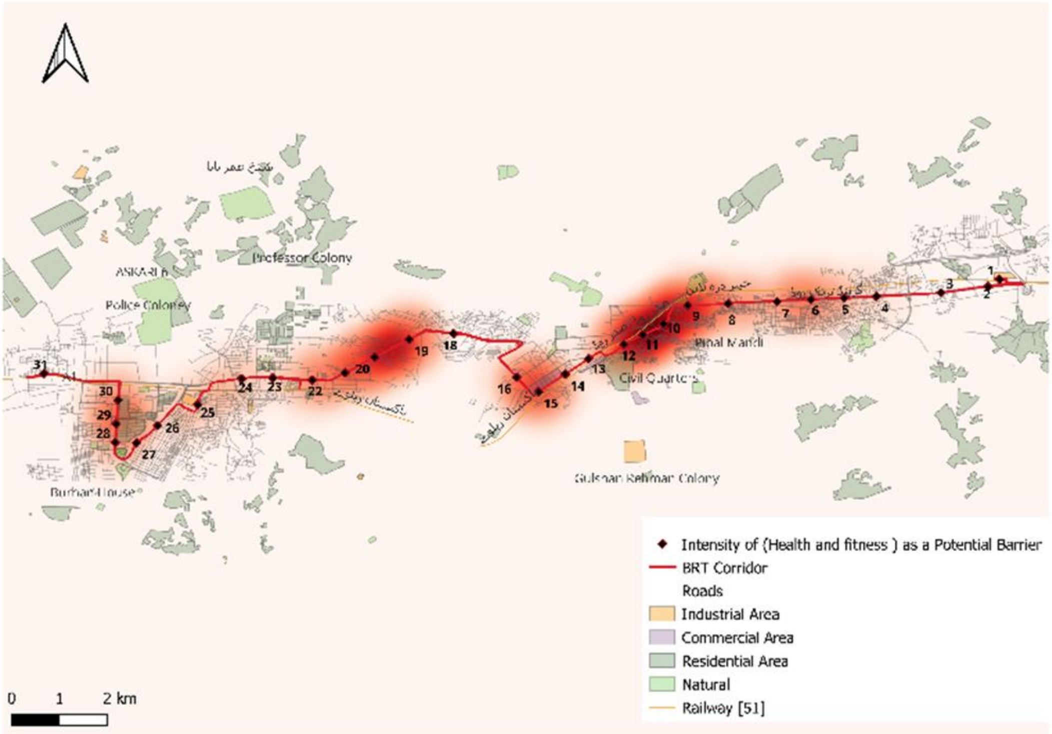

Figure 4.23: Health and Fitness as a Potential Barrier in Using BSS

Table 4.10: Health and Fitness as a potential Barrier

Station ID	Station Name
9	Malik Saad Shaheed
10	Khyber Bazar
11	Shoba Bazar
12	Dabgari Gardens
15	Saddar Bazar
19	Tehkal Bala
20	Abdara Road

Figure 4.23 shows the intensity of the potential Barrier (Health and Fitness). The map indicates that the intensity is high at the stations of Malik Saad Shaheed, Khyber Bazar, Shoba Bazar, Dabgari Gardens, Saddar Bazar, Tehkal Bala, and Abdara Road as tabulated in Table 4.10. Conversely, at the other stations, the index was low. This could be attributed to individuals with health issues or low fitness levels finding cycling physically challenging. Some may perceive cycling as more demanding than other modes of transportation, especially over long distances or hilly terrain. Concerns about safety, particularly for those with health conditions, may deter them from using bicycles due to fear of accidents related to their health issues. To address this,

community training centres and public awareness campaigns highlighting the benefits of using bicycles for daily commuting can help minimize these barriers.

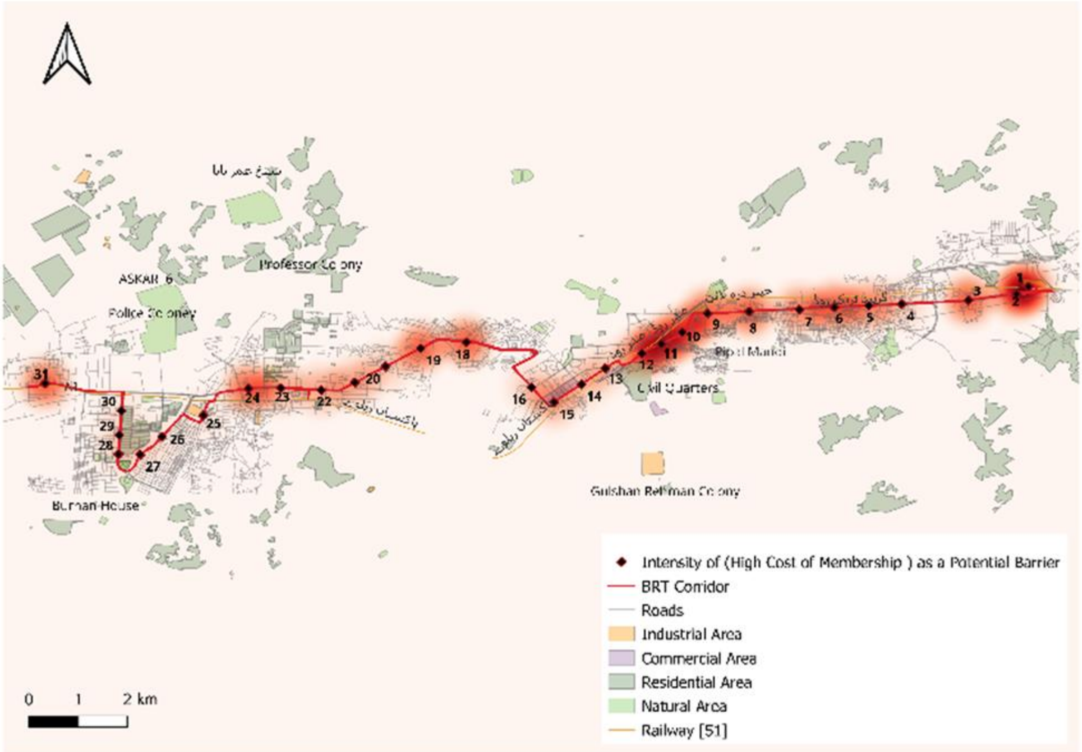

Figure 4.24: High Cost of Membership as a Potential Barrier in Using BSS

Table 4.11: High Cost of Membership as a potential Barrier

Station IDs	Station Name
1	Chamkini
2	Sardar Garhi
9	Malik Saad Shaheed
10	Khyber Bazar
11	Shoba Bazar
24	Board Bazar
31	Karkhano Market

Figure 4.24 depicts the high intensity at a particular station, as tabulated in the Table 4.11. Residents in that area may face financial constraints, making the ongoing membership fees for bike-sharing programs seem expensive, particularly for those on a tight budget. To address this obstacle, the concerned authority could consider offering discounted memberships for low-income individuals or students, making it more affordable. Additionally, expanding station locations in low-income areas would

enhance accessibility and make the service more appealing. Seeking subsidies or grants from government agencies or private organizations could also help offset the cost of memberships.

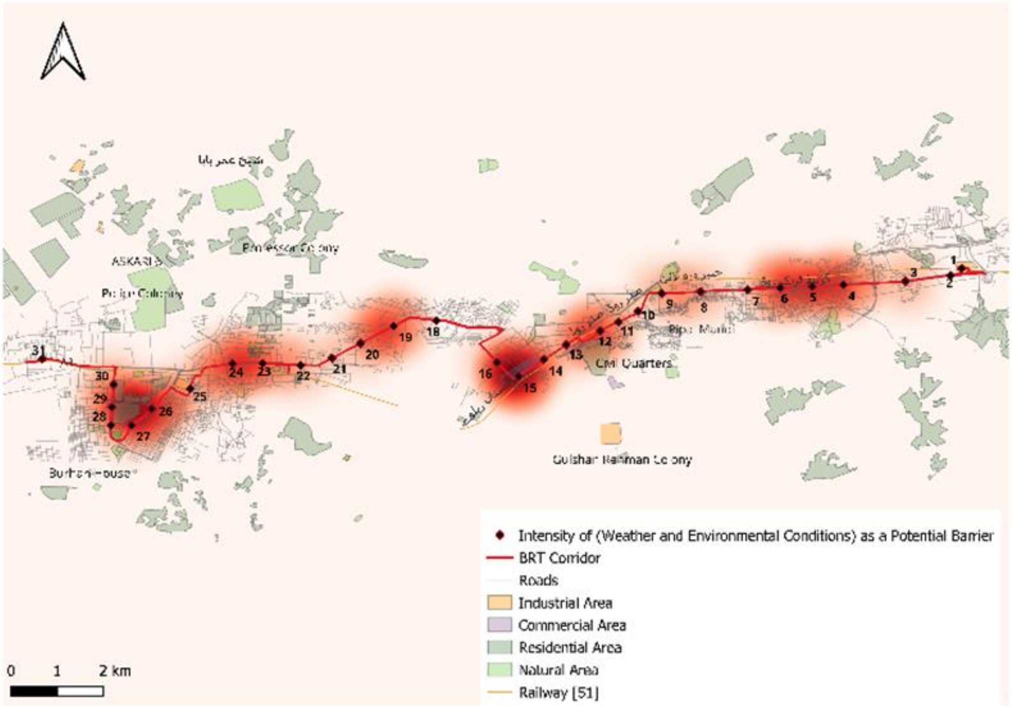

Figure 4.25: Weathering and Environmental Conditions as a Potential Barrier

Table 4.12: Weather and Environmental Conditions as a potential Barrier

Station IDs	Station Name
4	Faisal Town
5	Old Haji Camp
6	Lahore Adda
15	Sadar Bazar
16	Mall Road
19	Tehkal Bala
23	Islamia College
24	Board Bazar
26	Bab-e-Peshawar
27	Hayatabad Phase
29	PDA

Figure 4.25 displays the intensity of the potential barrier at the station, tabulated in Table 4.12. Inclement weather like rain, strong winds, extreme heat, or cold can create discomfort and safety concerns for cyclists, prompting them to opt for alternative modes of transportation. Cyclists may worry about arriving at their destination wet, muddy, or sweaty, especially if they need to maintain a professional appearance.

Weather conditions can impact this, reducing visibility for cyclists and other road users, thus increasing the likelihood of accidents and injuries. Wet roads can pose additional challenges and dangers for cyclists, especially those less experienced or confident. The lack of proper cycling infrastructure, such as bike lanes or shelters, can worsen the effects of adverse weather conditions, discouraging cyclists from riding their bikes. To address this issue, it is essential to enhance protected bike lanes, shelters, and bike-sharing stations to offer cyclists safe and comfortable routes, regardless of the weather.

Figure 4.26: Safety and Security as a Potential Barrier in Using BSS

Figure 4.26 shows the consistent safety and security index at all BRT stations. The perception of inadequate infrastructure, including bike lanes and paths, contributes to safety concerns among cyclists. Additionally, congested roads and aggressive driver behavior also play a role in these concerns. Worries about bike theft and the lack of secure bike parking facilities discourage individuals from cycling for transportation. Safety concerns extend beyond traffic safety to personal security, especially for cyclists travelling alone in poorly lit or isolated areas. To address these barriers, the relevant authority should provide proper bicycle infrastructure. This includes supporting initiatives to enhance cycling infrastructure, such as bike lanes, paths, and secure bike parking facilities. It is also important to obey traffic laws and signals and use hand signals to indicate intentions to another road user.

4.2.4 *Accessibility Analysis of BRT Station to Universities*

Table 4.13: List of Universities in Peshawar

University Name	Abbreviation	Travel Distance (Km)	Travel Time (minutes)	Nearest BRT Station ID
University of Peshawar	UP	1.8	24	22
Islamia College Peshawar	ICP	1.1	16	23
University of Engineering and Technology	UET	1	13	22
University of Agriculture, Peshawar	UAP	3.3	46	22
Institute of Management Sciences	IMAGES	7	94	25
Khyber Medical University	KMU	0.4	5	29
Shaheed Benazir Bhutto Women's University	SBBWU	6	82	8
CECOS University of IT and Emerging Sciences	CECOS	6.3	88	25
Brains Institute Peshawar	BIP	2	28	25
Qurtuba University	QU	1.4	20	26
Sarhad University of Science and Information Technology	SUSIT	9.7	130	26
Foundation for Advancement of Science and Technology	FAST	2.6	36	31
City University of Science and Information Technology, Peshawar	CUSIT	4.8	73	2
Gandhara University	GU	2.2	31	22
Abasyn university	AU	3.6	51	9
Iqra National University	INU	2.7	36	26
Pak International Medical College	PIMC	0.8	11	30

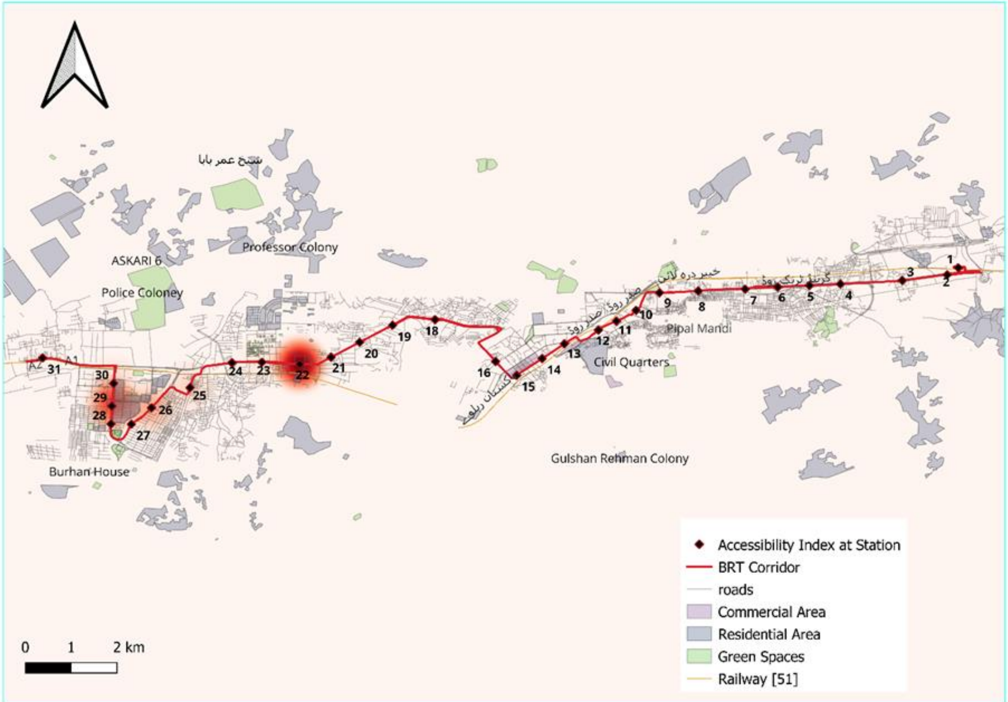

Figure 4.27: Accessibility Index of BRT Stations to Universities (α=1.5)

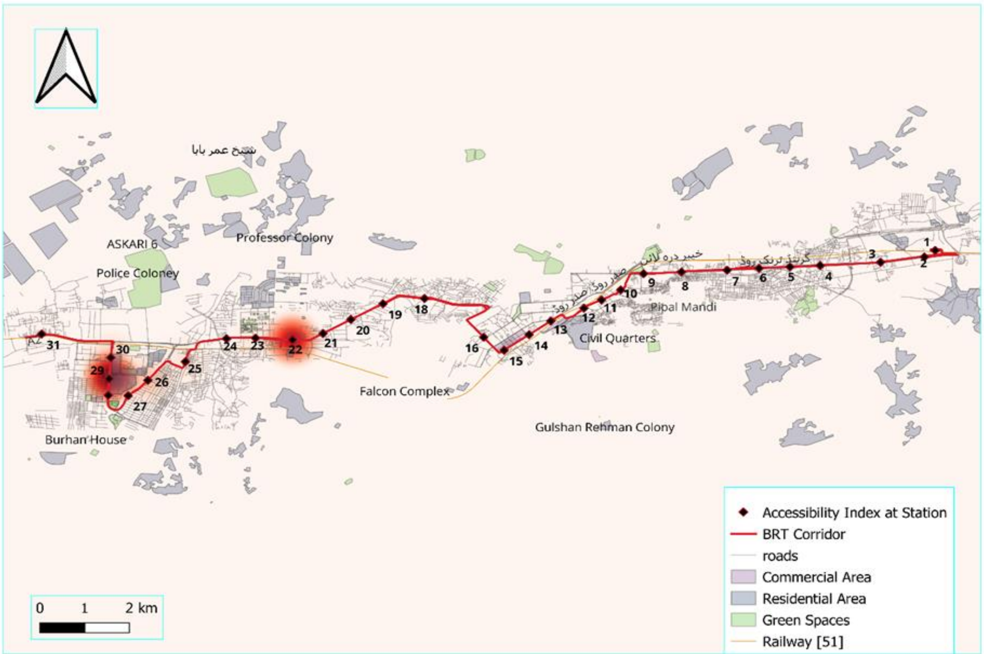

Figure 4.28: Accessibility Index of BRT Stations to Universities (α=2)

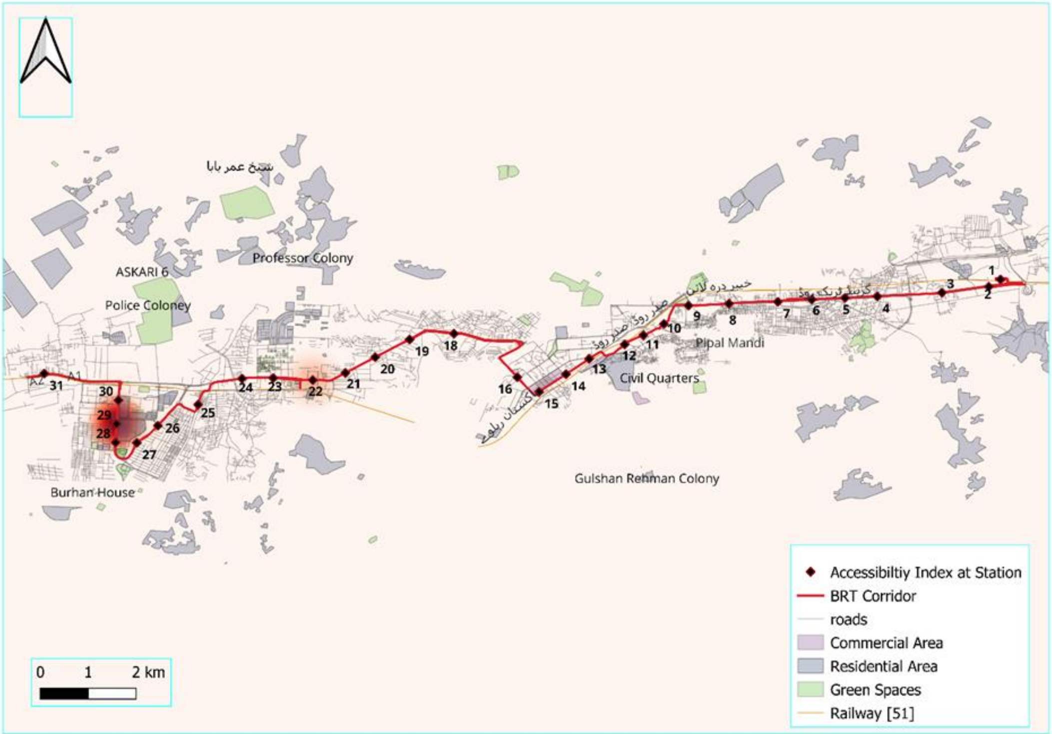

Figure 4.29: Accessibility Index of BRT Stations to Universities (α=3)

Table 4.14: Accessibility Indexes of BRT Stations to Universities

Stations Name (i)	Station ID	AI(α=1.5)	AI(α=2)	AI(α=3)	Universities (j)
University of Peshawar	22	0.155	0.036	0.0023	UP, UET, UAP, GU
Islamia College	23	0.015	0.003	0.0002	ICS
Mall of Hayatabad	25	0.027	0.004	0.0001	IMS, CECOS, BIP
PDA	29	0.089	0.04	0.008	KMU
Hasthnagri	8	0.001	0.002	0.0001	SBBWU
Bab-e-Peshawar	26	0.049	0.009	0.0004	QU, SUSIT,INU
Karkhano Market	31	0.004	0.001	0.0001	FAST
Sardar Garhi	2	0.002	0.002	0.0001	CUSIT
Malik Sadd Shaheed	9	0.003	0.003	0.0007	AU
Hospital Chowk	30	0.027	0.008	0.0005	PIMC

AI: Accessibility Index

Using the gravity model, Table 4.14 shows the accessibility indexes for all the BRT stations located near the Universities in Peshawar. The Figure 4.27 show that the PDA BRT station has the highest accessibility index, which is 0.04. This indicates that the travel time between KMU and PDA stations is minimal, following the concept of the Gravity Model. On the other hand, stations like Karkhano Market, Sardar Garhi, Hashthnagri, Malik Saad Shaheed, and the Mall of Hyathabad have very low accessibility indexes. This suggests that either the travel time is high or fewer opportunities (universities) exist in those areas. By applying the Gravity Model, we can predict the traffic flow between different zones based on population and the distance or travel time. Higher accessibility signifies a more significant potential for interaction. Considering the application of the gravity model, it is evident that stations with lower index intensities require special attention to maximize their accessibility. This discrepancy may be attributed to limited transportation options, inefficient urban planning and poorly developed infrastructure such as roads, sidewalks, and public transportation, as well as topographical challenges. To enhance the accessibility of these stations, we need to improve public transport services by enhancing frequency, coverage, and reliability. Investing in infrastructure such as sidewalks, crosswalks, and bikeways can improve connectivity for pedestrians and cyclists. Developing integrated transportation systems that allow seamless transfers between different modes of transport will reduce travel times and improve access. Lastly, involving local communities in the planning and decision-making will ensure that transportation solutions meet their needs and improve accessibility.

Furthermore, implementing policies that promote mixed land use development, such as building universities, residential areas, and commercial spaces near each other, can also enhance accessibility. This will reduce travel times and promote sustainable urban development by reducing the need for long-distance travel.

In conclusion, the gravity model provides valuable insights into the accessibility of BRT stations near the University and highlights the need for targeted interventions to improve accessibility in certain areas. By addressing the factors contributing to low accessibility indexes, such as limited transportation options and inefficient urban planning, we can create a more connected and accessible urban environment for all residents. Ultimately, improving accessibility will not only enhance the quality of life for individuals but also contribute to the city's overall economic and social development.

4.2.5 *Accessibility Analysis of BRT Stations to Recreational Facilities*

Table 4.15: List of Recreational Facilities in Peshawar

NAME	IDs	Travel Time (minutes)	Travel Distance (km)	BRT Station IDs
Garrison Park	1	51	3.6	9
Sher Khan Shaheed Stadium	2	51	3.8	18
Polo Ground	3	22	1.6	9
Arbab Niaz Stadium Peshawar	4	25	1.8	8
Khalid bin Waleed Park	5	32	2.3	18
Bagah Naran Park	6	24	1.7	26
Shahi Bagh Peshawar	7	20	1.4	8
Jinnah Park	8	28	2	8
Chacha Younas Park	9	10	0.7	8
Peshawar Club	10	3	0.24	16
Aasia Park	11	20	1.4	12
Tatara Park	12	9	0.65	28
Shalman Park	13	48	3.4	28
Khyber Park	14	11	0.75	28
Ghani Bagh	15	39	2.8	28
Peshawar Zoo	16	40	2.8	22
KP Assembly Park	17	16	1.1	10
Hayatabad Sports Complex	18	22	1.6	28
Peshawar Musem	19	29	1.9	9
Sethi House Museum	20	23	1.4	9
Qissa Khwani Bazaar	21	15	1	9

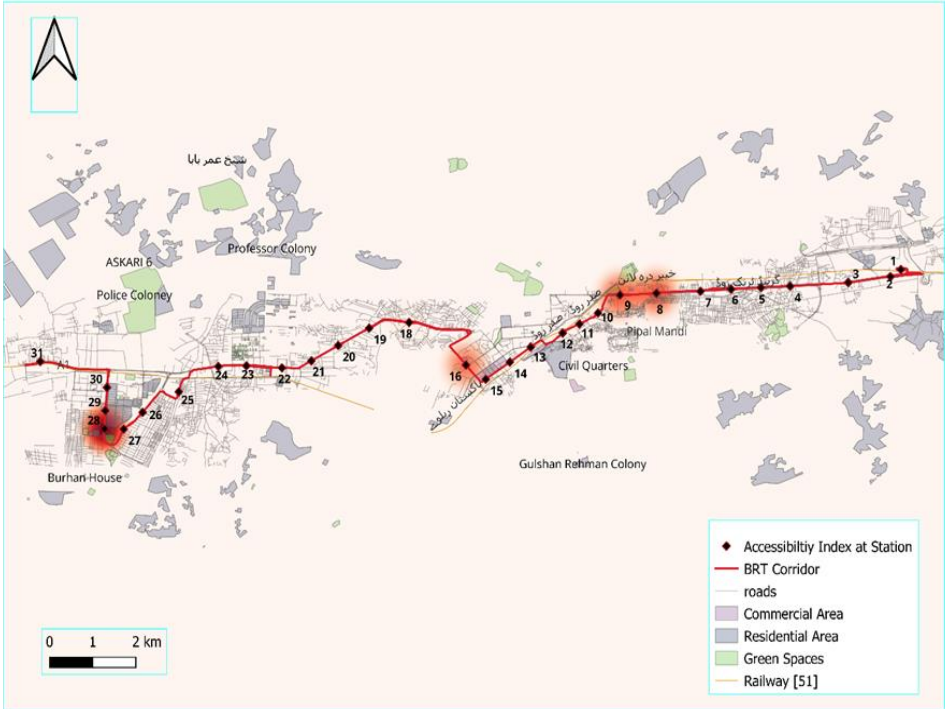

Figure 4.30: Accessibility Index of BRT Station to Recreational Facilities (α=1.5)

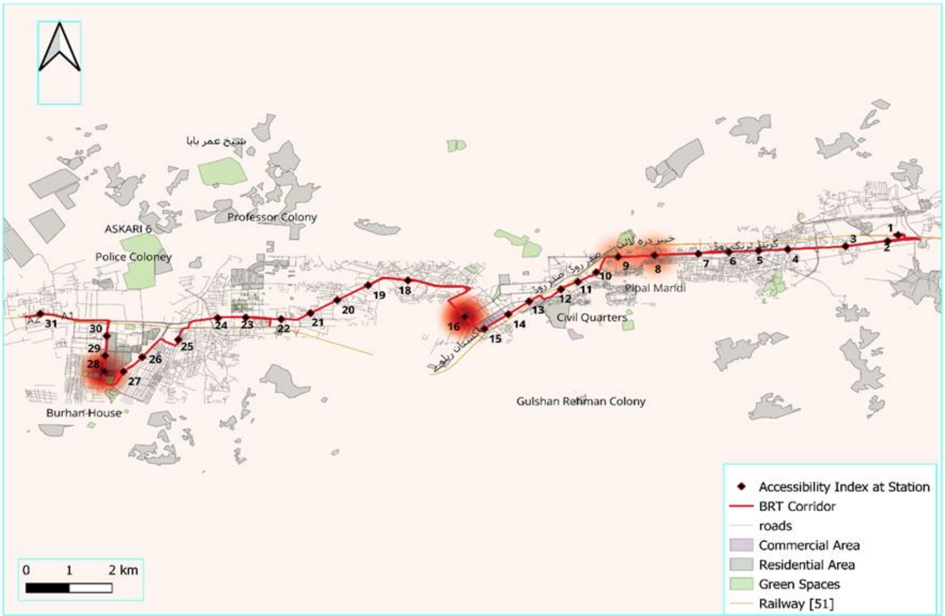

Figure 4.31: Accessibility Index of BRT Stations to Recreational Facilities (α=2)

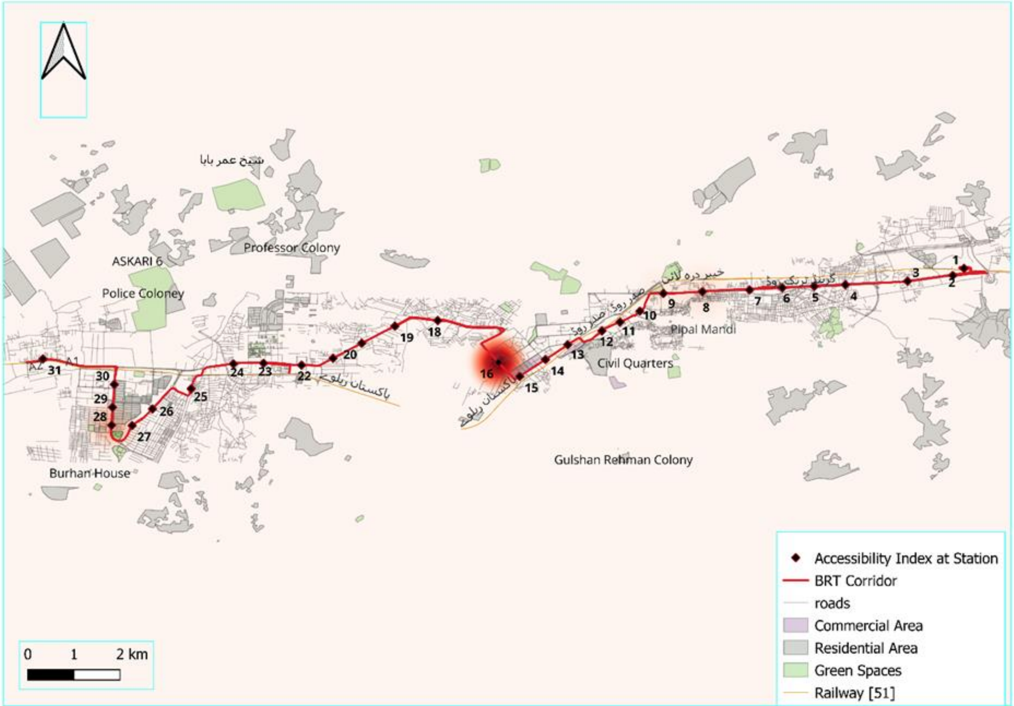

Figure 4.32: Accessibility Index of BRT Stations to Recreational Facilities (α=3)

Table 4.16: Accessibility Index of BRT Station to Recreational Facilities

Stations IDs	AI(α=1.5)	AI(α=2)	AI (α=3)	Recreational Facilities
Malik Saad Shaheed	0.225	0.0498	0.0026	1,3,19,20,21
Hashtnagri	0.230	0.0615	0.0049	4,7,8,9
Tatara Park	0.406	0.1188	0.0112	12,13,14,15,18
Tehkal Payyan	0.016	0.0027	0.0001	2,5
Mall Road	0.192	0.1111	0.0370	10
Bab-e-Peshawar	0.008	0.0017	0.0002	6
Dabgari Gardens	0.011	0.0025	0.0001	11
University of Peshawar	0.003	0.0006	0.0003	16
Khyber bazar Station	0.015	0.0039	0.0002	17

Table 4.16 shows the accessibility indexes of BRT Stations to recreational facilities in Peshawar. The results in Figure 4.31 and the table indicate that Tatara Park and Mall Road have high indexes. This suggests that the number of opportunities is at its maximum or the travel time is at its minimum between these stations and the recreational facilities. On the other hand, the remaining highlighted stations have low indexes, which could be attributed to increased distance, poor connectivity, lack of direct routes, non-recreational land use, safety concerns, or poorly maintained walking/cycling paths. To enhance the accessibility of these stations, it is crucial to improve pedestrian and cycling infrastructure around BRT stations and lead to

recreational facilities. This can be achieved by implementing dedicated lanes, removing Obstacles, and ensuring seamless transitions between different modes of transportation. Additionally, considering shuttle services or on-demand transportation options to directly connect to recreational facilities, especially those located further away, could be beneficial. Launching awareness campaigns targeting diverse audiences about the accessibility of BRT stations and nearby recreational facilities is also recommended.

Furthermore, conducting regular surveys and collecting user feedback can help identify specific issues and areas for improvement. Collaborating with local authorities, urban planners, and community organizations to prioritize accessibility and promote active transportation can also significantly enhance the overall accessibility of BRT stations to recreational facilities in Peshawar. By addressing these challenges and implementing targeted interventions, we can create a more inclusive and sustainable transportation system that encourages people to utilize public transit and enjoy recreational activities in the city.

CHAPTER 5: CONCLUSIONS AND FUTURE RECOMMENDATION

5.1 Conclusion

The study's findings suggest that sociodemographic factors play a crucial role in implementing bicycle-sharing systems (BSS) in a specific area. Understanding the sociodemographic characteristics of the population helps ensure fair and equal access to BSS, considering variables such as income level and accessibility. By analysing this data, it becomes possible to optimize the design and placement of bicycle stations, making them convenient and accessible for different population segments. These insights also inform the development of policies, such as pricing structures and incentives, to encourage specific groups to utilize BSS.

Additionally, the study identified various barriers to adopting BSS in Peshawar. Addressing and overcoming these barriers makes it possible to establish seamless first-mile/last-mile connectivity, attracting more users to the BRT system, particularly for short trips within neighbourhoods. This, in turn, can enhance overall public transport ridership and accessibility, especially for individuals who cannot afford private vehicles or reside far from BRT stations.

Furthermore, by utilizing gravity model indexes for Universities and Recreational facilities, it is possible to enhance the accessibility between the BRT Corridor, Universities, and Recreational Facilities. This improvement in connectivity can further improve the overall efficiency and effectiveness of the BRT system, benefiting both the academic community and individuals seeking recreational opportunities.

5.2 Recommendations

Based on the results of this research, it is suggested to develop a comprehensive bicycle infrastructure that includes a network of protected cycling lanes connecting BRT stations to residential areas, educational institutions, and recreational spaces and overcoming those barriers needs of the time people face during Bicycle mode use. Additionally, it is recommended that secure and convenient bicycle parking facilities at

BRT stations and key destinations be established to promote ridership and deter theft. The study also proposes ensuring that BSS stations are easily accessible and equipped with user-friendly amenities such as docking systems, repair tools, and information panels.

To address limited accessibility in certain areas identified on the maps, strategically place stations near key destinations, public transit hubs, and densely populated areas to enhance convenience and accessibility. Furthermore, it is recommended that an integrated ticketing system be implemented that allows riders to pay for both BRT and BSS trips using a single card or mobile app. This will streamline the payment process and improve the overall user experience.

In addition, it is suggested that the benefits of cycling and the integrated BRT-BSS system be promoted through targeted campaigns across various media channels. Emphasizing the convenience, health benefits, and environmental advantages of cycling can help encourage more people to use these sustainable modes of transportation.

By following these recommendations, Peshawar can create a more cyclist-friendly environment that maximizes the potential of BSS-BRT integration to build a more sustainable, equitable, and healthy city for all residents.

5.3 Limitations

Bicycle Sharing Systems (BSS) have the potential to significantly contribute to creating a more sustainable and socially inclusive urban transport system, especially when integrated with public transport services. However, to fully harness the benefits of this integration, further empirical research is necessary to address the gaps identified during this study.

One area that requires investigation is the Optimization of Bicycle stations using Location Allocation Modelling. Another area required the exploration of the impacts of an integrated transport system combining BSS and public transport, focusing on the environment and the Air Quality Index. Understanding how this integration affects these factors is crucial to assessing the system's overall sustainability.

Another aspect that needs to be explored is the effect of integrating BSS with transit stations on ridership. It is essential to determine how the availability of bicycle sharing affects the number of people using public transit. This information can help in designing more efficient and effective transport systems.

Furthermore, there is a need to develop and utilize specific methods for data collection and analysis of the integration between bicycle-sharing systems and public transit. By employing these methods, we can better understand the practices and mobility patterns associated with this integration. This knowledge can then be used to improve the overall functioning and usability of the integrated system.

In conclusion, while BSS has the potential to contribute significantly to a more sustainable and socially inclusive urban transport system when combined with public transport services, further empirical research is required to address the identified gaps. Specifically, research is needed to understand the impacts on the environment and Air Quality Index, the effect on transit station ridership, and the development of specific data collection and analysis methods.

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Appendices

Appendix-A

<u>User's preferences investigation survey regarding Spatial Integration of Bicycle Sharing System (BSS) to Public Transit Stations, a case study of Bus Rapid Transit (BRT) Peshawar</u>

Dear Participants,

Thank you for your interest in participating in my Master's research work titled **"Spatial Integration of Bicycle Sharing System (BSS) to Public Transit Stations, a case study of Bus Rapid Transit (BRT) Peshawar "**. Your participation in this survey is highly appreciated.

Pakistan is a rapidly urbanizing country with significant transportation challenges, including traffic congestion, air pollution, and inadequate public transportation infrastructure. Increased accessibility and availability of bike sharing offer cities and inhabitants several advantages, including healthier, more active modes of transportation, a reduction in traffic congestion and air pollution, and additional routes to and from public transit stations. This survey aims to assess the intention of people in Peshawar of using the Bicycle as a mode of transportation.

The questionnaire should take only 5 to 10 minutes to complete, and your input is of great importance for the success of this research. Your participation is strictly confidential, and no personal information is required.

Thank you for taking the time to complete this survey.

Regards,

Nasim Ullah Khan

MS Transportation student at NUST, Islamabad

SOCIODEMOGRAPHIC CHARACTERISTICS

1. **What is your Gender?**

- Female
- Male
- Other
- Prefer not to answer

2. **What is your age?**

- 18–24
- 25-34
- 35-44
- 45-54
- 55-64
- 65 or above

3. **What is your highest educational level obtained?**

- Matriculation (10th Grade)
- Higher Secondary (12th Grade, FSc/FA)
- Bachelor
- Postgraduate (MS or PhD)

4. **What is your monthly income (Rupees)?**

    - 0-25000
    - 26000-50,000
    - 50,000-100,000
    - >100,000
    - Prefer not to answer

5. **What is your employment status?**

    - Govt Employ.
    - Private Employ
    - Own Business.
    - Retired
    - Student
    - Other

ATTITUDES TOWARDS BICYCLE SHARING SYSTEM (BSS)

6. Do you ever use a bicycle for transportation to/from any of the following destinations, than (check all that apply)?

- Workplace
- Grocery Stores/services
- Schools
- Recreational facilities
- Transit stops and stations
- Other neighborhood destinations.

7. How many days per week do you typically ride your bicycle?

- 0
- 2
- 3
- 5
- 7

8. What will be your preferred distance to travel using the Bicycle?

- 1 Km to 2 Km
- 3-4 Km
- 5-6 Km
- More Than 6Km

9. What will be your preferred travel time using the Bicycle?

- 0 to 10 Min
- 11-20 Min
- 21-30 Min
- More Than 30 Minutes

10. Do you ever choose not to ride your bicycle due to adverse weather conditions?

- Yes
- No

If yes, under which conditions will you not ride (check all that apply?

☐ The threat of rain ☐ Heavy rain ☐ Drizzle ☐ Steady rain

☐ Fog

☐ Cold weather (above what temperature__________ ☐ Hot weather (below what temperature________)

11. What are the main obstacles to using the Bicycle?

- Health and Fitness
- Weather and Environmental Conditions
- Culture
- Gender
- Safety and Security
- Non-Availability of adequate Bicycle infrastructure facility
- High Cost of Membership
- Bicycle Stations are too far
- Not enough stations close to BRT stops

ATTITUDES TOWARDS INTEGRATION OF BICYCLE SHARING SYSTEM (BSS) WITH BRT STATIONS

12. For the access to BRT Station which mode of transport do you use?

- By Private Vehicle (Rickshaw, Taxi, etc.)
- By Bicycle
- By Walking
- By own Vehicle

13. For the access to BRT Station which mode of transport would you like the most?

- By Private Vehicle (Rickshaw, Taxi, etc.)
- By Bicycle
- By Walking
- By own Vehicle

14. How do you normally continue your journey after you get off a BRT Bus?

- I never take the BRT Bus
- Walk

- By own Vehicle
- By Private Vehicle (Rickshaw, Taxi, etc.)

15. **What prevents you from using Bicycle Sharing System when traveling to and from a BRT Bus station? (Check top 3 only)**
    - Not enough Bicycle stations at my Origin-Destination
    - Not enough Bicycle stations at bus stops
    - Distance: BRT Bicycle stations are too far away from my Origin-Destination
    - Distance: BRT Bicycle stations are too far away from BRT Bus stations
    - Not enough regular Bicycles at Stations
    - Nothing prevents me
    - Other
16. **I would use the BRT bus more often if Bicycle stations were integrated into them.**
    - Strongly agree
    - Somewhat agree
    - Neutral
    - Somewhat disagree
    - Strongly disagree
17. **I would ride the Bicycle more often if there were more bike lanes, paths, and trails that led to BRT Bus stations.**
    - Strongly agree
    - Somewhat agree
    - Neutral
    - Somewhat disagree
    - Strongly disagree
18. **Which mode of fare payment do you want to use?**
    - By Cash
    - By Card
    - By Mobile App
    - Single Payment for both BRT Bus and Bicycle(integrated payment system)

Appendix-B: Letter to Trans Peshawar

NUST INSTITUTE OF CIVIL ENGINEERING (NICE)

School of Civil and Environmental Engineering (SCEE)

National University of Sciences and Technology (NUST)

Sector H-12, Islamabad - 44000, Pakistan

NICE

Date:

To: The General Manager Operations
Trans Peshawar
KPUMA, KPK

Subject: **Application for Permission to Distribute Questionnaire Survey at Transit Stations**

Respected Sir,

With due respect, I am writing to request permission to distribute a questionnaire survey at various BRT stations under the jurisdiction of Trans Peshawar. The purpose of this survey is to gather valuable insights and feedback from commuters regarding their travel experiences, preferences, and suggestions for improving the transit system.

My name is Nasim Ullah Khan and currently enrolled in a master's (Transportation Engineering), working on *"Spatial Integration of Bicycle Sharing System (BSS) to Public Transit Stations, a case study of Bus Rapid Transit (BRT) Peshawar"* as my research topic.We are aware of the busy nature of BRT stations and understand the need to minimize disruptions to the daily operations of the stations. Therefore, we have carefully planned our survey methodology to ensure a seamless and non-intrusive process. Our team will be stationed at designated areas within the BRT stations, such as entrance/exit points or waiting areas, where we will approach commuters politely and request their voluntary participation in the survey. We estimate that each survey will take approximately 5-6 minutes to complete.

We will not obstruct the flow of Transit ridership within the stations. Any personal information collected during the survey will remain strictly confidential and will be used only for research purposes.We kindly request your permission to distribute our questionnaire survey and look forward to your favourable response, and we hope for a fruitful collaboration.

Yours sincerely,

Nasim Ullah Khan
Master in Transportation Engineering)

Dr. Muhammad Asif Khan
(Assistant Professor SCEE-NUST) Thesis Supervisor/Advisor

Assistant Professor
NICE (SCEE), NUST

General Manager Operations

Trans Peshawar

TransPeshawar (The Urban Mobility Compnay)
A compnay set up under section 42 of the Companies Act, 2017

No. OPS/MISC/2023/021
Date: June 14, 2023

Dr. Muhammad Asif Khan
Assistant Professor
NICE (SCEE), NUST

Subject: Application for Permission to conduct survey at all BRT Stations regarding MS research

Reference to your letter no. Nil dated June 14, 2023 regarding the subject (Copy enclosed).

The following team members are allowed to conductor survey at BRT stations and Buses for his research work in Transportation Engineering.

S. No	NAME	Designation	CNIC	CELL Number
1	Nasim Ullah Khan	Master Student at NUST, Islamabad	11101-7279989-5	03340150857

Station Staff have been informed regarding the distribution of Questionnaire at BRT Stations as per the following schedule.

#	Date		Time		
	From	To	From	To	Station
1	15-06-2023	18-06-2023	8:00 AM	6:00 PM	All BRT Stations

Kindly note that survey shall be conducted in a manner which does not affect passenger flow at the Stations and shall not cause disruption in bus operations.

15/6/23

Chief Executive Officer
TransPeshawar (The Urban Mobility Company)

Address: 1st Floor, TransPeshawar Building Main BRT Depot, Near Northern By-Pass Chamkani, Peshawar KPK, Pakistan
Tel: +92 91 2621393-5 Web: www.transpeshawar.pk Email: info@transpeshawar.pk