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AI-Driven Location Analysis and Population Demand Forecasting for E-Bike Sharing in the BRT Peshawar Network

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ABSTRACT

The implementation of BSS represents a key approach to enhance sustainable transportation patterns within cities. Public transportation stations at the end of travel routes can integrate BSS better to enhance both sustainable transportation alternatives and connectivity options. Research studies the potential benefits along with technological viability of linking BSS with Bus stations. A stated preference survey provides complete understanding of how people choose their travel modes. The survey allowed researchers to discover optimal sites and design framework for bicycle stations. The researcher used Geographic Information System (GIS) to choose suitable locations. Progress toward developing a BSS network requires consideration of three fundamental elements including population distribution pattern combined with land usage and transportation accessibility characteristics. The predicted results from this investigation will introduce better last-mile options. Academics exposed that BSS enhance accessibility through lowered traffic congestion alongside environmental improvements from reduced pollution levels alongside elevated physical exercise rates. The urban transport system achieves social equity through active promotion mechanisms. This study will focus on establishing the major obstacles that require solutions to enable smooth system unification. Relevant infrastructure along with amenities must be developed for this system to function properly. The delivery of services that cater to BSS users combined with security protection measures and access guarantees ensure infrastructure safety. The findings of this study demonstrate how this research establishes the success of the research provides essential knowledge about the sustainable development of Peshawar's urban transport network which benefits future policymakers and planners. Urban transportation planners together with public officials should use these findings when designing BSS system integration strategies.

Introduction

Modern cities worldwide now prioritize sustainable urban mobility development because they need to solve growing problems with traffic congestion along with air pollution and restricted use of public transportation. Organizations now focus on combining different transportation modes to create unified efficient transportation systems since addressing recent challenges. Metropolitan areas are busy implementing Bicycle Sharing Systems into their existing public transport stations as a major infrastructure advancement. Sustainable transport maintains its principles from the sustainability principle that "development that satisfies current requirements without jeopardizing the capacity of future generations to fulfill their own needs." The definition highlights how important it is to merge necessary social requirements with environmental restrictions to achieve future generational welfare (Arrieta et al., 2019).

The economic point of view expects sustainability to include complete integration. The creation of an integrated entity requires finding equilibrium between environmental and geographical elements in addition to economic and social systems and institutional structures. The perspective agrees sustainable mobility stands as an important component under the terms sustainable transportation or green transport. Green transport represents methods in transportation industry which prioritize environmentally friendly solutions. The fusion of environmental systems with economic and social structures forms sustainability while these systems either support or create obstacles to each other throughout multiple geographical dimensions (Meadows et al., 1972).

The Organization for Economic Cooperation and Development (OECD) defines sustainable transport through its purpose to safeguard public health and natural ecosystems. Beyond resource depletion and air pollution the notion extends to encompass multiple factors such as social ones and economic ones. Sustainable transport concerns resource deficiency and air contamination in a limited definition because these aspects represent primary environmental challenges. Wealthy urban countries remain unsuccessful in ensuring complete awareness about sustainable transportation despite recognizing its importance beyond environmental factors (Ottersen et al., 2014).

The inclusive strategy shows we need an integrated system that takes care of environmental elements and places social and economic matters first. The assessment of sustainable transportation demands an institutional structure that facilitates appropriate behavioral changes for sustainable transportation. Meeting sustainable mobility standards demands that all environmental domains act in harmony with social and economic components. The approach includes both present problem resolution and future population needs forecasting. The OECD defines sustainable transportation policy execution by emphasizing the requirement to use renewable along with non-renewable resources properly (Bhuiyan et al., 2022).

Research on urban transportation has become complex after bike-share schemes started being implemented. Research scholars debate the effect of bike-sharing on urban transportation since it can improve sustainability by directly changing motorized car usage. Opposing research suggests bike-sharing programs affect current transportation systems only moderately since they reduce driving activities yet fail to connect effectively with transit networks (Barbosa et al., 2018). A full evaluation of bike-share impact demands an assessment of how it affects public transportation since both systems utilize shared public funds.

The strategic objective should focus on efficient integration instead of competition since both bike sharing services and public transport operate concurrently. Planners need to purposely select bike-share station locations specifically for areas lacking quality public transit services according to the "first-last mile" accessibility requirements (Wei et al., 2023). Research indicates that bike sharing stands as a sustainable means of travel whenever public transportation systems lead to inefficient routes.

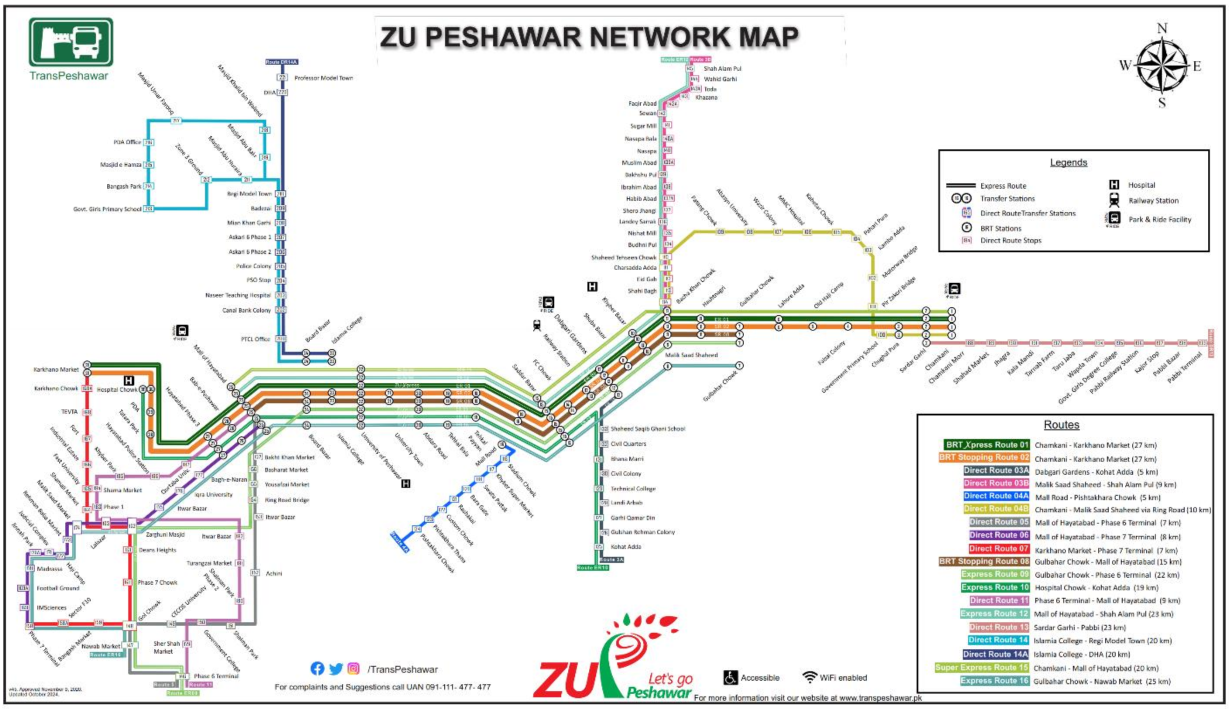
International authorities accept BSS as an environmentally friendly and operationally efficient mobility solution that provides multiple operational advantages including fast transportation and health benefits as well as cost-effective access. The protection of urban transportation requires people to use modes that operate independently of motors. Underdeveloped nations require the mandatory promotion of bicycles as an essential element. BSS operates as a public transportation system through short-term leasing services between different docking stations. The service relieves users from spending resources on bicycle storage and maintenance responsibilities. People commonly use bicycles as their main transportation choice for the final short commute alongside other modes of transport (Pangbourne et al., 2019).

Research interest about BSS integration with public transit has grown among both professionals and academic researchers. Numerous surveys and analytical findings based on actual data have generated important discoveries. Bike-sharing programs in San Francisco reduce e-hailing use which reduces traffic blockages and guarantees better transit schedules. E-scooters prove better than other forms at improving accessibility in the first and last leg of trips (Olabi et al., 2023). The integration of transportation with bike-sharing services receives support from people who live in areas with lower population density according to studies conducted in Washington DC. Research that uses regression models finds that bike-share cycling generates positive outcomes for Metrorail passenger numbers (Kaviti et al., 2019). The distribution of residents and job position together with proximity to the downtown core emerges as vital metrics through spatial metrics analysis of metro bike-sharing patterns (Zhu et al., 2023).

Peshawar is the capital city of Khyber Pakhtunkhwa (KPK) province with a 2017 population survey (Government of Pakistan, 2017) that resulted in a population of 4.26 million. Peshawar is a breeding ground of commerce, as well as a passage to Afghanistan, and a bridge between Pakistan and the Central Asian as well as the Middle Eastern countries. Due to this, it is a geostrategically important city in Pakistan in terms of supply line to the North Atlantic Treaty Organization (NATO) (Mayer & Zhang, 2020). In the last ten years, Peshawar has witnessed a massive growth with an astonishing increase of 92% in all private transport and automobile ownership. This has caused great congestion, economic and environmental damage, and safety problems. To resolve issues with disordered urban transportation model, Bus Rapid Transit (BRT) and Bus Service Systems (BSS) have been introduced in Pakistan which got completed in the year 2020. The BRT corridor SUV stretches over a distance of 26 kilometers with 31 stops on along the way. The mean distance between any two road points is 850 meters; at grade route will be 15 kilometers, flyover will be 8 kilometers and 3 kilometers will be pass.

Peshawar has made a successful effort in walking and cycling by re-thinking the city's transportation options since the implementation of the Zu Peshawar system. The BRT route is focused on dedicated bike lanes in parts of the road way give cyclists a safe of place. Visitants who cycle to the station may use the bicycle parking facilities which are each station. Mallinckrodt Drive, and features an innovative bike station system with 32 stations and an initial fleet of 360 bikes – which is also the first bike-sharing scheme in the country (Lemley & McKenna, 2017). This bike-sharing system links main educational and residential districts with the BRT system and tracts from the main route. For greater convenience, both kiosks, as well as within the Zu Mobile App, offer current information about the availability of bicycles. After launch of bike sharing, bicycle trips have increased by 6% as reported by Trans Peshawar and KPK Govt. BRT system has ample and accessible pedestrian way, escalators, elevators, stairs, ramps and pedestrian overpass/deck enhancing public safety of pedestrian. A 4 km multi-use cycling and pedestrian path is underway on a densely populated part of the city (Moraci et al., 2020). Stations are at intervals of substantially 800 m guaranteeing that any future development projects are within 400 meters of the Bus Rapid Transit network. The city has made efforts in upgrading drainage systems in order to alleviate flooding. TOD, efforts to designate three main commercial centers which are fully linked with BRT station to promote.

Figure 1: Displays the network map of BRT Peshawar below



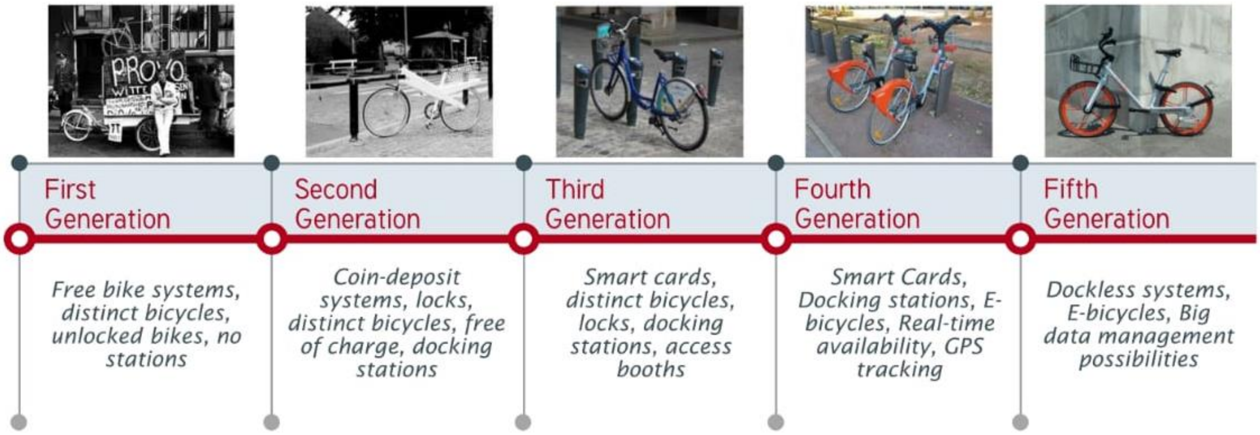
History of Bicycle Sharing System

In the year 1965 Netherlands initial bike-share system was launched, to handle Amsterdam traffic issues in the city center. A local organization, a white bicycle program was initiated, several white bicycles scattered throughout the inner city. These bikes were forever and every locked & located in various zones so that people are capable of use them at free of any time restriction. However, this tactic was unsuccessful due to the common incidents of cycle theft and vandalism. During the 1990s, Copenhagen came up with a second generation of shared bicycles with a coin lock-in. Unfortunately, this did not fully address the problem of theft, as the user's anonymity and absence of time-bounded rentals caused rentals unheard of before. Although the first couple of generations had their flaws, the third-generation of bike-shares is world renown. These include system integration like intelligent cards associated with public transit and technical developments that include transaction kiosks at docking stations (Wang et al., 2018). These prominent examples are the Velib system in Paris, the Hangzhou Public Bicycle system in China and the BIXI system in Montreal.

In 2016, a new form of bike-sharing was launched in major Chinese cities. This model, based on private ownership and app-based, dockless mode, became very popular, nowadays it is counted among the fourth generation of the bike-sharing system, higher than previously recognized three generations. According to the research report Bike-sharing Employment & Market Research, by

2017, dockless bike-sharing operators in China, led by senior peers such as MO Bike, two largest operator in the market put more than 16 million bikes from them into the market and solve more than 50 million per day in the common bike difficulty programs [State Information Centre, 2017]. A detailed record and summary of the evolution of bike-sharing systems can be found in Figure 2.

Figure 2: Various phases of advancement in worldwide bicycle-sharing networks



Integration of Previous Studies

Urban transportation experiences rapid growth because micro mobility has become a highly preferred trend. Micro mobility incorporates bicycles among its human-powered vehicles and modern electric vehicles including e-scooters and e-bikes. Worldwide adoption of micro-vehicles becomes increasingly common in various locations. Various micro-vehicles have experienced substantial growth for public and private use during recent years resulting in the general population's mass approval. Bicycle-sharing systems represent a significant growth of micro-mobility as these programs have spread throughout the world. There has been a rapid expansion of bike-sharing programs which started at 17 in 2005 before reaching 2,900 in 2019. The market has brought forward electric bicycles and pedal less which further enhanced the available vehicle selections (Kenworthy & Svensson, 2022). The implementation of station less bike-sharing systems experienced significant growth since 2010 in China before spreading quickly throughout worldwide locations.

Modern urban transportation has experienced a shift thanks to micro-mobility which supplies people with convenient along with eco-friendly mobility replacements for traditional travel methods. The rising availability of micro-vehicles combined with their expanding popularity demonstrates widespread acceptance that makes room for additional growth in this sector (Ibn-Mohammed et al., 2020). Since its Swedish launch in 2018 the European supplier of e-scooters expanded to 10 countries throughout one year. Recorded data shows the firm has exceeded 16 million rides.

A solution based on micro mobility exists to address international cities' transportation challenges as it helps cities transition from car ownership. According to the International Transport Forum (ITF) micro-mobility systems need kinetic classification of their vehicles. A micro-vehicle qualifies for micro-mobility requirements when weighing under 350 kg (771 lb.) and with a maximum operating speed below 45 km/h. These vehicles can only produce a kinetic energy output below 27 kJ because of this regulation which remains drastically lower than what a small car experiences during peak velocity operations. The micro-mobility concept covers vehicles from human-powered devices to electrically assisted products which include bicycles, e-bikes, kick scooters, skateboards and four-wheeled electric micro-cars (Belli et al., 2020). This selection remains unfinished because the micromobility concept persistently develops. The concept of micro-mobility continues to expand beyond identified vehicles and propulsion systems which ensures its development space for future progress.

This method promotes the implementation of rules for newly licensed 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 appurtenances, number of wheels or manner of seat. Though, the job of controlling and implementing how measures of efficient control of these various motor vehicles present a significant challenge for planners and policymakers worldwide. To address this issue, The ITF suggests the four-type classification of micro-vehicles according to their top speed and mass (Gruyer et al., 2021). Please see further information on classification of this status and a comprehensive understanding of micro-vehicles, their types, and their classification, please refer to "Safe micro-mobility."[ITF-2020].

The PT offers extensive distance travel options yet does not cover all parts of a city to the extent that autos do. Public transport faces challenges during initial and final distance travel because it has restricted access and flexibility (Figure 3). The first stages of the complete journey path become visible through this figure. The route consists of three distinguishable sections. The initial section of this itinerary takes passengers from A to B at the first milestone before the primary part extends from B to C. The entire public transportation journey starts from C when commuters choose to ride public transportation from C to D [21].

Figure 3: A preliminary itinerary for the entire tour

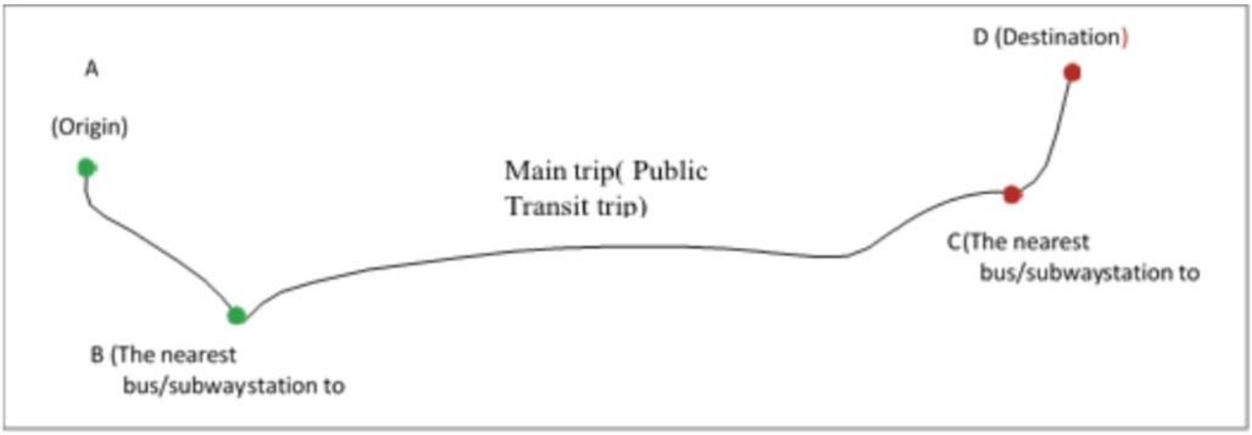


Table 1: Literature review on the integration of bike-sharing systems with public transportation

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	Public Transit	USA

	bicycles		
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

A review of literature about BSS integration stands as the first part of this research. Studies focusing on Chinese cities have become numerous in recent times. The cities achieved outstanding progress in their sharing solutions and successfully implemented their integration. These cities stand out because they possess vast quantities of information due to their advanced technology and issuance systems. Numerous investigations have adopted smartcard as their research methodology. Smartcard data reveals complete journey sequences beginning with bicycle sharing and continuing to metro transit within the same trip (Ma et al., 2020). A few research studies failed to obtain these systematic data sources these studies analyzed bicycle sharing station positions and accessibility to understand their effect on travel mode choices of people. The paper by Rogers (2023) explores how to combine multiuse paths (MUPs) with bicycle infrastructure. Public transit receives bicycle sharing infrastructure as an intervention to resolve the First/Last Mile challenge. The research demonstrates that integrating MUPs and bike share systems proves beneficial when creating TOD strategies. TOD strategies employ effective measures to overcome the issues which FLM travel presents. This implementation results in a dynamic improvement of all transit services. The analysis utilized survey methods to obtain understanding about how people behave regarding FLM travel patterns and the related structural obstacles. This research demonstrates why first-mile travel needs obstacle elimination as a key factor. Driversem target their travel primarily through using their vehicles. The establishment of bike share stations and transit stops and MUPs constitutes an essential factor toward building public confidence for MUP adoption. Efforts to eliminate FLM obstacles become especially vital when using public transit systems (Palladino, 2024). Shishir Mathur (2023) analyzed construction barriers that TODs faced throughout the United States the writer provides insights about planning land use with zoning combined together as PLUZ. The paper explores the main obstacles which block TOD project development. Modern urban planning together with zoning legislation in transit neighborhoods requires additional support to succeed. The paper presents insights about multiple aspects of knowledge. The paper investigates multiple development barriers of transit-oriented infrastructure by performing research on an extensive literature review serves as the base for surveys directed at transit agencies and local governments across each country. The solution of these barriers becomes essential because it will be the development of sustainable and efficient TOD in the United States needs these elements (Campisi et al., 2021).

Xue (2022) performed research to explore all variables which influence how people select bicycle-sharing for their transportation needs. This research analyzes the relationship that exists between user perceptions together with psychological expectations alongside loyalty as individual factors which influence bicycle-sharing domain decision-making processes. Studies seek to advance researchers' comprehension of the intricate bicycle-sharing decision-making procedure for choosing an alternative transportation system. Empirical data together with theoretical frameworks appear to form the foundation of the research which explores BSS user behavioral complexities (Laoudias et al., 2018).

The research by Alejandro Builes-Jaramillo (2022) examines the public bicycle-sharing system of Medellin Colombia through spatial temporal network methods. The research applies cutting-edge analytic techniques to accomplish its measurement goals. This research investigates the system operational dynamics from a perspective combining time factors with space-based elements. This research examines two main factors which are station usage patterns in addition to demand variations through time. The bicycle-sharing network exists as a connected system throughout the urban area of Medellín. The study's output will provide new comprehension about the subject matter. Urban planners together with policymakers can maximize their resource distribution through these findings. The overall sustainability and operational excellence of public bicycle modes must be improved through infrastructure development. The application of academic methods in this specific context will expose comprehensive natural connections existing in complex environments. The analysis will reveal important information that serves academic understanding needs. Sustainable transportation planning together with research on urban mobility relies on the methods presented by (Staffell et al., 2018). Żochowska et al. (2021) developed a GIS technique with Żochowska as the lead author which evaluates bike-sharing system spatial integration in urban areas. The study presents an approach based on the research utilizes GIS tools to analyze bike-sharing station spatial arrangements with the goal of station placement efficiency assessment. The evaluation uses accessibility along with geographic distribution as recognition factors to measure total spatial benefits. Bike-sharing station optimization follows the recommendations of both planners and policymakers. The urban area benefits from optimized station placement to achieve better accessibility and usability (Zhang et al., 2019). Böcker (2020) researched the process of integrating bike sharing into public infrastructure through a dedicated study.

Study results show that male bicycle-sharing service users and young people living by rail or metro stations display the most frequent bike-sharing activity. Results from the study demonstrate a positive relationship between ages' square values since age itself does not determine probability rates alone. This study emphasizes both time and place factors as elements that cause variations in bicycle-sharing usage patterns in multiple areas during different time periods. Pressing studies show potential biases toward wealthy individuals who use the service before others because they both possess higher economic resources and educational background. The research explained bicycle-sharing and public transport relationships thus making contributions to urban development policies and transportation planning (Mugenda, 2023). Grosshuesch (2020) investigates how dockless shared bicycles and shared e-scooters serve as mobility options to connect public transport users through their first and last transport miles. The study evaluates the existing regulatory structures which monitor micro-vehicles throughout urban United States territories ("Building Trust and Reinforcing Democracy," 2022).

Table 2: Principal discoveries from the literature about the integration of bike-sharing systems with public transportation.

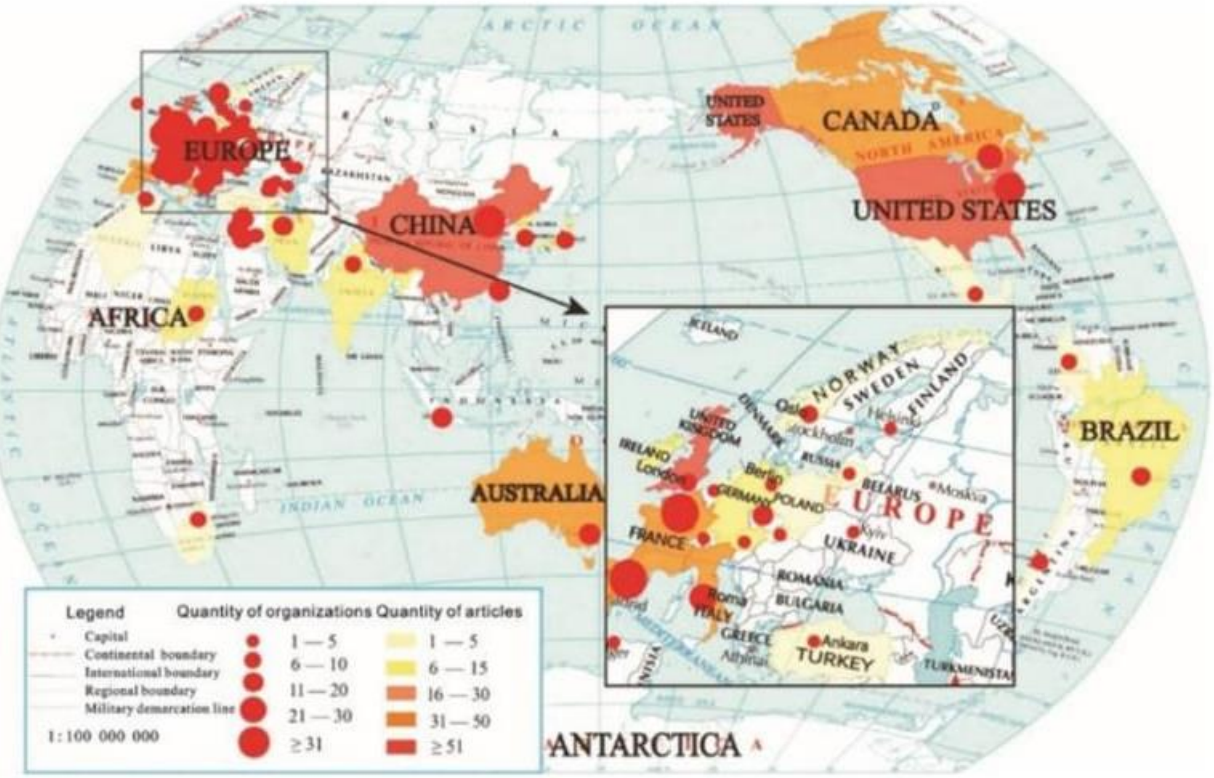
Authors	**Research Data**	**Key findings**
Bocker, 2020	System Data	Bicycle-sharing trips within 200 m of a PT station.
Guo, 2020	System data – Dockless BSS	Trips within 100 meters of a PT station involving bicycle sharing
Li et al, 2020	Analysis of Spatial Data	Provision of BSS stations at origin, PT 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

Table 2 presents different methods that study BSS connection to transit stations. The investigation of trip chain integration demands dedicated methods to locate relevant behavioral data because researchers need proven procedures to both collect and assess vital information. Several methods to evaluate the integration exist according to Tables 1 and 2. A standard assessment collects answers from participants about their practices of integration as well as their preferences. Table 2 presents the necessary data sources for BSS research through bicycle-sharing firms that provide Global Positioning System (GPS) information about locations and user process data including journey duration and trip lengths. Additional assessment procedures need establishment to determine trips conducted with or without public transportation service. Selection of bicycle-sharing rides by defining zones around public transit terminals remains the dominant research approach for dockless bicycle-sharing programs. Under this buffer zone selection procedure all micro-mobility sharing rides which commence or terminate receive classification as incoming or outgoing movements (Forum, 2021). Research buffer zones extend from 50 meters through 250 meters based on various methods according to [33]. The standard procedure involves removing non-sequence travel events in the data collection process. Research indicates that utilizing ID-based card data represents the best method for this procedure due to its ability to identify bicycle-sharing journeys alongside subway usage from individual users (Ackerman, 2020).

The research studies distribution by different nations and organizations becomes visible through Figure 4. Research articles from China and the United States make up around 66.82% of the total publications at 248 and 181 articles each. BSS research activity gives prominence to East Asia and combines strength with North America and Western Europe and the Middle Eastern region (UNESCO, 2021). BSS system development has reached a high level within the research sample areas as shown by details from Leon, London and BIXI Montreal and City Bike New York and You Bike Taiwan, China. Research productivity in South America and Eastern Europe stands substantially lower than other regions because they have published only 14 academic papers. Sustainable transportation systems in the subcontinent serve as a way to reach the BSS concept.

Figure 4: Regional Cartography of BSS Literature (MNR, China)



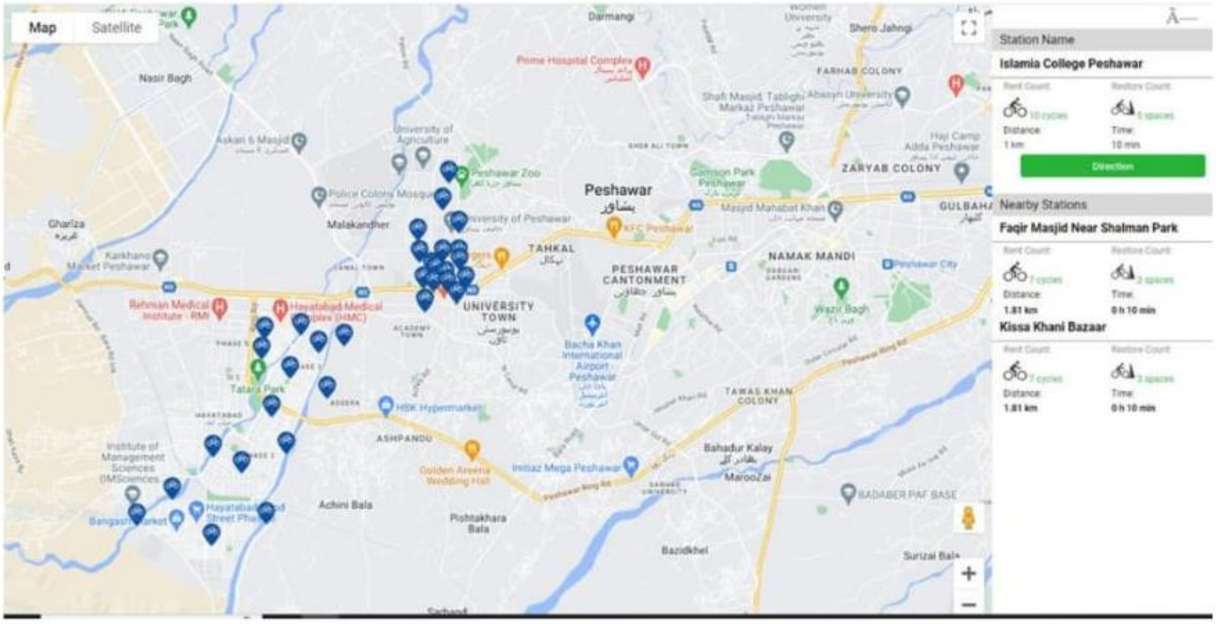
The present understanding of BSS in Pakistan

The expanding urban infrastructure in Pakistan now uses bicycle-sharing systems as an alternative sustainable transportation solution. Multiple bicycle-sharing projects have already been carried out and the Pakistani government actively supports additional growth in this field. Pakistan needs eco-friendly transportation which makes bicycle sharing systems crucial for building a sustainable transportation system in the country (Sánchez-Garrido et al., 2023).

In 2021 Peshawar introduced its bike-sharing program for Zone-1 serving the University of Peshawar and Zone-2 focusing on Hayatabad. More cities including Islamabad and Lahore have duplicated this initiative after Peshawar led the way with the bike-sharing programs. This section of the document provides a brief overview of the Peshawar Bicycle-sharing program (Hussnain et al., 2020).

The seventeen stations in Zone-1 specifically serve the educational institutions of University of Peshawar and Agriculture University. Islamia College Station serves the core corridor of the BRT Peshawar network. Figure 5 shows that Bike Sharing System has been established throughout Zone 1. Table 3 below illustrates the docking capacity for each station inside Zone-1.

Figure 5: Operational map of Zone 1 (Google Earth)



The 15 stations included under Zone -2 make up the total station count. Hayatabad along with its operations positions itself as a business area. Hospital Chowk operates as a connection between the central BRT lines in Peshawar. According to Figure 6 the Bicycle Sharing System operates through the schematic depicted for Zone 2. Table 5 shows the capability of Zone-2 stations for bicycle use.

Table 3: Capacity of BSS Station in 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 6: Zone-2 operational diagram (Google Earth)

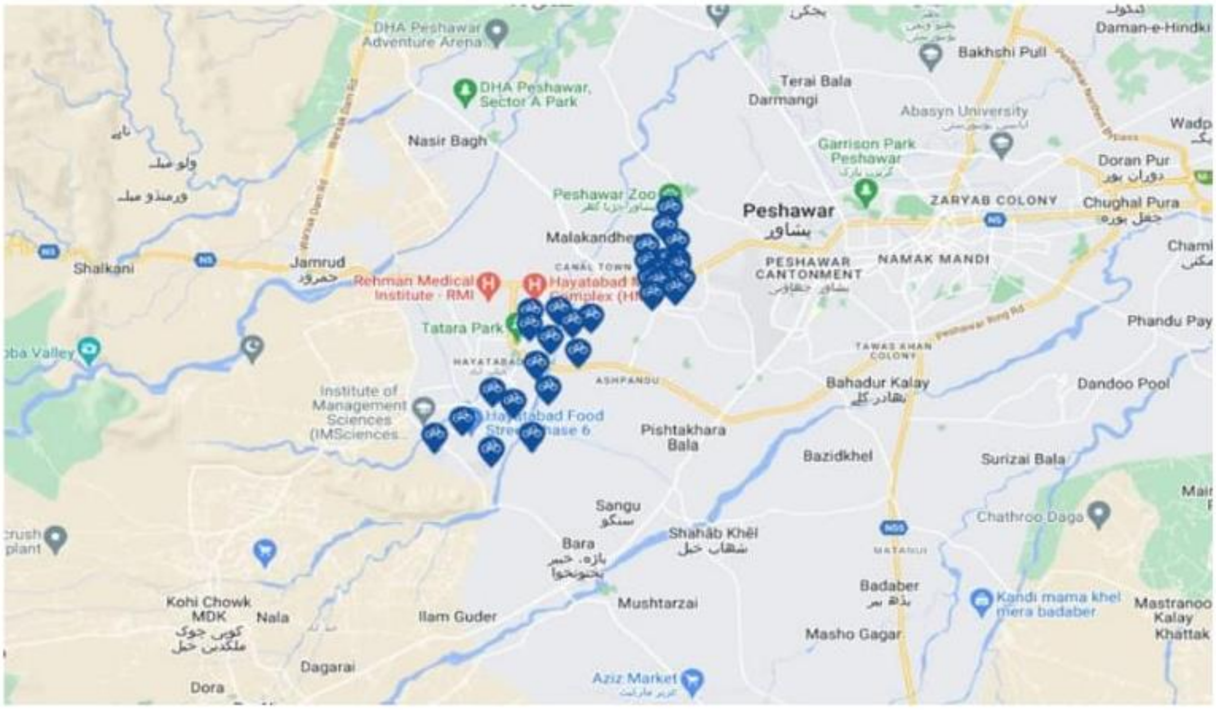


Table 4: Key Features of the Peshawar Bicycle Sharing System

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

Table 5: Capacity of BSS Station in 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**

Determinants affecting the integration of bicycles with transport stations

Characteristics of the travel and the quality of public transportation

The successful launch of the bike transit involves numerous things; in which the access and egress components of the trip are important and extensively deliberated upon. The amount of time and distance involved in riding from the bike transit stations to and from one increases the likelihood of individuals not using the service ("Active Transportation, Spring/Summer 2012, Issue 26," 2019). A study carried out In the Netherlands showed that people living within a 500-meter radius of any train station are 20% more likely to take a train instead of residents of a 500-1000 meters distance and 50% are more likely from residents more distantly located. Regardless of whether the given access mode or route is utilized to exit. Overall, bike transit is a preferred option for individuals within a range of access distances within a range of 1 to 5 km, the length of distance that people are prepared to cycle, we investigated (Campbell et al., 2016). The magnitude of cycling over the whole travel distance significantly affects the willingness to cycle (Wadud et al., 2016). Krygsman et al. (2004) investigated in their study that the cycling distance increases as the total travel distance approaches about 60 minutes, equal to at least 1/2 to 3/4 of the 90 whole trip mix. Shelat et al. (2018) found that the mean total distance of bike-transit trips in the Netherlands is 41 kilometres, that's also say that it's more of a slow journey that more suited for cycling. However cycling to transit may be less appealing compared to walking or using substitute transport methods where the access or whole distance falls beneath a certain threshold (Baobeid et al., 2021).

Land utilization and the characteristics of the constructed environment

The city environment determines how bicycle systems will operate with public transportation. Lin et al.'s (2018) research investigates the relationship between physical buildings and bicycling patterns that connect to public transport stations across Beijing Taipei Tokyo. The analysis indicates that research results obtained from one urban area cannot be generalized to other locations. The combination of multiple land uses creates a positive effect on integrated systems. The research conducted in Canada shows that population density acts positively on bike-transit usage. The data shows that employment density produces negative outcomes for bike-transit integration. Research by Hu et al. (2022) established that population density plays a key role regarding this issue. The establishment of bike-transit integration close to central city areas produces detrimental results. Still, the impact changes to positive as one travels farther away from these centers. This implies the highest advantages occur when population density reaches an optimal level for bike-transit. The highest metrics of ridership success are reached when integration standards are optimized (Lim et al., 2020). Furthermore, apart different aspects within the constructed environments because of land use practice affect the integration effectiveness of cycling and transit systems. The effective combination between cycling services and public transport exists in this context. An example of these conditions exists as the incline rate. Researchers determined that the incline of bicycle paths produces negative effects while people use transport systems.

The standard of interchange quality and the accessibility of amenities

Better facilities at interchanges and station areas reduce many of the problems commuters experience during transfer operations. Cyclists frequently choose to board their bicycles with public transport but the practice creates space problems which leads to conflicts with other passengers. Bicycles obtain entry to public transit in most European alongside North American countries but not during peak traffic rush hour periods where transportation gets overloaded with passengers. Racks attached to the front of buses serve as a solution for North American public transportation areas. These racks face full occupancy limitations when passenger loads become high (Miller et al., 2015). An alternative method for bicycle transportation exists when onboard carrying becomes impossible. Board the system after securing the bicycle through its bicycle entry function. Facilities that handle bicycles play a critical role in establishing transportation links between cycling networks since they prove more affordable than allowing bikes on transit vehicles. Train station bike parking facilities enhance bike-transit integration while bus-station bike lockers receive limited use which demonstrates that bike parking functions best in high-speed transport and Bus Rapid Transit systems (Belaïd & Arora, 2023).

Access to Bicycle Sharing Station

When isolation exists between living quarters shared bicycles continue serving as an essential mobility solution. The network serves users who walk for 10 minutes up to users who walk for 15 minutes. The proportion of bike activities reached 30% when walking distances were between 10 to 15 minutes. The combination of bicycle trips stands as a competitive method of transportation than bus trips, particularly during peak hours, as a feeder mode (Sochor et al., 2018).

According to Kapuku et al. (2021) the combination of bike-sharing services with transit systems results in better travel time benefits than operating these systems independently. The combined use of bike-sharing and transit services in Seoul South Korea provided better time advantages than traditional bus transportation or shared bikes separately. This research demonstrated a substantial time improvement of thirty-four percent. The total savings amounted to 33% across the integrated bike-sharing and transit model as well as independent shared bike usage respectively. Users benefit from bus service through the ability to save time because they do not need to wait in lines. The combination of feeder modes that include buses makes shared bikes more competitive (Ma et al., 2018).

The accessibility and degree of rivalry among options

To make bicycle transit effective the market competitiveness of alternative transport methods needs bicycle availability. A failure to consider automotive competition leads to minimization of time value perception among potential users hence overestimating bicycle-transit system capabilities but mostly impacts non-auto users. Individuals view driving as the fastest option compared to cycling which increases their interest in using bicycle transit. Public transit stations which are easily accessible drive people toward driving choice instead of bike use (Boysen et al., 2020).

Automobile owners need stronger time efficiency incentives as well as other benefits to motivate them to choose bike transport. The accessibility to park at rail terminals combined with the chance to procure transportation from a family member or friend has proven influential in preventing people from choosing bicycle transit. The adoption of bicycle transportation will experience a negative effect due to these factors. Cars make up one part of many direct competitors found in bicycle transportation industries. Cycling promotion might cause riders to choose bicycles for all their travel especially when covering short distances thus potentially reducing the adoption of bike-transit systems (Nikitas et al., 2021). Research shows that in Austin USA over half of shared bike users would have selected public transportation but they used shared bikes instead. Bike-share trips in Chengdu, China led to the cancellation of bus routes by 28% of users and subway routes by 8% of users.

Advantages of integrating bicycle sharing with transport stops

Advantages of Transportation

Urban transportation networks become more sustainable and efficient due to the combined use of bicycle sharing at public transit stations.

Bicycle sharing systems linked with public transportation stations offer effortless transit opportunities between bike travel and mass transit services. Restoring access to bicycle-sharing programs at transit stations enables people to choose bikes for short trips thus creating two-fold reductions in traffic congestion and pollution levels. The approach cuts down overall vehicle count to decrease road congestion alongside its environmental consequences ("Global Economic Prospects, June 2020," 2020). Bicycle access convenience at public transit stations leads commuters to choose sustainable transportation which decreases both traffic jams and air contaminants.

Advantages of Health

The relationship between public health and built environments works as either a support structure or a barrier system primarily through its involvement with mobility systems. The options for transportation which exist determine how healthy both individuals and society become. People together with society benefit from environments that encourage walking and cycling along with different active transport options. People acquire better chances for achieving daily recommended physical activities when walking and cycling act as suitable alternatives to driving based on CDC recommendations (2009). Regular physical activity for thirty minutes a day provides health benefits which equals the heart disease risk reduction similar to that achieved by keeping away from smoking ("2023 Alzheimer's Disease Facts and Figures," 2023). During daily short periods of physical exercise this level of movement helps decrease diabetes risks while lowering blood pressure and enhancing functional ability.

Ecological Advantages

The transportation sector demands from metropolitan cities causes' massive energy usage alongside substantial greenhouse gas (GHG) emission releases. The rising need for transportation makes the transportation sector play an increasingly prominent role in total energy utilization and greenhouse gas release. Bike sharing technologies can decrease energy consumption levels together with greenhouse gas production significantly. The environmental advantages of bike sharing become most effective by studying what happens when people transfer from other forms of transport to bike sharing systems and assessing the environmental effects of these transitions (Zhang et al., 2019b). Assessments of bike-sharing system environmental benefits have been performed through the use of big data analytics in recent research. Authors collected multiple data sources to identify the connection between transportation services through geospatial modeling. An evaluation took place regarding the ecological impact of bike sharing programs. The analysis encompassed two situations to establish whether bike sharing benefits remain accurate when public transport usage is excluded from the evaluation (Jiang & Luo, 2022). Research revealed a substitute relationship between bike sharing and bus services where 39% of trips involved bus passengers and subway users made up 13.5% of bike trips. Bike sharing exhibits direct correlation within the city center especially during daylight hours. Bike sharing services both replace bus journeys and cooperate with subway system use in areas containing numerous public transport stations. Bike sharing trips form very limited connections with metro routes. Researchers examined the environmental effects of bike sharing mode changes in two different circumstances based on bike sharing usage patterns with public transit services. The analysis of bike sharing systems included automobile and walking modes as the activities it replaced. According to the research findings bike-sharing journeys substituted other types of transport in 66.1% of cases. Studying the replacement behavior of bike sharing with public transportation remains essential because it affects the perceived environmental benefits of bike sharing services. Bike-sharing operates actively as a vital tool that decreases both energy usage and emissions of greenhouse gases despite other alternative systems. Bike sharing must be promoted independently for use as a separate mode of transportation and jointly with public transportation. This research produces implications which provide valuable information to urban transportation planners and public transit policy specialists for their future transportation planning tasks. The data from this study holds significant importance despite how bike sharing journeys influence the replacement of private vehicles and public transport services. The two situations generate notable reductions in pollution and power consumption. The evidence establishes a reason for policymakers to encourage the implementation of bike-sharing programs (Styne et al., 2017).

Possible obstacles to the integration of bicycles with transportation stations

Obstacles to Regional and Local Level Planning

According to Shishir et al. (2023) system-wide planning needs to evaluate how land uses around each station influence the total ridership numbers of the transit system. Municipal zoning as a TOD instrument demands regional and long-term planning processes for successful execution according to these examiners. Transit-Oriented Developments (TODs) appear predominantly in selected areas of mostly automobile-dependent metropolitan regions because there is no proper planning. Real estate developers place particular emphasis on development. Proper preparation acts as an essential tool for managing risks that occur during development. Higher levels of planning integration stand as two crucial priorities according to them. Mathur and Gatdula (2023) identifies transportation planning issues due to insufficient coordination between transit agencies and municipal/regional land use authorities and transportation planning organizations which prevent transit-oriented developments from being executed.

Urban Design Hierarchical Obstacle

Widespread accessibility requires bike-sharing stations to be located strategically around all entrances and exits and near all bus stops at transit stations. The establishment of numerous bike-sharing stations throughout a network is crucial to enhance accessibility because it enables riders to use cycling as a secondary transport mode linking with public transit systems ("OECD Employment Outlook 2019," 2019).

Bike-sharing programs gain more cyclists when parking facilities are safe and easily accessible because these facilities decrease the risks of theft and vandalism thus creating an attractive setting. Overall bike safety increases through well-designed lit parking areas which additionally create an environment of peacefulness combined with enhanced security for riders.

Addressing both rider protection and addressing structural problems represents the core solution to resolving this issue. Bicycle safety demands dedicated traffic-free cycling paths to connect train stations with nearby communities in order to safeguard riders from roadway threats. The successful promotion of cycling adoption requires activities aimed at public education about cycling benefits and proper practices which leads individuals to choose multiple transportation modes (Dwivedi et al., 2020).

Economic and Financial Barriers

TODs encounter substantial obstacles against their growth because of economic and budgetary challenges. The barriers to TODs appear through three main factors: (1) weak economic base and real estate pressures, (2) limited financing methods and strict loan underwriting practices that prevent mixed development and affordable housing solutions and (3) the need for considerable parking infrastructure. Development expenses for Transit-Oriented Developments in United States metropolitan and established urban zones reach exceptionally high levels along with their associated risks (Mattioli et al., 2020). Districts with basic infrastructure deficiencies together with environmental challenges tend to increase project development expenses and risks.

Major changes or project cancellations have been proved to occur frequently with TOD developments. The scarcity of available land for development together with negotiations to combine different properties raises development expenses along with potential project risks. Investment in Transit-Oriented Developments (TODs) starts at a high level and causes longer development periods. Development challenges faced by developers worsen due to required public financial support for both Transit-Oriented Development planning and implementation. The provision of financial support from conventional lenders for Transit-Oriented Developments (TODs) incorporating mixed land uses faces resistance owing to market uncertainty regarding these projects in the United States (Chava & Newman, 2016). TODs with mixed-use elements stand as a unique real estate product because they are emerging products in many areas.

Conclusion

The research results emphasize that specific socio demographic characteristics become crucial factors during bicycle-sharing system (BSS) implementation in particular regions. Identifying socio demographic population traits enables the creation of BSS access frameworks that consider factors such as income status and accessibility needs. Bicycle station optimization starts when analysts process this data to improve station layout designs and placements because it helps various groups reach sites more easily. Such research helps authorities develop policies that establish price regulations and reward systems to enhance BSS usage within specific population segments. Several barriers prevented the use of the BSS in Peshawar according to the study.

By resolving these obstacles first-mile/last-mile services will connect seamlessly which leads to increased BRT system usage particularly for inside-neighborhood short trips. The improved public transport accessibility enables more people who cannot obtain automobile access to use BRT or live separate from stations to reach their destinations.

The use of gravity model indices applied to universities and recreational facilities enables better measurements of accessibility between the BRT corridor and academic centers and leisure spots. Improved connectivity will boost the total operational effectiveness and service quality of the BRT system which benefits students in academic institutions alongside those enjoying leisure activities.

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