An Inquiry into Shared Dockless Bikes as a New Urban Mobility Mode: An Exploratory Case Study of Shanghai and Xi'an, China

Thesis submitted for the degree of Master of Philosophy

By

XI PENG

Department of Geography, University College London University College London, 2024

Declaration

I, Xi Peng confirm that the work presented in my thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Abstract

Dockless bikes are perceived to be one of the key travel modes that can help resolve the daunting problem of urban traffic congestion as well as environmental issues such as carbon emission. The main objective of the study is to analyse riding patterns, especially unruly riding patterns, of dockless bike riders and determine, besides internal reasons such as personal characters, if city "urban mobility system" (UMS) and infrastructure impact the unruly riding and parking violations, using Shanghai and Xi'an as case studies. This research utilizes an exploratory approach because most of the extant literature was based on quantitative user data only and few of the existing studies studied the relationship between dockless bikes and infrastructure as well as UMS in the city. Thus, apart from the big data technique like POI and K-means, this study also employs observational methods to review the influence of different infrastructure conditions on riding and parking misbehaviors, again taking Shanghai and Xi'an as examples. The study concludes that the level of perfection of UMS and infrastructure considerably alleviate dangerous riding and illegal parking behaviors, especially during rush hours, so as the launch of proper rules and regulations.

Keywords: Dockless bikes, urban transportation and infrastructure, riding and parking misbehaviors, big data

Impact statement

The main research theme of this study is to utilize dockless bike riders travel data along with observational materials to show how dockless bikes work as a part of the urban transport system, explore what problems they have led to as well as the reasons behind and put up with corresponding solutions and suggestions. From the collected dataset, we know that unruly riding on dockless bicycles happens less in locations with relatively complete infrastructure, and private bicyclers have more standardized riding behavior than dockless bicyclers. In this experiment, the total data collection time at subway entrances in Shanghai and Xi'an often exceeded 100 hours. The total number of dockless bicycles in the total samples collected was 8,440, of which the number of private bicycles was 1,926. The main focus of this study is the dataset with high POI (Points Of Interest that geographically connect users and convert them into next actions on the map) density. Through the big data method, using the dataset, firstly, it was found that the demand for dockless bicycles in locations with more POI categories is correspondingly higher. At the same time, dockless bicycles are more likely to gather in locations with more POI categories rather than with more numbers of POIs, which is also the main research result of POI method in this study and also means that locations with more types of POIs are also the main observation spots of this study. Secondly, under the observation method, two kinds of datasets deserve the focus: the places where unruly riding of dockless bicycles occur with high frequency and, as reference, the places with low frequency. There, the relationship between the ratio of the above mentioned riding violations to the total number of bicycles and infrastructure was confirmed to be negative, and so it can be included that there can be positive influences on the construction or improvement of specific infrastructures. Potential beneficiaries of this research include:

- 1. For transportation, improving road conditions can increase the supply and usage of dockless bicycles to the public and, meanwhile, effectively reduce the occurrence of unruly riding behaviors and improve road safety. At the same time, one-time improvement of infrastructure can reduce social waste of resources and reduce the impact on public life during urban construction.
- 2. 2. For social welfare, increasing the supply and usage of dockless bicycles reduces carbon emissions and protect the environment. Sharing economy circulates idle resources and reduces waste in production. In addition, infrastructure plays an important role in

economic growth and long-term development, and infrastructure in locations with a wide variety of POIs helps reduce urban congestion and promote urban transportation development; furtherit can connect different regions and narrow regional gaps.

- 3. For policymakers and officers, perfecting transportation-related laws and regulations reduces unruly riding behaviors and improving infrastructure will help cities development and prosper.
- 4. Finally, for research on urban construction, this study supplements the existing works by exploring the relationship between dockless bicycles and infrastructure with the big data method beside the observation method. More importantly, this study can also increase scholars' attention to big data research methods and promote the development of related disciplines.

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List of Abbreviations

API Application Programming Interface

APP Application

BPNN Back Propagation Neural Network

CBS Community Bicycle Schemes

CNN Convolution Neural Network

DB Dockless Bike

DID Difference-in-Difference

EDCCJC Environmental Development Center and the Central Joint Certification Center

FBS Free-floating Bike-sharing System

GHG GreenHouse Gases

GPS Global Positioning System

GTWR Geographical and Temporal Weighted Regression

GWR Geographically Weighted Regression

LBS Location Service

LSTM Long Short Term Memory

OD Origin Destination

OLS Ordinary Least Squares

POI Points of Interest

QR Code Quick-Response Code

UMS Urban Mobility Systems

SBS Station-based Bike-sharing System

SGWR Semiparametric Geographically Weighted Regression

Acknowledgments

Here, I may be grateful for a lot of time in the past four years.

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Thanks to UCL, I have become a better person, stronger, and more independent.

Chapter One: Introduction

1.1 Background

Dockless bikes (DB), also regarded as shared bikes, are bicycles that can be rented for a short duration and left at any public sphere once the client has completed his or her ride and are often paid with the application on the rider's smartphone developed by the operating organization (Shabaan, 2020). As a typical example of sharing economy, dockless bikes circulates idle resources (bikes) and transfers the right to use the resources to others for a fee so that the transferor receives a return whereas the sharer creates value by utilizing other people's idle resources (Jones et al., 2016). DBs are currently considered as one of the primary means of transportation, especially in short-distance travel, and are believed to ease the urban traffic congestion under proper management (Du et al., 2013). Thus, studying DBs plays a significant role in the development of modern transportation, society and economy.

Given the increasing prevalence of dockless bikes in urban areas and the associated challenges, this study aims to analyze the usage patterns and irregular behaviors of dockless bikes, investigate the impact of urban infrastructure on these behaviors, and propose strategies to optimize urban transportation systems and improve the usage environment of dockless bikes, thereby enhancing the efficiency, safety, and sustainability of urban transportation.

Firstly, dockless bikes are the main research objects in the sharing economy because they reduce the idleness of resources, make full utilization of the available resources and reduce unnecessary social production waste. Dockless bicycles can break the limitations of personal use of bicycles, and a bicycle can be used by users with different needs in different periods of time within a day, so that the value of bicycles has been fully demonstrated. At the same time, because there is no need for a fixed parking place, it also effectively saves the space resources of the city, and effectively saves resources from both the time dimension and the space dimension.

Secondly, shared bikes have become a key research area of focus in the environmental protection sector because, as non-motorized vehicles, they do not produce exhaust emissions. Scholars believe that, unlike motor vehicles such as cars, the use of DBs as an energy-saving

and eco-friendly way of travel can help energy consumption and so reduce air pollution in urban centers and society at large (Bieliński et al., 2019). For example, mountain bikes and motorcycles were taken as the research objects of the "Report on Pollution and Carbon Reduction in the Full Life Cycle of Shared Cycling" jointly issued by the "Environmental Development Center and the Central Joint Certification Center" (EDCCJC). In addition, from the perspective of the carbon footprint of various links such as operation scheduling, storage charging, server energy consumption, recycling, and regeneration, DBs are a sustainable and low-carbon means of transportation. Moreover, each dockless bike in its entire life can reduce the emission of particulate matter in the carbon neutrality process by over 0.5 tons with an average of 134 kilograms (Bieliński et al. 2019). Hence, it is evident that DBs play a vital role in promoting the green transformation of the global transportation field and ensuring the realization of the dual carbon goals in this sector.

Thirdly, it is important to study dockless bikes and their impact on the society, especially the urban centres. The shared bicycles also have crucial implications for the disciplines of urban governance. Although DBs have brought positive influences to the entire society and the natural environment, such as solving the "last mile" problem for citizens' travel, there are still many problems in the development process, including a series of urban social governance issues (Jones et al., 2016). The shared bicycles are quasi-public goods offered by private companies for a fee. It is worth observing that DBs are excludable and non-competitive to a certain extent, which hinders the internalization of market spillover benefits and exhibits strong externalities unique to quasi-public products (Chen et al., 2020; Shaaban, 2020; Wu et al., 2019; Du et al., 2013; Jones et al., 2016). The production of DBs can quickly revitalize the traditional bicycle manufacturing industry, alleviate traffic congestion, and comprehensively form four positive externalities: production efficiency, public transportation benefits, social benefits, and environmental benefits; the proliferation of civilized phenomena has led to the emergence of negative externalities in road traffic and urban governance (Wu et al., 2019). The most noteworthy of all externalities is the growing issue of dangerous riding of unmanned DBs and the random parking of unmanned vehicles as the shared bike system is not mandated to establish fixed lock piles and service terminals.

The flexibility of DBs lies in when using the DB, the rider is required to open the DB application (integrating GPS, Internet, mobile payment, and other advanced technologies) in the mobile phone to scan the QR code on the vehicle body to easily unlock it and make a

payment for the trip and payment functions (Fishman & Cherry, 2016). However, the advantage of "no pile" of shared bikes also causes "disorder" problems including random parking and potential safety issues. The flexibility of DBs has made it more challenging to find enough parking spaces around some particular crowded places such as subway stations (Wu et al., 2019; Wu et al., 2012; Fishman & Cherry, 2016). Randomly parked bikes have caused inconvenience to citizens that DBs have silted up and even occupied sidewalks. So far, scholars believe that the problem of shared bike parking chaos in the urban is mainly due to the seriously imbalanced supply of shared bikes (Chen et al. 2020; Fischer, 2020). Therefore, many researchers have forecast the demand for shared bikes based on the factors that affect the usage of dockless bikes to reallocate some of DBs in advance and so to mitigate the discrepancy between supply and demand of the number of DBs in different areas (Icebike, 2022; Yang et al., 2019; Celebi & Isik, 2018). Chen & Weber (2022) considered that riding on motor vehicle lanes is the prevalent form of unsafe riding behavior, and special bicycle lanes should be set up for shared bikes. Besides, 56% of bicycle riders, including electric and traditional bicycles, passed the red light signal (Wu et al., 2012; Fishman & Cherry, 2016). Furthermore, as many as 91% of bicycle riders do not wear helmets, 3.4% even ride in the opposite direction of traffic and 0.4% were found to use mobile phones in the ride (Du et al., 2013; Jones et al., 2016). The most closely related to bicycle accidents are single bicycle accidents related to infrastructure, roads, and railways. Thus, these challenges must be taken actions to ensure the desired benefits of DBs in modern communities, especially in the urban travel field. Fischer (2022) suggested that early warning of cycling dangers could also reduce serious accidents. In addition, theurban construction field can provide more comprehensive infrastructure to alleviate the issue of risky riding and illegal parking. However, the potential effects of the current "urban mobility systems" (UMS) in lowering adverse effects of DBs require further proofs and tests. The aim of this study is to explore the impact of urban infrastructure on the use behaviour of dockless bicycles by analysing the use patterns and irregularities of dockless bicycles and to propose strategies to optimise the urban transport system and improve the environment for the use of dockless bicycles in order to improve the efficiency, safety and sustainability of urban transport.

1.2 Objective and Research Question

Recently, the sharing economy has been booming, among which bike sharing is the most eye-catching sector worldwide, which has a massive scale and continues to develop rapidly. However, it is also the fastest to encounter problems because shared bikes have a broad

demand base, but at the same time, they lack the necessary growth conditions and fully-fledged regulations. A series of misbehaviors of dockless bike riders including unruly riding and randomly parking aggravate the public's concern about dockless bikes and even the sharing economy. The research aims to analyze the features of these misbehaviors through both online track records of riders from DB apps and observational self-taken videos at critical spots of DBs to understand the reasons, apart from personal factors, behind the phenomena and put up with constructive suggestions to reduce these riding misbehaviors.

With the rapid development of the economy, cities around the world are prosperously growing and expanding. From an international perspective, the 2010 to 2014 period saw a rise in the number of DBs globally, but the development of DBs has not been considered in the old-time urban construction and planning. The challenge of fragile UMS in the old city has become increasingly prominent, especially when the systems in the old city become backward, outdated and distributed unreasonably. For example, most of the roads are used beyond the service life, and the streets and lanes are so narrow to cause traffic jams. At the same time, a large number of dockless bikes at places with dense traffic especially like subway stations in the old city do not have sufficient parking spots or supporting infrastructure and so have to be parked at will, leading to a series of traffic and even safety issues. Therefore, besides personal factors, this study also seeks to determine whether random parking and unruly riding, main misbehaviors of dockless bikes, can be caused by the lack of adequate and appropriate UMS and infrastructure for shared bikes.

In addition, misbehaviors including cyclists running red lights, going the wrong way, using mobile phones, not wearing helmets have been observed, but it still lacks specific literature to describe whether the lack of infrastructure is the driving factor for dangerous riding and risky parking. Although, Shaaban (2020) and scholars such as Imani & Eluru (2016) all mentioned the impact of local stops and infrastructure on DB parking but did not explain whether the expansion and improvement of these systems will reduce the dangerous riding and parking behavior of shared bikes.

Recently, the sharing economy has been booming, showing strong prospects for development, and gradually expanding globally. Among them, shared bicycles are the most eye-catching field in the world, with its low cost and convenient use scenarios, its scale is gradually developing. However, it is also the fastest to encounter problems in the

sharing economy. Although bike-sharing has a broad demand base, at the same time, they lack the necessary conditions for growth and exhibit a series of problems. On the user side, a series of misbehaviors of dockless bike riders including unruly riding and randomly parking, have brought harm to urban management and public transportation order, aggravating the public's concern about dockless bikes and even the sharing economy.

The causes of improper behavior of dockless shared bicycle users generally include external and internal factors. Internal factors such as the rider's own quality or lack of riding awareness, although important, are difficult to quantify and analyze. However, the impact of external factors (such as the lack of urban travel system and infrastructure) on riders' behavior is easier to study through data analysis. This study mainly starts with external research to explore the degree of influencing factors of different non-standard behaviors, and then studies the influence of factors with the greatest degree of influence of non-standard behaviors from the perspective of space.

Thus, this study adopts the combination of qualitative analysis and quantitative analysis. In the qualitative aspect, through literature review to explore the reasons behind the non-standard behavior and the degree of influencing factors. In terms of quantitative analysis, this study analyzes the characteristics of these bad behaviors and understood the reasons behind these phenomena through the online tracking records of cyclists on DB app and the observation of selfie videos at key points in DB. Therefore, how to reduce the influence of the biggest factor of irregular behavior in space is proposed. At the same time, it is hoped to put forward the optimal path to mitigate the irregular behavior from the perspective of spatial planning.

This study aims to analyze the usage patterns and irregular behaviors of dockless bikes, investigate the impact of urban infrastructure on these behaviors, and propose strategies to optimize urban transportation systems and improve the usage environment of dockless bikes, thereby enhancing the efficiency, safety, and sustainability of urban transportation. To achieve this objective, the study focuses on the following four main research questions:

1. What are the spatiotemporal distribution characteristics of dockless bikes and private bicycles in different urban environments, particularly the differences in usage patterns between weekdays and weekends?

- 2. What are the irregular behaviors exhibited by dockless bike users and private bicycle users (such as unsafe riding and random parking), and what is their impact on urban transportation and public spaces?
- 3. How does urban infrastructure (such as bike lanes and parking facilities) influence the usage behaviors of dockless bikes and private bicycles?
- 4. How can urban transportation systems be optimized and the usage environment of dockless bikes and private bicycles be improved to reduce irregular behaviors and enhance the efficiency and safety of their usage?

1.3 Method and Data

To explore the above problems, the main research methods in this dissertation are literature reveiw and big data and observation analysis.

First of all, literature review through the study of dockless shared bicycles, to understand what is the non-standard behavior, and the reasons behind the formation. Then, find out the degree of influence factors of different non-standard behaviors. Through qualitative analysis, the causes behind irregular behavior are revealed, and theoretical support and reference are provided for quantitative analysis.

The rationale for quantitative analysis is that the method of big data can effectively predict the hot spots of dockless bikes. For example, at the functional composite location of POI, that is, the multifunctional composite area of the city has more demand for DBs and there will be less demand in areas with fewer types of POIs. Hence, to effectively verify the above basis, the first thing to do when determining the relationship between facilities and shared bikes is to predict the demand for dockless bikes in different regions. Secondly, to verify the impact of the cities UMS in different locations on the prevalence of dangerous riding without DBs, the main method adopted in this study is the observation method. This is because dangerous riding patterns can be subdivided into different behavior patterns, such as not wearing a helmet,

running a red light, and going against the road. The observation research method can be useful in effectively counting the occurrence rate of each dangerous riding and disorderly parking behavior. Additionally, this technique will be used to determine the occurrence rate of risk behaviors of private bikes and DBs and, further, to help verify whether the risk-riding behavior is caused by an individual's behavior.

While the findings from previous studies are essential to the current research, they essentially revealed the extant issues and offer three solutions for the problem of random parking of DBs and risk riding. However, the main basis of this research includes the key factors concerning road infrastructure for DBs and demand for these services. The gap in the past literature involves failure to indicate if the current UMS systems could sufficiently solve the dangerous riding, disorderly parking, and ways of improving the development of the required systems.

Then, regarding the research methods, this study summarizes the previous research methods of dockless bikes and identifies infrastructure, the most important factor affecting DB's irregular riding behavior, and according to POI, identify the most intensive area of DB travel and the general situation of the surrounding infrastructure. Still, in this study, after using the big data method to obtain the dense locations of DBs, some popular locations will be selected as observation points for shared bikes, and the observation method will be used to count the behavior of DB riders and analyze the how infrastructure can improve cycling irregularities.

The two main tasks of this study are to analyze the spatial and temporal patterns of dock-less shared bike usage by figuring out demand hotspots for shared bikes and, in detail, observing different riding behaviors of DBs riders from others, and then to make suggestions for rules and regulation perfection and infrastructure improvement accordingly. The first method used to predict the demand hot spots for dockless bicycles is POI. POI data plays a significant role in the research of tourism spatial patterns, urban planning practice, regional accessibility research, commercial spatial layout research, and hotspot identification. Each piece of data is a feature of a "point of interest" (POI), specifically referring to the number of various merchants or facilities within a 500-meter radius circle centered on this location and the area with a large number indicates that it belongs to the demand for DBs larger locations.

After obtaining the dense points of dockless bicycles, this study will use the observation method to observe and compare the riding behavior of dockless bicycles in the densely populated areas of the two cities and make statistics to decide whether, how and why dockless

bike riders behave differently from private bike riders, and the relationship between them and infrastructure is further analyzed.

Also, this research will use the observation method to decipher differences in road systems between locations, and then a T-test was used to verify the relationship between dockless bicycle violations and road systems and infrastructure. This method tests whether dockless bike violations are mainly caused by personal sense and behavior of dockless bike riders and whether they are also due to a lack of infrastructure.

To achieve the study objectives and address the research questions, this dissertation employs a combination of literature review, big data analysis, and observational analysis. These methods are chosen to provide a comprehensive understanding of the usage patterns and irregular behaviors of dockless bikes and to assess the impact of urban infrastructure on these behaviors.

- 1. Literature Review: This method will be used to explore the reasons behind irregular behaviors and the degree of influence of various factors. It will provide theoretical support and reference for the quantitative analysis.
- 2. Big Data Analysis: This method will be used to predict the demand hotspots for dockless bikes and analyze their spatiotemporal distribution characteristics in different urban areas. It will help in understanding the role of dockless bikes in urban transportation systems.
- 3. Observational Analysis: This method will be used to observe and record the actual riding and parking behaviors of dockless bike users at critical locations such as subway stations. It will help in identifying the occurrence rate of different irregular behaviors and their relationship with urban infrastructure.

1.4 Organization of the Thesis

The second chapter introduces the existing research status of dockless bicycles in detail, including the problems, demand and measures of dockless bicycles in different countries and dockless bicycles in China. The following results would be concluded: what factors are related to the irregular riding behavior of dockless bicycles, and what are the most critical influencing factors?

Followed by details of methodology in chapter 3. Chapter 3 briefly describes the main research tools used for data collection in this dissertation. Chapter will address the above question by conducting an empirical analysis of dockless bicycle usage patterns and urban mobility system integration in Shanghai. Section 5 will use an observation approach to compare cycling behaviour between Shanghai and Xi'an. Finally, the conclusion and discussion chapter will summarise the whole paper, including conclusion, limitations of the current study and suggestions for further study.

Chapters 4 and 5 mainly introduce the use of big data methods and observation to conduct qualitative and quantitative analysis respectively in Shanghai. Through the analysis of the use time and research locations of Shanghai's dockless bicycles, it is known that the main concentration of dockless bicycles in Shanghai is the subway station and the period is the morning peak and evening peak; however, there is no obvious period for concentrated use on weekends. This also proves that shared bicycles are mainly used for commuting on weekdays, while leisure trips are mainly used on weekends. Second, use the observation method to analyze whether different cycling violations are caused by specific local infrastructure. To obtain effective experimental data, this study used 20 hours of video recording to conduct statistics on popular dockless bicycle locations in Shanghai and Xi'an. After counting different data, compare different popular locations and analyze the underlying reasons that lead to different dangerous ridings. In this study, the violations of dockless bicycles are mainly divided into two columns, including dangerous riding behaviors and random parking; dangerous riding behaviors are further divided into not wearing a helmet, riding at red lights, and going against the road. Illegal parking behavior includes parking in the green belt, affecting pedestrians, and other classifications. The main content of this chapter is to verify the relationship between infrastructure and violations in different geology.

The main content of the experiment in Chapter 6 is similar to Chapter 4 and Chapter 5 which leverage the big data and observation methods to conduct data statistics and empirical analysis of popular places in Xi'an. After collecting the data from Xi'an, the area was used as a control group to compare with popular places in Shanghai, and the reasons leading to cycling risks were obtained.

Through the above steps the research purpose of this study, that is, to compare the impact of infrastructure on dangerous riding of dockless bikes and risk parking, was achieved. Secondly,

it can also be compared whether the dangerous riding and disorderly parking of the dockless bike is a personal behavior or is caused by the lack of infrastructure. This research has the following contributions:

- 1. Contribute to the understanding of dockless bike usage on mobile apps during the last years in large cities in China.
- 2. Contribute to the understanding of misbehaviors of dockless bike riders from other riders and the potential reasons, both internally and externally, for misbehaviors of dockless bike riders.
- 3. Contribute to the feasible solutions to the misbehaviors regarding rules and regulations perfection and infrastructure improvement to both reuique and help dockless bike riders to reduce misbehaviors.
- 4. Contribute to the feasible solutions to reduce the riding risk of cyclists and alleviate road congestion caused by random parking.
- 5. Contribute to the advocates for the development of shared bikes and effectively advocates a green travel lifestyle.

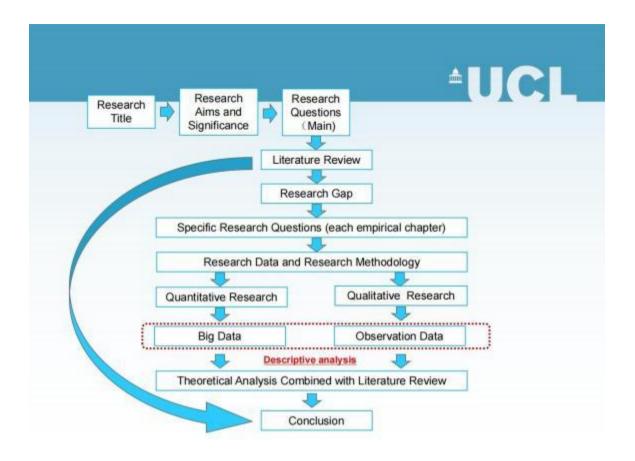


Figure 1.1 Structure of the research

Chapter Two: Literature Review

2.1 Introduction

2.1.1 Introduction to Dockless Bikes

With the rapid development of the economy, the sharing economy has also experienced remarkable growth and over 2,000 cities globally have launched sharing services, among which, the rise of DBs is more prevalent with over fifty years of history. As an emerging mode of travel, shared transport relies heavily on advancements in mobile technology which successfully make young people increasingly accept it as a new form of traveling mode. Compared with public bicycles with piles, the dockless shared bicycles under the development of "Internet +" cancel the traditional fixed parking pile, and users do not need to borrow or return the car to the fixed parking pile but can borrow and return the car in the designated area, which makes it more convenient to borrow and return the car. Many cities globally have floating shared bikes. Chen et al. (2020) compared the conventional "station-based bike-sharing system" (SBS) with a dock and the "free-floating bike-sharing system" (FBS) without a dock and discovered major differences in the utilization of these two bike systems. Through the questionnaire, it can be concluded that SBS still exists and has customers, as they solved the problem of rental difficulty and alleviated customers' concerns about lack of places to change cars. While DBs are developing rapidly worldwide, some challenges in the development process continue to slow down their expansion. Fischer (2020) mentioned that several shared bicycle suppliers are competing, which leads to the explosion of the number of bicycles. So far, the number of dockless bikes in Beijing has exceeded 1.9 million. According to the statistical analysis of the "Major Cities Traffic Analysis Report", the rapid development of Internet shared bicycles has played an important role in alleviating urban congestion. Compared with the same period in 2016, the congestion delay index of Beijing, Guangzhou, Shanghai, Chengdu and other cities decreased by 4.8%, 2.7%, 1.8% and 2.5% respectively. The emergence of shared bicycles has played a significant role in easing traffic pressure, energy saving and emission reduction. DBs have become a critical research object for many scholars, especially since their increased use promises numerous positive effects on cities. Experts have been trying to understand the main factors affecting the use of dockless bicycles (Chen et al., 2020). Bieliński et al. (2019) argue that DBs are an environmentally friendly mode of transportation. Due to their ability to stop and go at any moment, deploying a reasonable number of DBs has always been considered the most effective way to solve traffic congestion. Researchers have

found that shared bike travel is positively correlated with the urban population, tourism, number of bicycle stations per capita, congestion, length of bicycle lanes, and higher temperature, and negatively linked to precipitation.

The number and locations of DBs are likely to be the factors that determine the success of this industry. Although the dockless shared bicycle has shown a blowout development since its emergence, it still faces many problems due to the mismatch between its emergence and the development and integration of the city. Specifically, the lag of urban infrastructure, transportation planning and related policies has failed to provide relevant support for the sudden emergence of shared bicycles, which has led to a series of problems such as parking chaos of shared bicycles. The current literature examines the impact of different road factors on cycling risk. It has also studied the influence of various forces on the demand for DBs. However, it has not considered whether the demand for dockless bikes in different cities will have diverse changes when the relevant factors are kept the same. Most of the existing literature has verified the relationship between multiple factors and cycling risk. These factors include road conditions, traffic, and rider behavior. Through data analysis and analysis, these studies have many mathematical methods to predict the optimal supply and demand of DBs in many regions, providing a scientific basis for the reasonable allocation of shared bicycles. As such, future studies need to consider the differences in the infrastructure of various cities and their capacities. The significance of comparing the existing infrastructure differences of different cities is to avoid that the optimal quantity calculated by the mathematical model exceeds the capacity of the city. The current interventions employed to solve uneven sharing of DBs and illegal riding include forecasting demand, improving infrastructure, and establishing relevant laws and regulations. To determine whether these solutions are feasible, this study chose China as the research location and compared the relationship between infrastructure and bicycle riding risk between first-tier cities like Shanghai and second-tier cities such as Xi'an to allocate the optimal supply and demand quantity and resource allocation under the existing capacity.

DBs regard bicycles that can be rented by the public. In the West, they are usually divided into two types, including the "community bicycle schemes" (CBS) and "smart bicycle schemes" (SBS) (Alta, 2018). In China, shared bicycle enterprises are mainly privately owned and operated for profit, in contrast to the non-profit bikes available in the country. Bike sharing refers to the form of bicycle-sharing services established by enterprises and

governments in cooperation with campuses, bus stops, residential areas, and other locations with high demand (Icebike, 2022). Generally speaking, the community bicycle programs provided by Western governments and the shared bicycles provided by the Chinese government are DBs, implying that they do not belong to the rider and must be parked in certain locales after use. The most fundamental difference between DBs provided by private companies and those offered by the local government is that the former do not need to be parked in a fixed location after use. In 2017, China gave the definition of dockless shared bicycles as follows: Shared bicycles are based on Internet technology to provide residents with public transport connections and transfers and short-distance travel purposes, and the bicycle service system used by many people is a component of the urban slow traffic system. In fact, the dockless shared bicycle is a bicycle with Internet control function rented by the enterprise to the user, and the user pays the rent to the enterprise through the mobile phone to borrow the bike at a nearby station and ride to another station to change the car. From various definitions, dockless shared bicycles are the product of the combination of traditional bicycles and the Internet, so it is not only an innovation of traditional transportation methods, but also an innovation of industrial forms. On the one hand, dockless bike sharing is a commercial service. Through the investment of enterprises to provide users with shared bicycles, enterprises obtain profits and benefits. It can be seen from this commercial operation model that dockless shared bicycles belong to a new commercial service in the field of transportation. On the other hand, dockless shared bicycles are a chronic mode of transportation for convenient travel, which can promote the optimization of traffic structure. First of all, dockless shared bicycles are suitable for short-distance travel and transfer with public transportation, which can better meet the needs of users for short-distance travel. Secondly, the convenience of shared bicycles is very high, anyone does not need to own a vehicle, but can rent a bicycle to reach the destination by paying a certain fee through the mobile phone. In short distance travel, the travel cost of shared bicycles is much lower than that of taxis, buses, etc., and it will not be affected by traffic congestion, which can improve the overall efficiency of travel. The concept of dockless bicycles in this study mainly refers to bicycles that are rented for a short duration and need to be paid for, and the rider does not have the obligation to park them in specific areas.

2.1.2 The Importance and Research Value of Dockless Bicycles

Alta Planning (2018) believes that DBs Alta Planning (2018) believes that DBs play a vital role in the economic development of society and environmental protection. They provide users with convenience as the rider is never concerned about the issue to find a docking station and encounter insufficient parking spaces at the docking station. Many extant studies emphasize the value of DBs bicycles and indicate that the demand for these services will continue to grow in the future (Fischer, 2020; Chen et al., 2020). For example, in France and China, there has been a substantial increase in DBs usage over the past decade. Scholars further prove that since future DBs are beneficial, they are bound to be popularized in other cities in the future (Spinney, 2020; Fischer (2020); Chen et al., 2020). Although the existing shared bicycles are not available in some cities worldwide, with the development of the economy, they are bound to become one of the new forms of travel in the future. According to the available data, more than 1,000 cities have shared bicycle systems, and there are about 9 million shared bicycles. The latest modeling by Zag (2022) shows that the number of DBs and electric scooters in London alike is still growing. In particular, there have been more studies on shared bicycles in the academic sector recently because the dependence and impacts of DBs and on infrastructure continue to emerge. Neverteless, Spinney (2020) pointed out that although the expansion of bicycle usage is desirable, there are also numerous concomitant environmental and social problems. Under the background of the current sharing economy boom and the trend of urban traffic structure transformation to smart and green, the research on DB can play a positive role in better meeting the travel needs of the public, effectively solving the transfer problem of urban transportation, alleviating urban traffic congestion, and building a green travel system, and ultimately promote the development of urban sharing economy. DBs are worthy of research and have value in modern research including but not limited to economic development, environmental protection, urban planning and research, or public policy. It is also of great significance for improving bicycle utilization rate, energy saving and emission reduction, improving user experience, optimizing traffic structure and green and low-carbon travel system.

Although the dockless bike sharing industry is in a stage of rapid expansion, there are still many problems. At present, shared bicycles generally adopt a pileless model, which is convenient for residents at the same time, and the phenomenon of disorderly parking is also generated. The shared bikes are randomly parked outside the designated parking areas, such as sidewalks, green Spaces, etc. This not only affects the use of other areas by residents, but

also affects road access and pedestrian safety. However, due to the emergence of shared bicycles, there are relatively few theoretical studies in this area. Although some studies have explored the supply and demand relationship of shared bicycles, their long-term development model and relationship with urban infrastructure are still insufficient. This also explains the significance of the research of DB in order to provide a more solid scientific basis for solving existing problems and promoting its sustainable development.

2.1.3 Micromobility, Liveable Cities, and Active Travel

2.1.3.1 Micromobility

Micromobility has emerged as a transformative concept in urban transportation, offering a range of lightweight and flexible mobility options that cater to short-distance travel needs. This section delves into the theoretical underpinnings, practical applications, and broader implications of micromobility, particularly in the context of modern urban environments. Micromobility refers to the use of lightweight vehicles, such as bicycles, e-bikes, and electric scooters, for short-distance travel. These modes of transport are designed to fill the gaps in traditional transportation systems, particularly the "last mile" problem, where the final leg of a journey from a transit hub to a destination is often inconvenient or impractical. The rise of micromobility is closely tied to advancements in technology, urbanization, and changing societal attitudes towards sustainable and efficient transportation.

The theoretical framework of micromobility is rooted in several key concepts, including the Trip Chaining Theory, which examines how individuals combine multiple trips into a single journey. Micromobility provides the flexibility needed to efficiently link these trips, enhancing overall mobility. Additionally, the Last Mile Problem is a critical area where micromobility excels. By offering convenient and accessible options for short distances, micromobility can bridge the gap between public transit and final destinations, thereby reducing reliance on personal automobiles. In practice, micromobility has shown significant potential in addressing urban transportation challenges. Cities around the world are increasingly integrating micromobility solutions into their transportation networks. For instance, cities like Copenhagen and Amsterdam have long been pioneers in promoting cycling infrastructure, which has led to high rates of bicycle usage and reduced traffic congestion. More recently, cities like Paris and Berlin have introduced extensive e-scooter sharing programs, further diversifying the range of micromobility options available to residents.

The benefits of micromobility extend beyond just convenience. Environmental sustainability is a major advantage, as micromobility vehicles are typically zero-emission or low-emission,

contributing to cleaner air and reduced carbon footprints. Additionally, micromobility can enhance public health by encouraging more active forms of transportation, such as walking and cycling. Studies have shown that regular use of micromobility options can lead to significant improvements in physical fitness and overall well-being.

2.1.3.2 Liveable Cities

The pursuit of creating liveable cities has become a central goal in urban planning and design, driven by the need to enhance the quality of life for urban residents. Liveable cities are those that prioritize the well-being of their inhabitants through thoughtful urban design, efficient infrastructure, and a focus on sustainability. This section reviews the existing literature on liveable cities, highlighting key theoretical frameworks and empirical findings that define the characteristics and benefits of such urban environments. The concept of liveability in urban contexts is rooted in several theoretical frameworks that emphasize the importance of holistic urban planning. New Urbanism, championed by architects and planners such as Andres Duany and Elizabeth Plater-Zyberk, advocates for the creation of walkable, mixed-use neighborhoods that reduce reliance on automobiles and foster a sense of community (Duany & Plater-Zyberk, 2000). This approach emphasizes the importance of compact urban forms, diverse housing options, and accessible public spaces, all of which contribute to a more liveable urban environment.

Another influential framework is the Healthy Cities movement, which focuses on the impact of urban environments on physical and mental health. This movement, spearheaded by Trevor Hancock and Ilona Kickbusch, argues that cities should be designed to promote health through clean air, safe streets, and ample opportunities for physical activity (Hancock & Duhl, 1988). The integration of green spaces, parks, and recreational facilities is seen as crucial in this regard, as they provide residents with spaces for relaxation and exercise, thereby improving overall well-being.

Empirical research on liveable cities has identified several key characteristics that contribute to their success. One of the most critical factors is the quality of the built environment. Studies have shown that cities with well-designed public spaces, such as parks, plazas, and waterfronts, tend to have higher levels of resident satisfaction (Kaplan, 1995). These spaces not only provide aesthetic appeal but also serve as venues for social interaction, which is essential for fostering a sense of community and social cohesion. Transportation infrastructure also plays a significant role in determining the liveability of a city. Research indicates that cities with efficient public transportation systems and extensive cycling networks tend to have lower levels of air pollution and traffic congestion (Pucher & Buehler, 2010). For example, cities

like Copenhagen and Amsterdam have prioritized cycling infrastructure, resulting in high rates of bicycle usage and reduced reliance on cars. This shift towards sustainable transportation not only improves environmental quality but also enhances the overall health of residents. The availability and accessibility of essential services, such as healthcare, education, and retail, are also crucial components of liveable cities. Studies have found that neighborhoods with a high density of amenities tend to have higher levels of liveability (Frank et al., 2006). This proximity to services reduces the need for long commutes, thereby saving time and reducing stress for residents.

Liveable cities are also characterized by their focus on social equity and environmental sustainability. Research has shown that cities that prioritize affordable housing and inclusive public spaces tend to have more diverse and vibrant communities (Massey & Denton, 1993). Affordable housing ensures that a wide range of income levels can access the benefits of urban living, while inclusive public spaces provide opportunities for social interaction across different demographic groups. Environmental sustainability is another critical aspect of liveable cities. Studies have highlighted the importance of green infrastructure, such as urban forests and green roofs, in mitigating the urban heat island effect and improving air quality (Jim & Chen, 2009). Additionally, the integration of renewable energy sources and sustainable waste management practices is essential for reducing the ecological footprint of cities.

2.1.3.3 Active Travel

Active travel, encompassing walking and cycling, has garnered significant attention in contemporary urban studies due to its multifaceted benefits for health, environment, and urban sustainability. This section reviews the existing literature on active travel, highlighting key findings and theoretical frameworks that elucidate its importance and impact.

Active travel is fundamentally about promoting physical activity through everyday transportation choices. The concept is grounded in the understanding that integrating physical activity into daily routines can counteract sedentary lifestyles, which are prevalent in modern urban settings. Theories such as the Social Ecological Model (SEM) provide a comprehensive framework for understanding the determinants of active travel. This model posits that individual behavior is influenced by a complex interplay of personal, social, and environmental factors (Sallis et al., 2008). For instance, personal factors might include attitudes towards physical activity, while social factors could involve community support and cultural norms. Environmental factors encompass the availability of infrastructure like bike lanes and pedestrian paths.

A substantial body of research underscores the health benefits of active travel. Studies have consistently shown that regular physical activity, such as walking and cycling, reduces the risk of chronic diseases, including cardiovascular disease, diabetes, and obesity (Panter et al., 2010). For example, a longitudinal study in the UK found that individuals who commuted by bike had a significantly lower risk of developing heart disease compared to those who used motorized transport (Celis-Morales et al., 2017). The health benefits extend beyond physical health; active travel has also been linked to improved mental well-being. Research indicates that active commuters report lower levels of stress and higher life satisfaction (Götschi et al., 2015).

Active travel's environmental benefits are equally compelling. Cycling and walking produce zero emissions, making them crucial tools in the fight against climate change and air pollution (Pucher & Buehler, 2012). Cities that prioritize active travel often see reductions in traffic congestion and noise pollution, contributing to a more pleasant urban environment. For instance, Copenhagen's extensive cycling infrastructure has not only improved air quality but also enhanced the overall livability of the city (Nielsen et al., 2018). The integration of active travel into urban planning is thus seen as a key strategy for achieving sustainable urban development.

Research has identified several determinants of active travel, including individual preferences, social influences, and environmental conditions. Individual factors such as age, gender, and income play a role in shaping travel behavior. For example, younger and older adults may prefer walking, while middle-aged individuals might opt for cycling (Giles-Corti et al., 2015). Social influences, such as peer support and community initiatives, can also encourage active travel. Environmental factors, particularly the availability of safe and convenient infrastructure, are critical. Studies have shown that cities with well-developed cycling networks and pedestrian-friendly streets have higher rates of active travel (Frank et al., 2006).

The role of policy in promoting active travel is well-documented. Policies that support active travel include the development of dedicated cycling lanes, pedestrian-friendly streets, and integrated public transport systems. For instance, cities like Amsterdam and Berlin have implemented comprehensive policies to promote cycling, resulting in high rates of bicycle usage (Pucher & Buehler, 2010). Infrastructure improvements, such as the construction of bike lanes and the provision of secure parking facilities, have been shown to significantly increase the uptake of cycling (Dill & Carr, 2007). Additionally, policies that discourage car use, such as congestion pricing and parking restrictions, can also encourage active travel.

Equity is an important consideration in the promotion of active travel. Research indicates that low-income and marginalized communities often face barriers to active travel, such as lack of infrastructure and unsafe neighborhoods (Lindsey et al., 2013). Addressing these disparities is crucial for ensuring that the benefits of active travel are accessible to all residents. Studies have shown that equitable access to active travel infrastructure can lead to improved health outcomes and enhanced social cohesion (Foster et al., 2014).

2.1.3.4 Integration of Dockless Bicycles

The integration of dockless bicycles into urban transportation systems has emerged as a significant area of research, given the potential of these systems to address various urban challenges. Dockless bicycles, as a subset of micromobility solutions, offer unique opportunities and challenges that have been extensively explored in recent literature. This section reviews the existing research on the integration of dockless bicycles, focusing on their role in urban transportation, their impact on urban environments, and the broader implications for policy and infrastructure.

Dockless bicycles have been positioned as a transformative element in urban transportation ecosystems. Research indicates that these systems can effectively address the "last mile" problem, bridging the gap between public transit hubs and final destinations (Shaheen et al., 2018). This capability is crucial in enhancing the overall efficiency of urban mobility, as it reduces reliance on private automobiles and encourages more sustainable travel patterns. Studies have shown that dockless bicycles are particularly effective in dense urban areas where short-distance travel is common (Feng et al., 2019). The environmental impact of dockless bicycles has been a focal point of research. Studies suggest that these systems can contribute to reduced carbon emissions and improved air quality by providing a zero-emission alternative to motorized transport (Zhou et al., 2020). Additionally, dockless bicycles can enhance the overall livability of cities by promoting physical activity and reducing traffic congestion (Fishman et al., 2016). However, challenges such as improper parking and spatial distribution have also been identified, highlighting the need for effective management strategies to maximize the benefits of these systems (Chen et al., 2020).

The integration of dockless bicycles necessitates thoughtful policy and infrastructure planning. Research has highlighted the importance of regulatory frameworks that balance the need for innovation with public safety and order (Faghih-Imani & Eluru, 2016). Effective policies include the establishment of designated parking areas, enforcement of usage regulations, and collaboration with private operators to ensure responsible deployment and maintenance of bicycles (Shaaban, 2020). Infrastructure improvements, such as the expansion of bike lanes

and the provision of secure parking facilities, have been identified as critical in supporting the widespread adoption of dockless bicycles (Ma et al., 2020). User behavior and adoption patterns are central to the success of dockless bicycle systems. Studies have explored the factors influencing user preferences and adoption rates, identifying convenience, cost, and accessibility as key drivers (Wu et al., 2019). Research also highlights the importance of user education and awareness campaigns in promoting responsible usage and reducing negative behaviors such as improper parking (Hua & Zhao, 2020). Understanding these behavioral dynamics is essential for designing effective interventions and improving the overall user experience.

2.2 Existing Problems of Dockless Bicycles

DB's problems focus on indiscriminate parking and dangerous riding.

2.2.1 Indiscriminate Parking:

Indiscriminate parking will bring public safety problems. Hua & Zhao (2020) argue that DBs bring convenience to users. However, at the same time, even equipped with real-time positioning function, they have the problem of random parking and placement that affects public safety. For example, DBs are littered on sidewalks and fire exits, affecting pedestrian travel and traffic order. Besides, the lack of a fixed parking location results in an imbalance between supply and demand. There is a need to prevent the imbalance in the number of shared bikes and ensure the relationship between supply and demand. Chen et al. (2020) also pointed out that although these bikes are more convenient in usage than traditional bicycles, the deregulated nature of the system has led to the emergence of irregular parking behaviors among users that cannot be ignored, leading to negative impacts such as violating pedestrian rights, blocking bicycle lanes, and hindering traffic. At the same time, from the user's point of view, the indiscriminate parking behavior of shared bicycles has greatly affected the demand for users to borrow and change cars, especially during peak hours. Although some scholars have proposed that these problems can be solved by increasing the amount of parking, because they believe that the existing phenomenon of indiscriminate parking is because users can not find a suitable parking space in order to finish the trip as soon as possible, so they will park in the roadside and other illegal parking areas. Increasing the number of vehicles can meet the needs of users during peak hours, so that it is easier to find officially planned parking areas for vehicles. However, the reality shows that excessive use of shared bicycles will not only affect the appearance of the city and social order, but also cause a waste of resources.

2.2.2 Dangerous Riding Behaviors

Dangerous cycling is also a key issue. A recent study utilizing the Internet-based survey of shared bicycle riders in 1960 to assess the incidence of eight behaviors in the past month and found that the proportion of participants who reported always or often restless riding behaviors in the past month ranged from 1.1% who rode bicycles with passengers to 97.6% who failed to wear helmets (Wu et al., 2019). However, online surveys were biased due to the participants' non-random selection and poor self-reported memories (Araujo et al., 2017). Other observational studies focused on China show that a study in Beijing found that 56% of bicycle riders, including electric and traditional bicycles, passed the red light signal (Wu et al., 2012; Fishman & Cherry, 2016). Another survey considered several unsafe behaviors of electric bicycle riders in Suzhou including the rate of riding on motor vehicle lanes at 1.9%, the rate of running red lights 4.8%, the rate of riding in the opposite direction of traffic at 3.4%, the rate of using mobile phones at 0.4%, and the rate of not wearing helmets at 91% (Du et al., 2013; Jones et al., 2016). It can be seen that dangerous riding has become one of the key problems of existing dockless shared bikes. Existing research on dangerous riding behavior has focused on the risk of dockless shared bikes crossing the line. Zhang et al.(2019) pointed out that non-motor vehicles crossing the line and occupying the motor vehicle lane is one of the most typical dangerous riding behaviors. Ma et al.(2020) put forward 12 categories of dangerous riding behaviors, and pointed out that illegal occupation of motor lanes leads to the highest possibility of traffic accidents. Some scholars also used questionnaire survey to explain the relationship between the dangerous riding of dockless bicycles and the personal characteristics of riders. All the above studies show that dangerous riding has become the most important factor hindering the safe riding of dockless bicycles.

Scholars such as Shaaban (2020) and Faghih-Imani & Eluru (2016) all highlight the impact of local docking points and infrastructure on DBs parking, but these researchers fail to propose how to improve the existing infrastructure and rationalize road facilities and the number of stops. In particular, online surveys of shared bicycle riders and other observational reports also pointed out that the phenomenon of dangerous riding exists with observational methods. To implement the sustainable development of dockless bicycles and reduce the impact of shared bikes on society, it is necessary to find factors affecting DBs and corresponding measures to reduce related risky behaviors.

2.3 The Influence Degree of Different Factors on Dockless Bicycles

In view of the three major influencing factors mentioned above: the location of the site itself, infrastructure and riding environment, scholars also conducted research on their impact on dockless shared bicycles and discussed the degree of impact of these related factors on irregular behaviors.

2.3.1 Location of the Site

Overall, the location of the site itself has a relatively high degree of influence, and the location of the site is an important prerequisite for determining whether riders can regulate their behavior. Especially in densely populated areas, the impact of site location will be more significant. Since dockless shared bicycles are used more frequently in areas such as office commuting and commercial service facilities, it is easy to cause irregular behavior if parking areas can be set up to match the use in this related area. This is especially true during rush hours or on weekends (Yan et al. 2020). In addition, the accessibility of the site, that is, the distance of the location, also affects the user's behavior. Fischer (2022) proposed that if the location of the site is relatively remote, it is difficult for people to reach. Even if the site is located near a public area, users will still be more inclined to park the dockless bike in an area they think is more convenient, even if it is not a regulated parking location. This also shows the importance of site location, reasonable planning of site location can improve the user's convenience and reduce the possibility of irregular behavior.

2.3.2 Infrastructure

Infrastructure has the highest degree of impact, and its quality and completion of construction directly affect users' non-standard behavior to a certain extent. Physical facilities and design elements within street right-of-way with the primary purpose of serving bicycles. These facilities can be divided into two broad categories: travel-related infrastructures and endof-trip facilities. The former, also known as Separated Bicycle Facilities (SPFs), protects the bicycle flow by separating the bicycle flow from the motor flow within the right of way, including strip facilities along the street and intersection facilities. Fishman (2020) argued that in areas where parking facilities are missing or insufficient, the phenomenon of indiscriminate parking is more likely to occur. If cyclists do not find a suitable parking spot within a suitable distance, they will also tend to park in areas with available Spaces rather than planned parking areas. Especially during peak hours, a large number of dockless shared bikes will suddenly be concentrated at a regional point. Insufficient facility space often results

in the existing parking area being unable to meet the higher volume of use. Even when cyclists reach the parking area, they are forced to park in unplanned places, such as on the side of the road. Secondly, the road infrastructure also directly affects the behavior of cyclists. Chardon (2017) believed that when the non-motorized lane is infringed, the rider is prone to irregular behavior, such as driving in the motorway. Or the road width of the non-motorized lane is small, a large number of non-motorized driving space is insufficient, and cyclists will obtain more space by speeding or occupying the motorized lane (Chen & Ding 2022). The presence or absence of green belts on roads can also affect cycling behaviour. When green belts of road facilities separate motorized and non-motorized vehicles, cyclists are less likely to occupy motorized lanes. In addition, networks with dedicated or divided bike lanes have been shown to promote cycling better. At the same time, EI-Assi's (2017) study of Toronto found that bike-sharing users were more concerned about being able to rent bikes smoothly, so more rides gathered in areas with abundant bike supply. Looking at the design of all types of infrastructure, the overarching trend is to establish the place of cycling in the space, to raise priorities, and to promote regulatory and awareness change. Bike lanes and sidewalks are more closely aligned in street space, for example by placing bike lanes within side parking strips rather than between side parking strips and vehicle lanes, or by placing two-way bike lanes together. Intersection design, a few years ago commonly used front waiting area, second crossing waiting area, recently improved to corner waiting area; Street crossing strips are also gradually juxtaposed with sidewalks to enhance non-segregation and reduce bicycle exposure to motorized traffic. The shift in positioning of bicycles is also reflected in signs and signal Settings, signs and ground text that remind vehicles to yield to bikes and stop here, and bicycles sharing phase more with pedestrians than vehicles. Another clear trend is the more refined allocation of road space through right-of-way redrawing. In many countries, existing regulations classify bicycles and motor vehicles in the same category and mix them on motorways. Later, bicycles had separate lane Spaces, and many roads changed from two-way 4-lanes to two-way 2-lanes with turning lanes.

2.3.3 Riding Environment

The cycling environment, on the other hand, has a relatively low impact, mainly indirectly influencing riders' irregular behaviors through influencing users' riding experience and sense of security. The process of urban residents' transportation travel is actually an interaction process between individual travelers and the travel environment. Cyclists obtain and perceive road traffic information through the eyes' fixation and scanning of different targets during the

cycling process, transmit it to the central nervous system of the brain, analyze the information to realize behavior decision-making, and finally implement it through organs such as the receiver and the foot. Briefly speaking, this process is that cyclists produce psychophysiological reactions to the travel environment perception, form behavioral intentions, and interact with perceptual behavior control to produce final behaviors. This process completes the judgment of the quality of travel. This influencing factor is also closely related to infrastructure. The shaping of cycling environment cannot be separated from the creation of good infrastructure, the environment of surrounding blocks, and the shaping of social safety atmosphere (Celebi & Isik 2018). The creation of a good foundation helps to form a regulated riding style, and people tend to ride within the prescribed lanes. The environment of the surrounding blocks can enhance the cyclists' willingness to ride, form a good cycling experience, and never affect their cycling behavior. In terms of street landscape, existing studies have proved that street greenness and sky openness have a positive impact on bicycle travel, and good streetscape greening and spacious street view can improve the comfort of riding. At the same time, the positive social safe riding atmosphere will also promote and drive people's standardized riding behavior. In contrast, China's bicycle travel environment is even worse, and the phenomenon of bicycle right of way being invaded at will can be seen everywhere. The difference of bicycle travel environment directly affects the cycling behavior of cyclists, and also determines whether travelers will choose to travel by bicycle to some extent. Relatively speaking, the impact of cycling environment is lower than that of site location and infrastructure.

2.4 Measures for Improving Dockless Bicycles

2.4.1 Forecast Demand

By analyzing the use needs of users of dockless shared bicycles, reasonable resource allocation can be carried out according to the needs. Plan the distribution location and quantity of dockless shared bicycles in advance through the prediction of use demand. Zhang & Srivathsan et al. (2017) proposed dynamically predicting the demand for bicycles based on the inventory level and the number of users to balance the population of DBs between different sites. However, the study needs to address how the number of dockless bikes should be balanced between different stations. Lu & Zhu (2022) combined a predictive model of broken bicycles and a travel distance predictor with maintenance allocation optimization to predict high-risk locations of broken bicycles. These locations include places where bicycles seized by the traffic police are piled up with them. It was found that the

number of dockless bikes with violations was much greater than that of ordinary bicycles. Ji et al. (2020) mainly studied the differences in user needs and travel characteristics of docked and dockless bikes and the gaps in GPS trajectory data in dockless bike programs. The results show that regular and occasional users share similar ride times and distances for both bike-sharing systems.

Besides, there are significant differences in spatiotemporal distribution between docked and dockless bike-sharing systems, where POIs and the built environment will work together to promote shared bikes. Li et al. (2022) developed a spatiotemporal model to understand the spatiotemporal purpose of dockless bicycle travel. They conducted a case study in Washington, which included 83,002 active users and 19,370 POI locations and datasets. The results confirm sustainable urban mobility planning and efficient fleet redistribution in future smart cities. Among them, OD travel and POI data can effectively understand the purpose of travel. Cheng et al. (2020) used the CARA model to understand POIs to quantify the correlation between human activities and urban settlements. The CARA model is further evaluated by retrieving urban residential areas in Tengzhou City from dockless bicycle trajectories. Compared with the actual map, the accuracy rate reaches 83.3%, proving the model's reliability and feasibility. This study proves that human activities have a logarithmic relationship with settlements. Through the above literature, it has been verified that the demand for dockless bicycles is directly related to the number of types of POIs, and there are more cyclists in areas with more functions and rigid requirements. Therefore, POI can be used as an effective way to predict the demand for dockless bicycles.

Arai (2018) analyzed through K-means and classified dockless bicycles into 39 categories to test the phenomenon of random parking and people's riding experience. Wang (2021) classified through K-means and "Gaussian mixture model" (GMM) clustering methods to understand the user's travel mode and reasonably allocate the maximum number of dockless bicycles. This method can effectively predict the demand for dockless bicycle travel, solve the problems faced by suppliers and visualize the data. This paper also discusses the advantages and disadvantages of K-means and GMM for continuous and discontinuous data through specific cases. Ieromonachou et al. (2011) introduced a data-driven neural network to predict the demand for dockless bikes. This method has been verified to predict the demand for dockless bikes effectively and can be used as a tool for sustainable development. Xu

(2018) predicts user demand on working and non-working days by developing a method combining cluster analysis, "backpropagation neural network" (BPNN), and comparative analysis based on rental data. Zhang & Wang (2019) believe that a dynamic price system can be used to capture the different paths of cyclists and the demand for dockless bikes at that time for pricing. For example, the price can be appropriately raised when DBs are in short supply. The pricing model could be more conducive to the subsequent development of dockless bicycles. However, although an example shows that the proposed negative price dynamic pricing strategy is effective in attracting users and achieving a more balanced bike repositioning, especially when the number of bikes is limited, this model may lead some shared bike users to switch to other public transportation. From the above literature, we can see that the existing quantitative methods can indeed predict the demand for dockless bicycles in different locations and reduce unnecessary resource surplus. Therefore, like the evidence provided in the above literature, it is evident that there are many DBs with riding problems in the recent past.

2.4.2 Improve Existing Infrastructure

As urban traffic becomes more congested, some local governments are planning various programs to promote bicycle use. To enable the safe operation of shared bikes, lanes or paths and even streets, which are physically separated from vehicle lanes, will be designed and constructed (Chen et al. 2007). The design of traffic facilities at intersections will enhance the safety of cyclists. These projects will not only improve the safety and comfort of bicycle users but also help prompt bicycle share modes. Ji & Yuan (2020) insisted that the driving distance and time of both regular bikes and DBs are similar. Dockless bikes have a longer riding distance than docked ones. However, increasing the number of docking stations can bring docked and dockless bikes both into closer riding distances. A proposal to increase the shared bicycle parking spots outside the bus stations to improve the attractiveness, especially in the suburbs, has been issued in many cities. Hickman et al (2019) argue that increasing the share of environmentally friendly modes of transportation by implementing push-pull strategies, including parking restrictions in most areas while expanding pedestrian zones and bicycle infrastructure, can reduce average cycling time. In the past few years, public transportation policies and road facilities have been continuously improved. Now there are specific studies that prove that infrastructure construction should be strengthened to ensure the safe riding of dockless bicycles in the future, for example, improving the physical separation between cycling and motor vehicles and reducing the distance between stops and riding points. But there is still plenty of dangerous ridings happening now. The reasons behind are undecided: whether the infrastructure has been upgraded but is still unreasonable, or whether the country's existing infrastructure construction plan, known as the development of dockless bicycles, has been implemented in practice.

2.4.3 Enhancing Regulations

The encroachment of infrastructure, i.e. existing environmental space, can affect cycling behavior. However, from the perspective of system and policy, the constraints on riding behavior are still insufficient. Nie & Yang (2014) believed that the cause of severe injuries of cyclists was that they were not protected while riding. The results provide background knowledge for considering establishing or modifying pedestrian regulations to protect cyclists and help develop safety measures and protective devices for cyclists. Qiu & Chan (2023) held that the government should install corresponding electronic devices to track the retrograde behavior of electric bicycles and running red lights and punish them accordingly. At the same time, supervision and administration should be improved at intersections where accidents occur frequently.

Qiu & Chan (2023) believed that the government should install corresponding electronic devices to supervise the retrograde behavior of electric bicycles and running red lights and punish them accordingly. At the same time, supervision and administration should be improved at intersections where accidents occur frequently. Todd & Cheshire (2021) believe that mandatory helmet rules in first-tier cities may affect the attractiveness of BSS and may reduce the number of shared bicycle users. Yang (2014) believes unsafe riding behaviors lead to a sharp increase in deaths. Testing the riding speed of e-bikes with handheld radar found that most have speeding behaviors, and unsafe riding behaviors, such as speeding, violating road rules, and not wearing helmets, are common among e-bike enthusiasts.

The results show that the model forecast accuracy can be improved by differentiating between working days and non-working days. Through the above-mentioned existing methods, it can be found that there are three main ways to solve the risk of riding bicycles without piles. The first solution entails predicting the demand, the second approach is to increase the construction of riding infrastructure, and the third one is to improve the existing legal policy. From the above solutions, it can be seen that the second and third interventions

are directly related to the construction and administration of the city. Although the existing literature review gives solutions, it does not say whether these methods are effective and can reduce the dangerous riding behaviors of dockless bicycles. Although widening roads and increasing parking spaces for dockless bikes can solve existing problems, the above literature needs to consider the differences in urban infrastructure construction and the capacity of cities, so as the number of dockless bikes to be balanced at the current city level.

2.5 Dockless Bicycles in China

Shared bicycles are currently the representative of China's "sharing economy" and have been developing very fast. With the popularity of 4G network technology and smart phones, dockless bikes equipped with GPS devices have become one of the fastest growing shared travel methods in China due to their flexible use and low cost. The development of dockless bike-sharing in China mainly includes two stages. The first stage (2015-2018) saw the emergence and rapid development of Internet dockless shared bicycles. At this stage, dockless shared bicycles have developed rapidly and emerged rapidly in major cities, among which the most representative bicycles are Mobike and ofo, accounting for more than 80% of the market. By the end of the second quarter of 2017, users had reached more than 32 million, and the number of daily rides peaked at more than 17 million. The second stage (2019-present), this stage of dockless shared bicycles into a stable stage of development. Since the dockless bike sharing first appeared, it has covered more than 300 cities and regions in China, attracting users of different ages and genders (Gu et al. 2019). However, with the rapid expansion of dockless shared bicycles in cities, the resulting problem of irregular behavior has gradually emerged, In Shenzhen, for example, shared bikes in Nanshan District suffered serious damage and subsequently appeared in large numbers on second-hand trading platforms; And bikes were stolen and shut down.

Some scholars argued that the encroachment of non-motorized space in China has led to indiscriminate parking. Yang (2017) proposed that space for non-motorized lanes in Chinese cities, especially in big cities, is limited. Chinese cities are usually densely populated areas, especially in the past decade, the spread of motor vehicles has greatly caused urban congestion problems, and parking has also become difficult. In order to solve the problem of parking difficulties, most big cities have changed non-motorized lanes into parking Spaces, which occupies the space of non-motorized lanes and non-motorized vehicles. Such encroachment

affects people's use of non-motor vehicles, and the unmet riding and parking space affects people's judgment and behavior, which then causes the problem of bicycle riding in the motor lane and disorderly parking.

Other scholars also believed that the public transportation part of the travel system in big cities is built earlier, such as Shanghai. Previous construction failed to take into account connectivity with other public transport, especially bicycles (Wang & Liu 2022). Most of the transfers were originally designed for people to walk. Bike-sharing appeared later than these public transportation systems. As a result, the early construction did not take into account the parking space of shared bicycles. But people also need to use shared bikes for transfer, so this lack of planning also causes people to park and leave randomly. In addition, in public areas such as commercial areas with a large flow of people, this situation will also occur because the number of shared bicycles far exceeds the capacity of the space, in the case of insufficient space, people can only park shared bicycles outside the designated parking area, resulting in countless chaotic parking of shared bicycles.

In addition, in China, the irregular riding behavior of dockless bicycles is also very serious. Many literatures have recorded in detail the specific performance of irregular riding behavior of dockless bicycles. In China, common irregularities include running red lights, driving the wrong way, not wearing a helmet, and disorderly parking. Studies by Yang et al. show that when using dockless shared bicycles in China, many riders often reverse course, do not ride according to regulations and stop at will due to factors such as being in a hurry, which increases the risk of riding.

In response to these phenomena, Chen et al. (2020) proposed to organically integrate shared bicycles with urban space. The entry of shared bicycles into the city has undoubtedly added new elements to the urban space and broken the balance of the urban space. The incorporation of shared bicycle space elements into the urban transportation system and space can achieve a win-win situation between shared bicycle benefits and urban space. In addition, the elimination of unreasonable Settings in public areas and other places, so that shared bicycles can be scientifically set and parked, and promote the matching of shared bicycle parking needs and demarcated areas, so as to facilitate the use of users. Since the dockless shared bicycle is an Internet-based bicycle operation, it will produce a lot of time and spatial data, some scholars

through Python and other programs to mine the dockless shared bicycle data, and show that optimizing "electronic fence planning, parking area layout, vehicle scheduling optimization, vehicle accumulation and disorderly parking" can effectively improve irregular riding behavior.

On the whole, with the rapid growth of the number of shared bicycles in China's cities, more and more urban space is occupied, and some irregular behaviors have more and more serious impact on urban facilities. In view of these phenomena, scholars have carried on the correlation analysis of urban space, and put forward the corresponding solutions.

2.6 Behavior Differences between Private and Dockless Bikes

Since 2010, China has been the largest bicycle market worldwide. Juelin et al. (2017) believe that compared with traditional bicycles, shared bikes increase the flexibility of travel, because it is impossible for private-owned bicycles to be carried and used whenever and wherever possible and so to be used as the last mile of public transportation. Chen et al. (2020) believe that dockless bikes are more efficient than traditional ones and are a practical option for the last mile. Dockless bikes solve this problem and thereby increase overall bicycle usage, significantly increasing existing bicycle trips. Dockless shared bicycles and dockless public bicycles are both low-carbon, green and healthy modes of travel produced in the context of encouraging green travel. Although the two share common characteristics in terms of environmental protection, energy saving, convenient travel and reducing urban traffic pressure, they still have the following differences. First of all, in terms of the main body of operation, the piled public bicycles in most parts of China are dominated by the government, and the government plays a leading role in both the government purchase service model and the state-owned enterprise business model. The dockless shared bike is invested and managed by the relevant enterprises, and the infrastructure is funded by the enterprises, and it is for the purpose of profit. In terms of parking methods, dockless shared bicycles, compared with dockless shared bicycles, eliminate fixed parking piles. The piled public bicycle is to set up different number of parking piles at a certain distance around the crowded area to provide users with services. Without these parking posts, users can rent and return bikes more easily in designated areas, but there are advantages and disadvantages. There is no fixed parking space, which is convenient for people to use but will lead to disorderly parking. And the pile bicycle because the parking space is fixed, it is less prone to disorderly parking. In terms of charging methods. Piled public bicycles are free for a certain period of riding time after

paying the deposit, while dockless shared bicycles are mainly for profit, so they also need to charge different fees according to the length of riding time after paying the deposit.

2.7 Conclusion

This literature review highlights the significant role of dockless bikes in modern urban transportation systems and the challenges associated with their rapid expansion. While DBs offer numerous benefits, including reducing traffic congestion and promoting green travel, addressing issues such as indiscriminate parking and dangerous riding behaviors is crucial for their sustainable development. Future research should focus on developing more effective solutions to these challenges, including improving infrastructure, enhancing regulations, and optimizing demand forecasting.

Chapter Three: Methodology

3.1 Case study

This study first adopts the case study method, aiming to study the impact of infrastructure on people's irregular behavior in different regions. Through case studies and comparative analysis, this paper can select the most representative cases for detailed analysis, in order to understand the potential causes behind people's irregular behavior and the internal rules and patterns. Since this paper mainly discusses Chinese cities, there are many considerations for the selection of cases. Since dockless shared bicycles are mainly concentrated in first - and second-tier cities in China, this paper will choose first-tier cities as the core case study and conduct comparative analysis and research with second-tier cities. In addition to analysing the results of a large number of data, this paper also introduces the observation method as a qualitative method to explore the behavior of people using shared bicycles in different urban areas. The observation method mainly collects video data sets of cyclists' behaviors around subway stations, and chooses subway stations for observation, mainly because subway is one of the main modes of downtown transportation in China's first - and second-tier cities (Shlayan et al., 2016). China has a large number of dockless shared bicycles gathered in subway stations, making it possible to obtain sufficient video data support for observation. Besides, the observation sites are selected according to the following criteria:

- 1. In the significant data analysis results of the previous part, there are subway stations with apparent differences in the number of parking and access in the morning and evening peaks.
- 2. In the significant data analysis results, there are subway stations with differences in the number of trips on weekdays and weekends.
- 3. A representative of a particular area or a subway station with prominent characteristics in a particular area.
- 4. There is enough space for a smartphone-based camera and tripod to be placed on the side of the street, which can take a complete picture.
- 5. It did not affect the typical traffic pattern in any way (Huemer, 2022).

This study used fixed location based data set of Meituan bicycles and has been screened for use.

3.1.1 First-tier City and Subway Station Selection

In the selection of first-tier cities, this paper considers the convenience and openness of data acquisition, so it chooses Shanghai as the core case study object. Shanghai was chosen as the core case study object due to its status as a first-tier city with comprehensive data availability and its significant role in urban transportation research. The selection of other cities for comparison, such as Xi'an, was based on their differing levels of urban development and infrastructure, which allows for a comprehensive analysis of the impact of urban mobility systems on dockless bike usage. Specifically, Shanghai represents a highly developed urban environment with advanced transportation infrastructure, while Xi'an, as a second-tier city, provides a contrasting case with a less developed but rapidly growing transportation system. This comparative approach enables a deeper understanding of how urban infrastructure influences the usage patterns and behaviors of dockless bike users. Shanghai is located at latitude 31. 14 north and longitude 121.29 east, on the west coast of the Pacific Ocean and the eastern edge of the Asian continent and the forward point of the Yangtze River Delta; at the same times, it is bordered by the East China Sea in the east, Hangzhou Bay in the south, Jiangsu and Zhejiang provinces in the west, and the Yangtze River estuary in the north, where the Yangtze River and the East China Sea are connected. Shanghai is located in the middle of China's north-south coastline, and has convenient transportation routes. It is one of the four municipalities directly under the Central Government of China, and it is also the core area of the world-class urban agglomeration of the Yangtze River Delta region. At present, the population of Shanghai exceeds 20 million (Shanghai Statistical Yearbook, 2018). According to the map of Shanghai, Huangpu River lies in the middle of the geographical structure of Shanghai and splits the whole city into the east and the west bank of Huangpu River. The division of rivers has also led to inconsistencies in urban development. Depending on the characteristics of urban infrastructure and transportation systems, this study will choose Huangpu District on the west bank of Huangpu River and Pudong New Area on the east bank of Huangpu River as observation points in the city center. Huangpu District (Figure 3. 1) represents a typical old city of first-tier cities in China. It used to be traditional and prosperous but now becomes narrow and outdated with a conflict between the old mobility system and the fast-growing urban traffic. The modern urban area of Pudong New Area (Figure 3.2), which represents the newly constructed districts in firsttier cities, has the complete supporting facilities and mobility system services of modern Chinese cities. The brand-new mobility system provides an extraordinary living experience for urban residents. On the west bank of Huangpu River, many roads have single lanes and pedestrian-first walking paths. On the east bank of Huangpu River, Pudong New Area, built after the 1990s, many multi-lane roads filled this urban area. Pudong New Area's road width

is five times that of the west bank of Huangpu River (Minghua et al., 2019). Such a new and old transportation mobility system makes the travel situation of dockless bikes on both sides of the Huangpu River have a comparative significance.

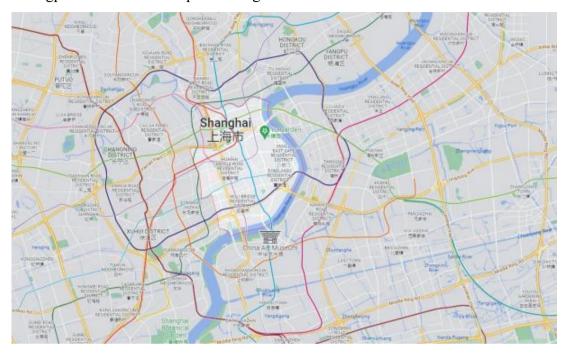


Figure 3.1 Map of Huangpu District in Shanghai.

In the pilot study, the Minsheng Road subway station in Pudong New Area has a wide pedestrian area and a wide bicycle lane, which is a typical area with a good planning and transportation mobility system. In that part of bicycle parking observation, it is common for people to regulate parking and access because the large parking area for bicycles makes the parking behavior orderly. However, such things do not often appear around subway stations without bicycle parking areas. Therefore, this study will also choose a subway station around the old city of Huangpu River for observation and research. Through different analysis and observation of new and old urban areas, this paper hopes to draw the key factors affecting different urban infrastructure construction.

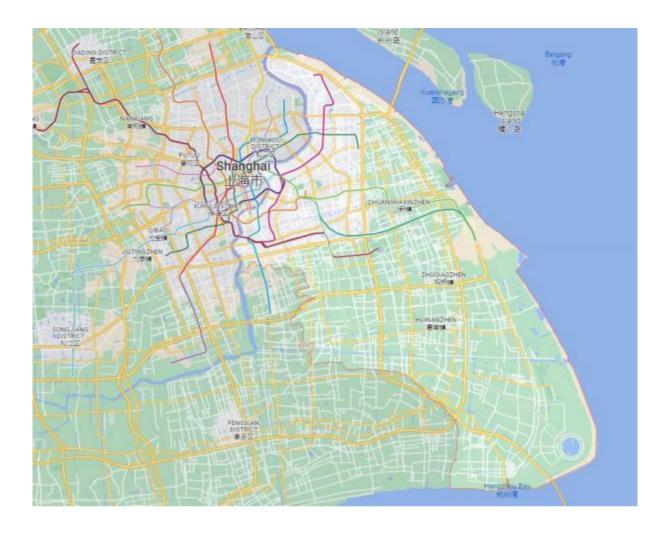


Figure 3.2 Map of Pudong New District in Shanghai.

3.1.1.1 Old Urban Area

Based on the above explanation, the selection of subway stations is mainly selected from the old and new areas. In the old urban area, there are two main subway stations were chosen, Xiaonanmen and Jiuting subway station.

3.1.1.1 Xiaonanmen subway station

There are many subway stations in Huangpu District on the west bank of Huangpu River. The se subway stations are landmarks in Shanghai, bearing the culture of the city. After years of re novation, no residents live around them, similar to the Great Ben neighborhood in Lond on, which carries the culture but does not have the function of living (Moote et al., 2004). The se subway stations are located in the center of the old city, which is busy, crowded and tumult uous (Yongli et al., 2018). The selection of subway stations in the old urban area was informe

d by GPS data analysis, which identified high-traffic areas and potential problem zones for do ckless bike usage. This data-driven approach ensured that the chosen stations were representat ive of typical usage patterns in the old urban area. For instance, GPS data revealed that Xiaon anmen and Jiuting stations had significant variations in bike usage during peak and off-peak h ours, making them ideal for detailed observation. The GPS data also highlighted the spatial di stribution of bikes, showing areas where bikes were frequently parked and areas where they w ere often left unattended, providing valuable insights into the parking behavior of users. Xiaon anmen subway station is located in Huangpu District of Shanghai and is the intermediate stati on of Shanghai Metro Line 9. This intermediate station was chosen because it is located in the heart of the city, connecting the commercial and residential areas. Located at the intersection of Zhonghua Road, Wangjia Pier Road and Qiaojia Road, Huangpu District, Shanghai, China, it is roughly laid along Zhonghua Road north-south. The station is about 160 meters from Jint an Road and Shachang Street to the north, about 160 meters from Zhonghua Road No. 3 Prim ary School to the west, about 130 meters from Sunac Bund One to the east, and about 130 met ers from Dongjiadu Road to the south. Its geographical location can better represent the use of dockless shared bicycles in the central area of the city. My observation and research are all ca rried out at Exit 1, because the exit is adjacent to the commercial complex and bus hub, and th e traffic density is the highest in the whole station during peak hours, which can capture the us er behavior characteristics in the extreme scene of pile-less bicycle turnover rate.





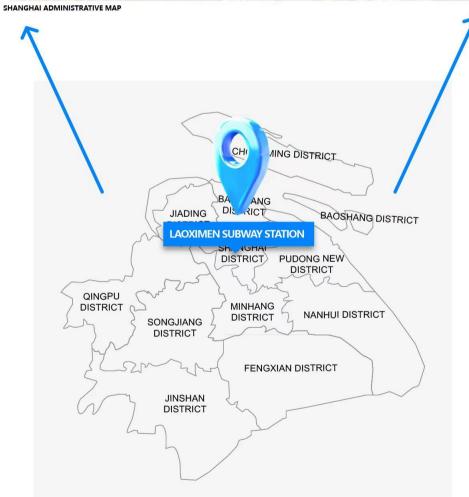
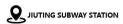


Figure 3.3 Map of Laoximen subway Station in Shanghai

3.1.1.1.2 Jiuting subway station

In Shanghai, Qibao, Nanxiang, Anting, Zhaoxiang, Sijing, Jiuting, Nujiang town, Zhou Pu, B eicai, Tang Zhen, Gao Qiao, and da Chang town, these places' names used to be traditional to wns in the outer suburbs of Shanghai, but now they are more known as subway stations with d ense residential population. As one of the old cities, Jiuting subway station is also chosen as the location of data collection. Jiuting Station is located on the south side of Husong Road in So ngjiang District, Shanghai, China. The west side of Huting Road is the last station of Metro Li ne 9. Compared with Xiaonanmen subway station, it is located in the suburban area of the city, and the surrounding land types are mostly residential quarters and industrial parks, which can reflect the cycling behavior of users in the suburban area of the city. Jiuting Station, as a hub subway station connecting urban and suburban areas, will have a large number of people gath ering in the morning rush hour, which can be taken as a typical in-depth study. My observation and research are all carried out at Entrance No.1, because it is also adjacent to the commercial complex and bus hub, and the density of passenger flow is the highest in the whole station d uring peak hours, which provides the largest sample size for this study.





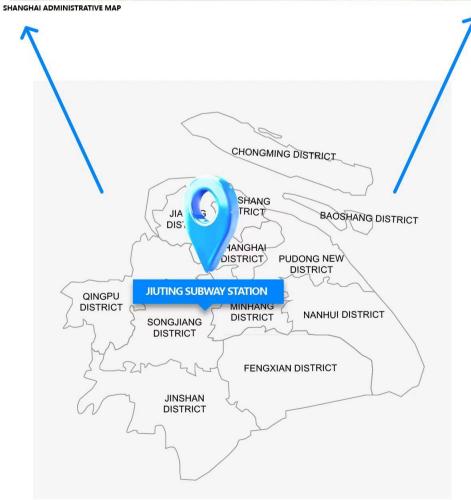


Figure 3.3 Map of Jiuting subway Station in Shanghai

3.1.1.2 New Urban Area

Compared with the old urban area, the construction of the new urban area will relatively take into account the development of urban surplus, and the infrastructure and supporting services are more abundant. In view of the location of Shanghai New Area, which does not distinguish between the urban core area and the urban suburbs, but is planned as a new area, the subway stations in this area have chosen a typical one for detailed analysis.

For new urban areas, Pudong New Area can be said to be a typical example of a new urban construction in China. From November 1, 2020, Pudong New Area has a permanent population of 5,681,512, as per the Seventh Census, which is the most populous urban area in Shanghai. The selection of subway stations in the new urban area was guided by k-means clustering of POI data, which identified clusters of high activity and demand for dockless bikes. The input data for the k-means algorithm included the number and type of POIs within a 500-meter radius of each station, ensuring that the chosen stations were representative of areas with significant infrastructure and usage. The k-means clustering algorithm was chosen because it effectively groups data points into clusters based on their proximity, allowing for the identification of areas with similar characteristics. The algorithm was run with multiple iterations to ensure the stability of the clusters. The resulting clusters were then analyzed to select the most representative stations, such as Century Avenue in Pudong New Area, which had a high density of commercial and residential POIs, indicating a high demand for dockless bikes.

Century Avenue subway station is the most representative subway station in Pudong New Area, east of Huangpu River, where Shanghai has a typical hub station with the most subway lines in Pudong New Area. The station covers four subway lines (Line 2, Line 4, Line 6 and Line 9), resulting in a larger passenger flow than other stations and a higher demand for shared bikes. In addition, the subway station is located in the financial and business center area of Pudong New Area, and the surrounding land types involve commercial shopping, residential and other complex land types, which can provide a variety of data sources for usage behavior. The selection of this subway station can provide sufficient research samples for the study. My observation and research are all carried out at entrance 1, on the one hand, because it is also adjacent to the commercial complex and bus hub, and the traffic density is the highest in the whole station during peak hours. And here, the traffic is the largest, and the

ratio of commuters to leisure users is 6:4 (pre-survey data), which can simultaneously record the riding modal differences between rigid demands and flexible demands of commuting.

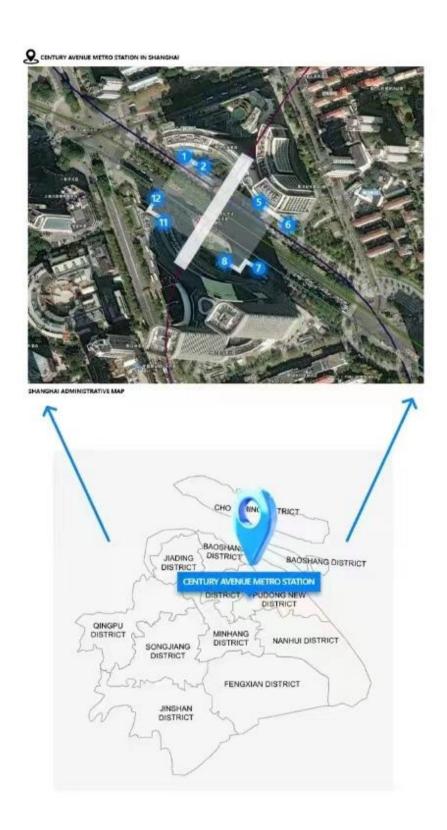


Figure 3.4 Century Avenue subway station in Shanghai

3.1.2 Second-tier City and Subway Station Selection

The comparison of second-tier cities as first-tier cities mainly selects the new and old urban areas for analysis. In the selection of second-tier cities, considering the comprehensive economic development level, infrastructure construction level and location, Xi 'an is finally selected as the city for analysis and comparison. Compared with the first-tier cities, the construction of transportation facilities in second-tier cities still lags behind the first-tier cities in terms of quantity and depth. The introduction of dockless shared bicycles is also late, and there are different stages of development. Shanghai has the largest subway network in China, while Xi 'an's network is smaller and focuses on the core urban area. By taking Xi 'an as the object of case analysis and comparison, common conclusions can be found from the cycling behaviors in different cities. Through comparison, the impact of infrastructure can be verified, so as to provide a reference for urban infrastructure and public transport construction.

3.1.2.2 New Urban Area: Beidajie Subway Station

Beidajie Station, located in Lianhu District, Xi 'an City, Shaanxi Province, China, is a subway station managed and operated by Xi 'an Rail Transit Group Co., LTD. It is a transfer station between Xi 'an Metro Line 1 and Xi 'an Metro Line 2. It is the first transfer station since Xi 'an Metro was put into operation because the bus station is named "Beidajie Station". On the west side of the station is Lianhu Park, on the north side is Anyuan Men, on the south side is Shaanxi Provincial People's Government, and on the east side is Revolution Park. North Street station is close to Xi 'an Huimin Street, Xi 'an Central Hospital, Xi 'an Jiaotong University Second Affiliated Hospital, Xi 'an Jiaotong University Stomatology Hospital, Shaanxi Provincial Maternal and Child Health Hospital, May Fourth Theatre, People's Theatre, etc. The surrounding land is relatively comprehensive and there are more people. On May 1, 2019, the passenger flow in and out of North Street Station reached 39800 people. Therefore, choosing this station for analysis can obtain enough analysis data to provide reference for the analysis of subway stations in second-tier cities. My observation and research are all carried out at the entrance B, because it is also adjacent to the commercial complex and bus hub, and the traffic density is the highest in the whole station during peak hours.





Figure 3.5 Map of Beidajie Station in Xi 'an

3.2 Data Collection and Methods

3.2.1 Big Data Method

POI is a term used to express geographical objects in geographic information systems. It is a geographical entity used in daily life, such as banks, shopping malls, schools, hospitals, and many more. POI data has unique "positioning" characteristics, including latitude, longitude, and address, which reflects higher accuracy, and it can accurately and, compared with the official statistical data, truly reflect human social and economic activities. POI data was collected using API tools from Gaode Map, ensuring high accuracy and up-to-date information. The data was cleaned to remove duplicates and verified against administrative divisions to ensure geographical accuracy. Each POI was categorized based on its type (e.g., bus station, subway station) and matched with dockless bike usage data to identify key usage patterns. The data collection process involved multiple steps: first, the API was used to extract raw POI data, which included detailed information such as the name, category, latitude, longitude, and address of each POI. This raw data was then processed to remove any inconsistencies and to ensure that all POIs were correctly geolocated within the study area. The cleaned data was then integrated with dockless bike usage data, which included information on the start and end points of each trip, the duration of the trip, and the type of bike used. This integration allowed for a detailed analysis of how different types of POIs influenced bike usage patterns. With the increasingly mature technology of POI data acquisition and update, POI data has been applied to the practical research of geographical phenomena. At present, the application of POI data in humanities-economic geography is in the exploratory stage, and POI data are used sporadically in the fields of tourist spatial pattern research, urban planning practice, regional accessibility research, business spatial layout research and hot spot identification of retail business centers. Each piece of data is the feature of a POI, which specifically refers to the number of various businesses or facilities in a 500meter radius circle centered on this location. In the data, we hide the specific name, coordinates, and type of each POI.

In this paper, POI data will be collected together with two other types of data. Combined with the visual results of the observation method, analyze the infrastructure, land use characteristics and passenger flow characteristics around stations in different DB environments, and find out which types of facilities can help alleviate the current situation of DB, and effectively help propose measures to improve the current situation of DB. POI data will be collected using API tools. The other two types of data include administrative division data, this paper mainly focuses on the administrative division data of Shanghai. And shared bicycle order data, order data is mainly to obtain unlocking and locking status data for OD travel records. This article will follow the following research steps. First of all, the POI,

administrative divisions and dockless shared bike usage data in Shanghai were collected, and the data was comprehensively cleaned. Duplicate data due to system failure or other reasons is deleted and geolocation data is verified against administrative divisions. Then, the POI data from different sources and shared bicycle usage data are converted into a unified standard coordinate system, and the WGS84 system is adopted in this paper. After that, ArcGIS was used to run the spatial analysis algorithm to match and associate the lock-opening and lock-closing locations of each shared bike with the surrounding POI, so that each shared bike usage record could correspond to specific commuting related places. Finally, based on the matching results, the spatial and temporal characteristics of Shanghai dockless shared bicycles and the preliminary relationship between these characteristics and infrastructure were obtained.

3.2.1.3 Shanghai's Transportation Urban Mobility System Data Collected

Data on the administrative divisions of Shanghai will be collected. There are 16 administrative districts in Shanghai, 7 of which are downtown, including Huangpu District Jing 'an District, Xuhui District, Changning District, Yangpu District, Hongkou District and Putuo District. Semi-central area semi-suburban 1, namely Pudong New Area. There are also 8 suburbs, namely Baoshan District, Jiading District, Minhang District, Songjiang District, Qingpu District, Fengxian District, Jinshan District and Chongming District, with a total area of about 6,340.5 km2, among which Huangpu District, Jing 'an District, Xuhui District, Changning District, Yangpu District, Hongkou District and Putuo District are considered to be commercially developed downtown areas. The rest are mostly suburban.

As the main research case, the DB-related POI data of Shanghai is collected. Main data collected include GPS travel data and POIdataset. The extraction of POIs of transportation facilities in Shanghai is more difficult than that of ordinary POI points, so it is extracted and calculated by the POI program of the Gaode Map (a map app similar to Google Map). Finally, 2,725 traffic POI points were obtained, as shown in Figure 3.3. Among them, the information on POI points includes location information- horizontal and vertical left, information type of POI points, graphic type, name of traffic station, and type of traffic station. According to the classification of POI points, Shanghai's internal transportation mobility system stations are divided into three types: bus stations, urban subway stations, and urban light rail stations.

The dataset comes from Meituan Bicycle, a bike-sharing app operator in Shanghai, which is the new name of Mobike mentioned earlier. It covers the travel orders in bike-sharing from May 1st to May 15th, 2020, including 17,684 independent users, 306,926 bicycles, and 1,023,603 orders. These travel orders have the following information, as shown in Figure 3.3:

- 1. The characteristics of the trip, including the start and end time of the trip, the latitude and longitude of the start and end positions.
- 2. Track-related information, including the time range of the track and a series of intermediate GPS points (Nicosia, 2022).
- 3. Other information, such as order ID, bicycle ID, and user ID.

1	orderid	userid	bikeid	biketype	starttime	geohashed_start_loc	geohashed_end_loc
2	1893973	451147	210617	- 2	2020/5/14 22:16	wx4snhx	wx4snhj
3	4657992	1061133	465394	1	2020/5/14 22:16	wx4dr59	wx4dquz
4	2965085	549189	310572	1	2020/5/14 22:16	wx4fgur	wx4fu5n
5	4548579	489720	456688	1	2020/5/14 22:16	wx4d5r5	wx4d5r4
6	3936364	467449	403224	1	2020/5/14 22:16	wx4g27p	wx4g266
7	5163705	917620	509044	1	2020/5/14 22:16	wx4gd2e	wx4g6pw
8	19818	583391	3190	1	2020/5/14 22:16	wx4fhkk	wx4fh7q
9	495333	185893	67441	1	2020/5/14 22:16	wx4emgw	wx4emgk
10	2803108	15906	295614	2	2020/5/14 22:16	wx4f8t9	wx4f8tj
11	271970	183740	38335	1	2020/5/14 22:16	wx4dzjf	wx4dzhn
12	289754	426024	40489	1	2020/5/14 22:16	wx4dy2p	wx4dwxv
13	1116773	342055	137447	2	2020/5/14 22:16	wx4f9mt	wx4f9k4
14	1983324	168457	218956	2	2020/5/14 22:16	wx4dwws	wx4dxnr
15	714809	559807	95403	1	2020/5/14 22:16	wx4g1zq	wx4g1yj

Figure 3.6 Travel GPS data of dockless bikes. Source: Author.

Orders with abnormal duration should be deleted before further analysis. According to previous research, bike-sharing orders with travel time less than 2 minutes or more than 120 minutes should be filtered out (Zhao et al., 2015). These orders may be related to two situations: first, some users may just want to confirm their account status instead of riding bicycles; secondly, they may improperly store or take away dockless bikes. In addition, the latitude and longitude coordinates of some bicycles are beyond the administrative scope of Shanghai, and these data will also be deleted directly.

The rise of POI data has promoted the innovation of urban research and provided a new research perspective on the aspects of urban internal spatial structure and function division, inter-city interaction, and other source data support. POI data is the basic data of "Location Service" (LBS), which can be obtained through the "Application Programming Interface"

(API) interface from open platforms such as Baidu Map, Gaode Map, Google Map, and OpenStreet Map.

POI refers to the point data of some landmark buildings and geographical entities closely related to people's lives, such as schools, hospitals, shopping malls, parks, and government agencies. POI data describes the spatial location and attribute information of these geographic entities (Thaipisutikul, 2020). It has a large number of data samples and abundant information, which can reflect various activities of Chinese cities to a certain extent. Each POI generally contains four aspects of information: name, category, latitude, longitude, and address. Compared with traditional land survey data, remote sensing data, and socio-economic statistical data, it is easier to obtain and process and has higher precision and awareness, which makes up for the shortage of conventional data such as population, price, night lights. Especially, the characteristics in which POI data is closely related to urban spatial layout can carry out information statistics, geographical positioning, and expression on various public service facilities in Chinese cities, providing great convenience for users.

In this study, POI data from the Gaode Map is utilized. Combining the point of interest and bike-sharing data, it can be revealed of the travel mode and lane, and purpose of bike-sharing users through POI frequency. According to the latitude, longitude, and search radius of the starting and ending positions of each trip, the points of interest around the starting and ending positions of each trip are extracted. As shown in Table 3.4, the POI classification of the Gaode Map is mainly divided into 14 categories, which can also more accurately explore the travel mode and travel purpose of dockless bike users.

POI category	POI types in Gaode Map API
House	Building, residential area
Food & beverages	Food restaurant, coffee house, tea house, ice cream shop, bakery, dessert house
Shopping	Shopping related places, shopping plaza, convenience store, home electronics hypermarket, supermarket, plants & pet market, home building materials market, comprehensive market, stationery store, sports store, etc.
Daily life service	Travel agency, information center, ticket office, post office, logistics service, telecom office, professional service firm, job center, electric supply service office, beauty, and hairdressing store, etc.
Education	School, university, museum, exhibition hall, convention & exhibition center, art gallery, library, planetarium, cultural palace, etc.
Transportation	Airport, port & marina, ferry station, ropeway station, subway station, bus station, railway station, parking lot, taxi
Company	Enterprises, company, farming, forestry, animal husbandry and fishery base
Sports & recreation places	Sports stadium, golf related, recreation center, holiday & nursing resort, recreation place, theatre & cinema
Medical service places	Hospital, clinic, emergency center, disease prevention institution, pharmacy, veterinary hospital
Public facility	Newsstand, public phone, public toilet, emergency shelter
Car related service	Filling station, car wash, car sales, car repair etc.
Tourist attraction	Park, square, scenery spot
Accommodation service related	Hotel, hostel
Finance & insurance service institution	Bank, ATM, insurance company, securities company, finance company

Table 3.7 POI category classification. Source: Baidu POI API.

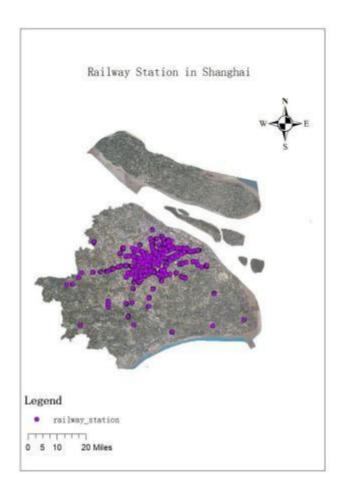


Figure 3.8 POI information of Shanghai traffic station. Source: Author.

It is very representative of analyzing the traffic mobility system through traffic POI. As the most intuitive factor in POI, traffic stations can intuitively show the usage of traffic stations in Chinese cities. Shanghai POI has the following fields, as shown in Figure 3.6, which will be explained as below:

- 1. FID: the number of traffic POI points.
- 2. Shape: the type of data, here are general points, lines, planes, multi-segment lines, and other types. Because of the characteristics of POI, they are all point data, marked as "point" in Chinese, which means point.
- 3. GML ID: GML is Geographic Markup Language, which provides a language model for expressing geographic information elements and can be used for data exchange on the Internet. The Open Geographic Information System Association (OGC) is responsible for formulating its standard, and this data also stores the coordinate information of our POI points.

- 4. Osm ID: Osm refers to OpenStreetMap, which is the data source of China's domestic maps. This map data is a bit like Google's own Map Maker map-making tool. It uses the collective strength of the public and the unpaid contribution to improve the map-related geographic data, which is also the data source for us to extract POI.
- 5. Code: this is the code of the POI point type, which matches with the POI point type on the right. As shown in the figure, "5621" is the data code of "Bus Stop" in this group of POI data.
- 6. F-class: This field is the type of POI point, which is also the proof of which kind of transportation station the POI point is. As shown in the figure, there are several types of bus stations, subway stations, railway stations, and light rail stations.
- 7. Name: This field is the name of each site, which is displayed here in Chinese.



Figure 3.9 POI information of Shanghai traffic station. Source: Author.

Yet, traffic stations appear in POI data but are not on the map of Shanghai will be deleted in the research. At the same time, for some data, it is necessary to repair the data, which is to complete some data with missing non-critical fields. Because the original POI data has many fields, if the fields storing non-critical information are missing, this record can still be regarded as valid. Some fields in the data have a corresponding relationship. If non-key fields are missing, they can be completed. The validity of this piece of data will not be affected after data completion and repair.

3.2.2 Observation Method

3.2.2.1 Observation Data Collected

The primary source of the observed data is a large number of videos taken in Xi'an and Shanghai subway stations between September 2021 and March 2022. Each video was taken at an exit of the subway station to ensure that significant information, including bicycle lanes, sidewalks, parking positions of dockless bikes, and subway station entrances, can be seen. The videos were recorded using a smartphone-based camera mounted on a tripod to capture a complete picture of the area without affecting the typical traffic pattern.

Observation Sites and Time:

Subway Stations: Four subway stations were selected for observation, including Xiaonanmen and Jiuting in Shanghai, and Beidajie in Xi'an.

Time Period: The observation period covered one week (Monday to Sunday) for each station, with a total of three weeks of observation.

Daily Observation: Each station was observed for 30 minutes during the morning peak (7:00-9:00) and evening peak (17:00-19:00) hours. Additionally, 16 working days, more than 2 Saturdays, and more than 2 Sundays were observed at each site, resulting in over 20 hours of video data per station.

Equipment:

Camera: A high-resolution smartphone camera with a wide-angle lens to capture a broad view of the area.

Tripod: A sturdy tripod to ensure stable and continuous recording.

Behavior Types Monitored:

Riding Behaviors:

- 1. Riding a bicycle under a red light.
- 2. Riding against the current.
- 3. Not holding the handlebar with both hands.
- 4. Riding on a non-bicycle lane.

Parking Behaviors:

- 1. The parking area of dockless bikes hinders passers-by or passing bicycles.
- 2. The parking interferes with the surrounding businesses.
- 3. Dockless bikes are not parked upright.
- 4. The parking location has an impact on the surrounding greening environment.

Observation can be seen as the foundation of everyday social interaction: when people participate in social life, they are diligent observers and commentators of others' actions(Ciesielska et al., 2018). The video data was analyzed to identify and code specific behaviors, such as not wearing a helmet, running a red light, and riding against traffic. Each behavior was categorized and counted by trained researchers, ensuring a comprehensive understanding of usage patterns and potential safety issues. The analysis process involved several steps: first, the videos were reviewed frame by frame to identify instances of specific behaviors. Each instance was then coded using a standardized coding scheme, which included categories for different types of unsafe behaviors. The coding was done by multiple researchers to ensure reliability and consistency. The coded data was then compiled into a database for further analysis, allowing for the identification of patterns and trends in cyclist behavior. Observation method can help us intuitively perceive the direct result of specific behavior and help us analyze the behavior behind the result. The data collection in this section will be concluded after summarizing the GPS conclusions in the previous section. The main data

collected were cycling and parking behaviors. According to the difference between the first different characteristics and weekend travel characteristics, this study chooses the observation point and sets the observation time to a whole week, which will last for three weeks, to ensure the integrity of the data. In addition, this study will also analyze the different travel characteristics of suburbs and downtown from their subway stations.

The primary source of the observed data is a large number of videos taken in Xi'an and Shanghai subway stations between September 2021 and March 2022, and each video was taken at an exit of the subway station. The video was taken to ensure that significant information including bicycle lanes, sidewalks, parking positions of dockless bikes, and subway station entrances can be seen. Bicycle lanes can reflect the city's mobility system. The width relationship between sidewalks and bicycle lanes is also the construction idea of urban builders, whether to pay more attention to pedestrians or transportation modes (Pucher et al., 1999). Besides, the observation sites are selected according to the following criteria:

- 1. In the significant data analysis results of the previous part, there are subway stations with apparent differences in the number of parking and access in the morning and evening peaks.
- 2. In the significant data analysis results, there are subway stations with differences in the number of trips on weekdays and weekends.
- 3. A representative of a particular area or a subway station with prominent characteristics in a particular area.
- 4. There is enough space for a smartphone-based camera and tripod to be placed on the side of the street, which can take a complete picture.
- 5. It did not affect the typical traffic pattern in any way (Huemer, 2022).

At the same time, the impact of building facilities on parking behavior was obtained from the percentage, reflecting people's attitudes toward dockless travel equipment. Trained observers and data collectors completed this shooting between September 2021 and March 2022. Each subway station recorded more than 20 days, and there were more than 30 minutes of shooting every day in the morning and evening rush hours. In addition, at each observation point, the morning and evening peak shooting of 16 working days, more than 2 Saturdays and more than 2 Sundays was completed. In other words, each observation point's video was over 20 hours

long and recorded two kinds of behaviors, including the riding and parking behavior of

dockless bikes. Therefore, videos totaling more than 100 hours are the original materials

(Albiński, 2018).

More specifically, in the observation of riding behavior, five unsafe riding behaviors were

selected for analysis:

1. Riding a bicycle under a red light,

2. Riding against the current,

3. Not holding the handlebar with both hands, and

4. Riding on a non-bicycle lane.

In the behavior observation of DBs, four unsafe riding behaviors were selected for analysis:

1. The parking area of dockless bikes hinders passers-by or passing bicycles.

2. The parking interferes with the surrounding businesses.

3. Dockless bikes are not parked upright.

4. The parking location has an impact on the surrounding greening environment.

The research methods include the observational study of parking in dockless bikes as well as

the relationship between the surrounding infrastructure and the parking places

(Borowska-Stefańska, 2021). Each of these behaviors is identified and coded by trained

researchers for each cyclist by manually watching each video hour. All cyclists appearing in the

video are coded; sometimes, if many cyclists are present at the same time, coding will be done

by rewinding the tape to capture the data of all cyclists. As each bike-sharing company in

China has unique and distinct colors and appearance of their DBs, compared with

individual bicycles, researchers can easily distinguish bike-sharing cyclists from individual

cyclists in the video.

3.2.2.2 Analysis Method: Independent Samples T-Test

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Independent samples T-Tester compares the means of two independent samples and automates the T-test effect size calculation, and the results obtained after testing are assumed to be applicable to the whole population (Fischer, 2020). The independent sample T-test can effectively test how DBs integrates into the existing urban mobility system. The test model also strengthens the credibility of the data results from the observation method. The video data was analyzed to identify and code specific behaviors, such as not wearing a helmet, running a red light, and riding against traffic. Each behavior was categorized and counted by trained researchers, ensuring a comprehensive understanding of usage patterns and potential safety issues. The analysis process involved several steps:

- 1. Video Review: The videos were reviewed frame by frame to identify instances of specific behaviors. Each instance was then coded using a standardized coding scheme, which included categories for different types of unsafe behaviors.
- 2. Data Coding: The coding was done by multiple researchers to ensure reliability and consistency. Each cyclist appearing in the video was coded; sometimes, if many cyclists were present at the same time, coding was done by rewinding the tape to capture the data of all cyclists.
- 3. Data Compilation: The coded data was then compiled into a database for further analysis, allowing for the identification of patterns and trends in cyclist behavior.
- 4. Statistical Analysis: The compiled data was analyzed using the Independent Samples T-Test to compare the means of two independent samples. This test was used to determine if there were significant differences in the frequency of unsafe behaviors between different subway stations and urban areas.

The test model also strengthens the credibility of the data results from the observation method. The selection of sample data for this study comes from the five subway stations mentioned above. The data of this study comes from the statistics and proportion of illegal riding behaviors and random parking traits in the videos. For example, the ratio of the number of people not wearing helmets to the total number of riders on that day was counted.

3.2.2.3 Data Analysis Method

The test model also strengthens the credibility of the data results from the observation method. The selection of sample data for this study comes from the selection of the above five subway stations. The above five subway stations are all primary data and will be

compared separately. For example, the comparison between three subway stations in Shanghai, the comparison between two subway stations in Xi'an, and the comparison between Shanghai and Xi'an. However, this article mainly takes Xiaonanmen Subway Station and Century Avenue Subway Station in Shanghai as examples because Xiaonanmen Subway is a representative of a relatively outdated mobility system while Century Avenue Subway Station is a representative of the relatively complete mobility system. The data of this study comes from the statistics and proportion of illegal riding behaviors and random parking and parking traits in the videos. Among them, the unruly riding behaviors have been mentioned above, and the primary data may classify and count different types of disruptive riding habits in different subway stations. For example, the ratio of the number of people not wearing helmets to the total number of riders on that day is counted.

Through the above data collection methods, the riding data of five subway stations will be obtained, and each subway station will exceed 103 hours. Theoretically, the number of unruly rides and random parking behaviors in a single subway station will show a normal distribution as it is well known that the number on weekdays is generally more significantly higher than that at weekends, and that there are also morning and evening peaks on weekdays. Therefore, the unruly riding behavior and disorderly parking behavior should present a normal distribution within these 103 hours. As mentioned above, this methodology takes Xiaonanmen Subway Station and Century Avenue Subway Station as examples, and so all results come from the Xiaonanmen Subway Station and the Century Avenue Subway Station data.

SPSS is used as an auxiliary tool to perform the T-test for analysis, which can effectively verify as a new mode of transportation, how dockless bikes integrate into the existing urban mobility system (Daniel, 2018). The steps are as followed:

1. Import the data of Xiaonanmen Subway Station and Century Avenue Subway Station into SPSS according to different hours. Furthermore, set the column type of the primary data of the Xiaonanmen subway station to 1 and the data category of the Century Avenue subway station to 2. 1 represents a subway station with a poor urban mobility system, and 2 represents a subway station with a relatively complete urban mobility system.

2.

- 3. Click Analyze in SPSS, compare means, and independent sample T-test. Secondly, put the original data into the test variable, and put the grouping variable of whether the urban mobility system is perfect into the grouping variable (Mooi, 2011). Then click Define Group, and enter groups 1 and 2 into Groups 1 and 2, respectively. The above input result is the whole data operation process.
- 4. The average value of undesired cycling behaviors and illegal parking behaviors at Xiaonanmen Subway Station can be obtained. To test whether the above results are significant, it is necessary to continue to judge.
- 4. It can see whether there is a significant difference through the Levine variance equality test. Focus on results that do not assume equal variances if there is a significant difference in the F-test. If the F test result is insignificant, then look at the results of the assumption of equal variance. Secondly, pay attention to the value of SIG. If the value of SIG is more significant than 0.05 and less than 0.1, it can be considered that there is a certain level of significance (Watkins, 2011). Finally, it can be judged whether there is a significant difference between the degree of urban mobility system improvement and unruly riding behavior.

In addition, the follow-up experiment will continue to compare different subway stations according to the above steps. For example, the Xiaonanmen subway station is compared with Xi'an's well-urban mobility system subway stations. The Xiaonanmen subway station is compared with the subway station with an inadequate urban mobility system in Xi'an. During the data collection, it was mentioned that different unruly riding behaviors should be classified and counted by group. After a macro comparison, an independent sample T-test measures the corresponding urban mobility system:

- 1. As a new mode of transportation, how do dockless bikes integrate into the existing urban mobility system?
- 2. Is retrograde behavior related to the lack of continuous physically separated bike lanes?
- 3. Is riding on a red light because of a lack of obvious bike signs?

	1
Observation Method	Videos were captured using a smartphone camera and tripod at five subway stations (Xiaonanmen and Jiuting in Shanghai, Beidajie in Xi'an) over a period of three weeks, covering one week (Monday to Sunday) for each station. Daily observation included 30 minutes during morning peak hours (7:00-9:00) and evening peak hours (17:00-19:00), resulting in over 20 hours of video data per station.
Types of Behavior Monitored	Riding Behaviors: Not wearing a helmet; Riding under a red light; Riding against traffic; Not holding the handlebar with both hands; Riding on a non-bicycle lane. Parking Behaviors: Parking area of dockless bikes hinders passers-by or passing bicycles; Parking interferes with surrounding businesses; Dockless bikes not parked upright; Parking location impacts the surrounding greening environment.
Video Data Analysis	Videos were reviewed frame by frame to identify specific behaviors and coded using a standardized scheme by multiple trained researchers to ensure reliability. Coded data was compiled into a database for further analysis. The Independent Samples T-Test was used to compare the frequency of unsafe behaviors between different subway stations and urban areas.

Table 3.1 Summary of observation methods

3.3 Ethic and Risks

This study recorded the behavior of cyclists through video, including some unruly and unsafe behaviors. This study adhered to strict ethical guidelines, ensuring the anonymity and confidentiality of all individuals captured in the video data. The study was approved by UCL's ethics committee, and all data was handled in compliance with data protection regulations. Specific measures were taken to protect the privacy of individuals: all video data was anonymized by blurring faces and license plates, and only aggregated data was used for analysis. Additionally, the study ensured that the presence of cameras did not interfere with normal traffic patterns or pose any safety risks to cyclists or pedestrians. The research team also obtained necessary permissions from local authorities and communicated with the public to ensure transparency and minimize any potential concerns. Personal information about

cyclists, such as their appearance and identity, has been carefully handled. Furthermore, UCL's ethics committee approved this aversion.

Chapter Four: Empirical Analysis of Dockless Bicycle Usage Patterns and Urban Mobility System Integration in Shanghai

4.1 Introduction

In recent years, with the upsurge of the "sharing economy", dockless bikes have taken up a very heavy proportion of travel and commuter across the whole society and has gradually become a trend that cannot be ignored in urban development (Ly, 2020). This mode of travel, which used to serve subway and bus connections in the city, has now gained a lot of popularity across the whole city. In urban research, there is a need to study travel via dockless bikes in cities to understand the interaction between this travel mode, its interactions with the existing infrastructure and how to improve the infrastructure to improve the problem of irregular riding in DB_o

At the same time, the travel mode and irregular riding behavior of dockless bicycles are closely related to their temporal and spatial characteristics. Existing studies also show that revealing the temporal and spatial characteristics of the behavior mode of dockless shared bicycles is conducive to supporting vehicle scheduling and operation, thereby improving the status quo of irregular riding (Xu, 2023). Regarding the time characteristics of dockless bicycles, Ma(2020), Gebhart and Noland (2014) et al. concluded that shared bicycles are mainly used for daily commuting, and the number of trips in the evening and winter is significantly reduced. In terms of spatial characteristics, Chen et al.(2022) proposed that the current hot spots for bicycle riding on weekdays are mainly distributed in the vicinity of hightech industrial zones with a high density of employment population and companies, while on weekends, they are mainly concentrated in some commercial areas with more recreational facilities. Moreover, the density of dockless bicycles and irregular riding behavior were higher in employment centers and business centers during the morning and afternoon peak hours, while the opposite was true in residential areas. Therefore, it is necessary to study the temporal and spatial characteristics of dockless shared bicycles, and further analyze the relationship between the surrounding infrastructure and irregular riding behavior according to their temporal and spatial characteristics.

In China, first-tier cities are generally considered the best places for dockless bike-sharing investigations. The number of dockless shared bicycles in these cities is generally large and

widely distributed, which can better meet the commuting needs of urban residents. In order to understand how dockless bikes are used in first-tier cities, this chapter conducts a time and space analysis of original destination (OD) data of the GPS of dockless bikes in Shanghai. Through investigating travel modes of different time periods (weekdays and weekends) and different urban areas (old urban areas, new urban areas and suburbs) all dockless bikes in the whole city, combined with the point of interest (POI) information related to metro stations in the city, the relationship between existing travel modes and infrastructure is obtained.

Firstly, the chapter introduces and describes the OD dataset for dockless bikes in Shanghai, based on GPS and POI dataset from the map. Then, a time analysis was performed to identify the characteristic differences of dockless bike trips on weekdays and weekends and the relationship to infrastructure. Secondly, the spatial information is analyzed to identify dockless bikes have different travel patterns in different urban areas, and if these differences are related to the urban infrastructure construction and mobility system distribution in different areas. On the basis of spatial analysis, the time travel situation is then superimposed for further analysis. Thereafter, the travel time around the subway station is investigated, on weekdays and weekends, during the morning and evening peaks. Finally, through a differential comparison between the data volume of the travel time around the subway station and the data volume of the whole city in the same travel time, The characteristics of dockless bicycles in the whole urban transportation are discussed in terms of the relationship between the degree of infrastructure perfection in different regions and the travel characteristics and travel behaviors of dockless bicycles.

Through the analysis of these steps in this chapter, firstly, the time analysis proves that there is an obvious morning and evening peak on weekdays, and that there is almost no travel in the whole morning at weekends. Finally, it proves that dockless bikes mainly commute on weekdays. In addition to the reason of commuting, it is also because the volume of DB is more in the middle of the week, and the DB management facilities and methods are more sensitive. The spatial analysis shows that the trips of dockless bikes in the city center are much higher than those in the surrounding areas. Also, the area around subway stations is often the point of highest travel volume. This is because DB-related facilities are better in the city center.

In summary, this chapter aims to provide a comprehensive analysis of the temporal and spatial characteristics of dockless bicycle usage in Shanghai, focusing on how these patterns interact

with the existing urban mobility system. The analysis will highlight key findings and their implications for urban transportation planning.

4.2 Research Gap and Contribution

4.2.1 Objective

Dockless bicycles have become a critical research object of many scholars, especially since the rise of dockless bicycles can bring many beneficial effects to cities. Experts have been trying to understand the main factors affecting the use of dockless bicycles. Bieliński et al. (2019) argue that dockless bikes are considered an environmentally friendly mode of transportation. Due to the nature of dockless bicycles that can stop and go at any time, deploying a reasonable number of dockless bicycles is an effective way to solve traffic congestion. Experts have also found that DBs usage rate is positively correlated with the urban population, tourism, number of bicycle stations per capita, congestion, length of bicycle lanes and higher temperature, and negatively correlated with precipitation. Jaber et al. (2022) used least squares to reveal how spatial factors affect bicycle use. Budapest is considered the city with the best public transportation, and all urban areas are within a five-kilometre radius. Moreover, one-third of public transport stops are within 125 meters of bicycle parking spots. The analysis by GWR found that areas in city have more bike-share travels tends to be underdeveloped in facilities and public transportation. Lack of adequate urban mobility system can be dangerous and have adverse effects. Alcorn et al. (2013) analyzed the impact of different traffic environments on dockless bicycles. They believed there was a positive correlation between dockless bicycles and comfortable mobility system. Austin, Houston, and Texas demonstrated a positive relationship between recreational and dockless bike use. In urban research, dockless bicycles interact with transportation mobility system. Inadequate mobility system will lead to random parking of dockless bicycles. Predicting the number of dockless bicycles used can help city builders establish a sound mobility system.

However, a deep study and analysis are still needed to fill in how dockless bikes, as a new mode of transportation, is integrated into the existing urban mobility system of cities in China. Although the rapid development of dockless shared bicycles provides convenience for short-distance travel, there is still a gap in the coordination and complementarity with the current traffic Settings and systems, which puts forward new requirements for the integration of shared bicycles into the current environment and infrastructure. Through spatial clustering analysis, the

usage pattern and demand of dockless shared bicycles can be better understood. Spatio-temporal OD analysis is carried out in Shanghai, and point of interest (POI) information related to subway stations in the whole city is analyzed. As well as the situation of dockless bicycle travel screened by cluster analysis, it can discover in which regions the demand for shared bicycles is high. This analysis can provide a basis for optimizing the configuration of dockless shared bicycles. Add travel system Settings in places with greater demand to alleviate the adverse impact of the lack of travel system. Through data analysis of the demand for dockless shared bicycles, the use of dockless shared bicycles can be understood from the preliminary planning, so as to carry out corresponding urban strategy adjustment and planning, further improve the city's comprehensive transportation system, thus improving the overall transportation efficiency and improving the travel situation of residents. Therefore, the main objectives are as follows:

- To understand the usage of dockless bicycles at the subway entrance in Shanghai and conduct a temporal and spatial analysis of the original destination (OD) data of dockless bicycles in Shanghai.
- Investigate the travel situation in different urban areas on weekdays and weekends, and analyze the travel situation of Shuaixuan dockless bicycles through POI combined with clustering.
- 3. Through spatial clustering analysis, the departure and arrival data of GPS locations of dockless bicycles in Shanghai on weekdays and weekends in a specific week and the POI locations of Shanghai Metro are analyzed.
- 4. Combining Shanghai's cycling patterns with different travel characteristics with regional characteristics and time and conducting comparative analysis through empirical evidence.

4.2.2 Research Gap and Contributions

The existing literature provides a foundational understanding of dockless bicycle usage, primarily focusing on demand prediction through POI analysis and spatial attributes, as well as comparing docked and dockless bicycle systems. These studies have significantly contributed to understanding of the usage patterns and preferences of dockless bicycle users. However, a critical examination reveals certain gaps in this research domain.

Firstly, the above literature mainly uses POI to predict the demand for dockless bicycles, predicts the trajectory of dockless bicycles through spatial attributes, and focuses on the

differences between docked bicycles and dockless bicycles in terms of user needs and travel characteristics, as well as the differences between dockless bicycle projects. Gap between GPS track data. Li (2022) predicted the relationship between dockless bicycles and houses through space, and Li & Shuai (2020) and Kumar et al. (2016) also predicted the demand for dockless bicycles based on the POI. However, the above literature lacks an analysis of the driving factors leading to dockless bicycles. For example, what are the drivers that lead to different riding patterns?

Secondly, there is a lack of analysis of the impact of different types of mobility system on the travel of dockless bicycles. Although the above literature has proved that the mobility system environment has an impact on the travel demand of dockless bicycles, it lacks the classification of mobility system.

Thirdly, there is a lack of combined analysis of the travel time of dockless bicycles and regional characteristics. Are the different travel modes related to the combination of time and region? Are the different usage peaks related to regions?

Addressing the aforementioned gaps, this research contributes to the field from several pivotal aspects:

- Analyzing the use of dockless bicycles at different times is conducive to maintaining
 the supply and demand balance of the number of dockless bicycles in different
 periods. According to different regional characteristics, it can provide good parking
 spots for dockless bicycles according to the capacity of different locations.
- 2. To answer from a macro perspective, as a new mode of transportation, dockless bikes is how to integrate into the existing urban mobility system.
- 3. Reduce traffic jams and other negative impacts caused by excessive deployment of dockless bicycles in popular locations.

4.2.3 Research Question

Based on the above discussion, this chapter proposes the following 6 research questions. These six research questions are mainly qualitative research questions, aiming to discover the travel characteristics of dockless shared bicycles in urban areas. And explore whether

the difference of travel characteristics is related to urban construction and travel system (infrastructure). And the influence of time and geographical travel characteristics on travel. At the same time, explore the impact of the number and type of POI on dockless shared bicycles. And the purpose of the rider's trip. The above questions are helpful to understand the relationship between bicyclists and urban construction, travel system and POI according to their travel characteristics, travel purposes and travel methods, so as to put forward relevant opinions and suggestions for the integration of dockless shared bicycles into urban public systems.

- 1. Do dockless bikes have different travel characteristics in urban areas?
- 2. Are the travel differences of dockless bicycles related to urban construction and mobility system distribution in different regions?
- 3. What impact do different time and geographical characteristics have on the travel mode of dockless bicycles?
- 4. How does the mobility system affect the travel of dockless bicycles?
- 5. What impact does the number and type of POI have on dockless bikes?
- 6. What is the purpose of a dockless bike rider?

4.3 Study Area and Dataset

4.3.1 Study Area: Shanghai

Shanghai is chosen as the main research object of this paper. As shown in Figure 4.1, Shanghai is currently divided into 16 administrative regions. Shanghai is divided from Huangpu River in the southwest-northeast direction into two major plates, Puxi and Pudong. Puxi Seven Districts (right in Figure 4.2), together with the Lujiazui area in Pudong, are regarded as the center of Shanghai, area with excellent mobility system, high-rise buildings and a high employment rate. This study covers all administrative areas of Shanghai except Chongming County in the northeast corner.

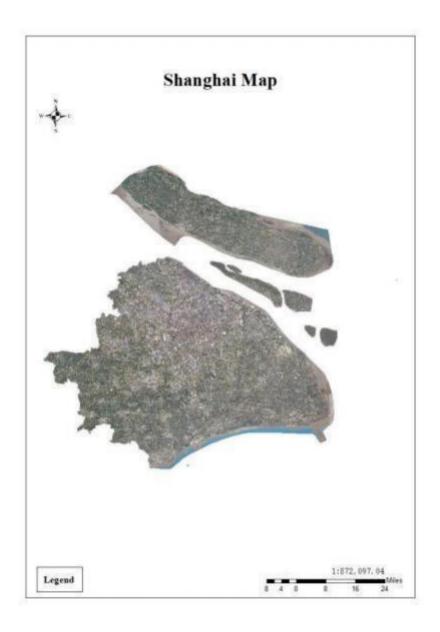


Figure 4.1 Map of Shanghai. Source: Author

According to the 14th Five-Year Plan for Shanghai Urban Transportation, the resident population and total travel volume in Shanghai will remain basically stable. In 2019, 32.42 million average daily trips were made by people in the central city on working days (an increase of 1.7% compared with 2015). Public passenger transport capacity continues to improve. In 2019, the average daily passenger traffic of public transportation in the city reached 16.47 million rides (an increase of 6. 1% compared with 2015), of which the average daily passenger traffic of rail transit reached 10.64 million rides (an increase of 26.5% compared with 2015), accounting for 64.6% of public passenger traffic.

The rail transit network is constantly being improved. In 2020, the operating mileage of rail transit was 729 kilometers, constituting the longest subway length in the world, compared with 399 kilometers in New York in 2020, 406 kilometers in London, 466 kilometers in Moscow, 225 kilometers in Paris and 708 kilometers in Beijing. Thus, Shanghai's rail transit boosts its convenience and advance, and also rail public transportation plays an important role in Shanghai's urban life.

According to the Shanghai Comprehensive Transportation Annual Report, in 2017 the public transportation system accounted for 33.2% of trips taken in Shanghai, while non-motor vehicles (including bike-sharing) accounted for 16.3%. Although Shanghai's rail transit has an absolute travel advantage, the distance between stations is often a problem for people. Since 2016, pileless bike-sharing has been very popular, with more than 30 private bike-share enterprises operating in China. In December 2016, Mobike and Ofo, two bike-sharing giants, operated more than 100,000 bike-sharing vehicles in Shanghai, making Shanghai the largest bike-sharing city in the world. By March 2017, Shanghai had a total of 450,000 bike-sharing, with 4.5 million registered users. According to the white paper China New Urbanization Research Institute (2017), in 2017, the usage rate of bike-sharing bicycles increased from 5.5% to 11.6%.

In Shanghai, dockless bike-sharing has become a new mode of commuting. Shanghai's dockless bike users are younger and mostly company employees. Some scholars have carried out studies on the riding mode of dockless shared bicycles in Shanghai, mostly focusing on the travel characteristics and their influencing factors. For example, Gao et al.(2021) analyzed the data of shared bicycles in Shanghai and concluded that the OD distance of most shared bicycles in Shanghai is less than 6km, the travel time is less than 40 minutes and the average travel distance and the time is 1.45km and 10 minutes respectively. However, the impact of irregularities related to infrastructure and dockless shared bicycles is less. Therefore, it is necessary to analyze the temporal and spatial characteristics of dockless shared bicycles in Shanghai, and point out the infrastructure distribution and construction in dense areas as well as the characteristics of riding behavior, so as to further guide and standardize the riding and parking support of shared bicycles, and take Shanghai as a pilot to create a benchmark for orderly cycling transportation system.

4.3.2 Dataset Description

In the research, transportation mobility system is regarded as the most relevant point with dockless bikes. Therefore, the POI data of Shanghai traffic system was collected to analyze the spatio-temporal characteristics of DB trips. Dockless bikes are considered by many people as the best tool to get to a bus stop, and to cover the last distance when commuting, in the workplace/residential area. Therefore, this paper studies and analyzes dockless bikes as a supplement to meeting public transportation needs.

Urban mobility system refers to the general material conditions required for the survival and development of society. Urban mobility system includes not only public facilities such as roads, railways, airports, communications, water, electricity and gas, commonly known as physical mobility system, but also social undertakings, such as education, science and technology, health care, sports and culture, known as social mobility system. Shanghai's transportation mobility system is mainly studied from the perspective of physical mobility system. From the POI point of view, bus stations and subway stations are the most obvious subjects for mobility system research. At the same time, Shanghai has the longest subway mileage in the world, and so is a very suitable research site for subway-related research. Shanghai'stransportation mobility system is mainly studied from the perspective of physical mobility system. From the POI point of view, bus stations and subway stations are the most obvious subjects for mobility system research. At the same time, Shanghai has the longest subway mileage in the world, and so is a very suitable research site for subway-related research.

The POIs were extracted and calculated using the Gaode Map POI program with 2,725 traffic reaords, among which the information includes location information (horizontal and vertical left), information type for POI points, graphic type, name of traffic station and type of traffic station. According to the classification of POI points, Shanghai's internal transportation mobility system stations are divided into three types: bus stations, urban subway stations and urban light rail stations.

At the same time, the data of shared bicycles will also be collected, including the order ID of Shanghai dockless shared bicycles, user ID, and track points during the cycling process. The two data will be jointly carried out spatial analysis in ArcGIS to identify the morning and evening peak demand for dockless shared bicycles around typical elements such as rail stations,

cycling traffic hotspots, traffic corridors and areas with contradiction between traffic supply and demand.

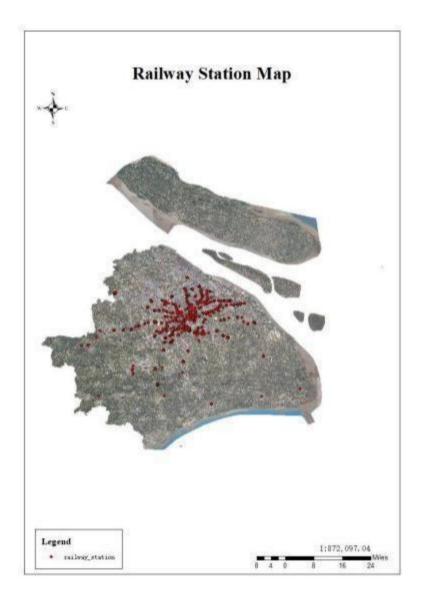


Figure 4.2 POI information for Shanghai traffic stations. Source: Author

4.4 Analysis of Results

Based on the proposed research questions, this section will analyze the spatio-temporal characteristics and spatial characteristics of shared bicycles in Shanghai, and answer the above research questions through POI data analysis. For the travel time data analysis, the data has been divided into two groups: working days and weekends. The data has also divided into departure data and arrival data, according to the data of each trip. This classification discussion can more intuitively cooperate with the travel space data analysis.

4.4.1 Temporal Signatures of Bicycle Usage

4.4.1.1 Time Period Analysis of Shanghai Dockless Bikes

As a basic element of travel information, first of all, the travel time and distance of Shanghai dockless shared bicycles were preliminarily understood. For the analysis of travel time, the arrival time of GPS data from dockless bikes is calculated by subtracting the departure time. Liu et al (2021) shows that 80% of Shanghai citizens cycle within three kilometres, and the per capita cycle distance is 1.8 kilometres. The average ride time using dockless bikes in Shanghai is 16.20 minutes. Among them, 6-8min orders are the most, and orders with a riding time of more than 1h account for a small proportion. According to the statistical data set, most of the travel time for bike-sharing is under 30 minutes, which shows that dockless bicycles are mostly used for short-distance travel. Taking cycling speed into consideration, most users travel under 2 kilometers. Among them, the orders of 1-2km are the most, about 80% of the orders are within 3km, and only a small part of the orders are more than 10km. This shows that most riding is for short periods of time over short distances. And it consumes physical strength, usually serving the last 1km of subway and bus travel.

Next, the use time period of people using dockless bicycles is analyzed. The time characteristics of the use of dockless shared bicycles determine the demand concentration of certain periods, and the carrying capacity of the complete degree and capacity of the infrastructure to these demands will directly affect the norms of user behavior. As mentioned earlier, GPS data for each trip contains departure time and location information and arrival time and location information, and the GPS data is divided into two groups: working days and weekends.

For the analysis of travel time on working days, take the arrival trip as an example: that is, the time when people park after riding a dockless bike. In Figure 4.3, it can be seen that there are two peak usage periods on weekdays, namely 7:00-9:00 a.m. and 5:00-7:00 p.m., which is consistent with the morning and evening peak periods of other modes of transportation. This also shows that the demand for shared bikes will increase during the weekday commute. This phenomenon shows that dockless shared bicycles, as a supplementary means of transportation, can meet the needs of residents in a short distance and time. This spike in use also shows that the use of dockless shared bikes can indeed ease the distance problem between transfers, help alleviate traffic congestion, and assume the role of sharing the pressure on public transport and urban roads. But at the same time, during these periods of concentrated use, shared bicycles often face parking difficulties, leading to the phenomenon of indiscriminate parking. However,

this regularity can in turn provide planning and management basis for the standardized use of shared bicycles, so as to better meet the needs of people at different time stages.

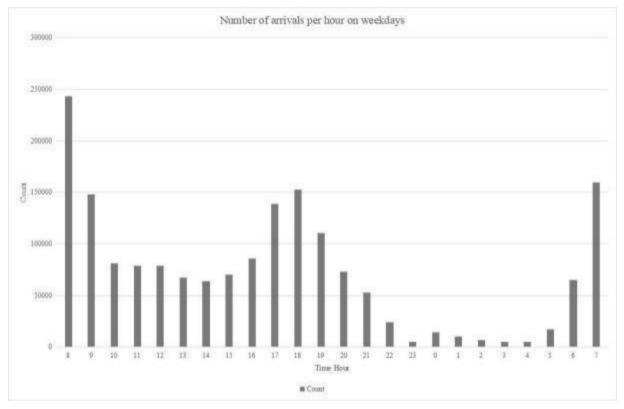


Figure 4.3 Number of arrivals per hour on weekdays. Source: Author.

In order to reduce the contrast variables for weekends, the arrival time of dockless bikes is used for the analysis. The distribution of usage on weekends is relatively uniform, as shown in Figure 4.3. There is only one usage peak on weekends: that is, the late peak period. In addition, the usage ratio from 10:00 p.m. to 5:00 a.m. on weekends is obviously greater than that on weekdays, which may be due to the lively weekend nightlife. However, the overall number of trips drops significantly compared with working days. This may be due to the fact that people who use shared bikes on weekends are mainly for leisure. Some short distance travel people will save money by walking or other ways because they do not have time constraints. In addition, some people will choose to stay at home on weekends, and this part of the population will also reduce the overall number of trips. Therefore, on weekends, due to reduced time constraints and higher freedom of travel choice, the overall peak tendency is less obvious than on weekdays, and the total number of trips decreases. Then, it can be found that, looking at the time period of 23:00 to 24:00 on weekends and working days at the same time, although the proportion of weekend usage obviously increases, the total weekend usage is not much higher than that on working days. On weekends, the use of users is more dispersed,

which may be due to the more diversified travel of weekend residents, involving entertainment, shopping, medical treatment, dinner and other activities, and the route of cycling may be different compared with weekdays. More focused on popular destinations around the city. Some locations where bike sharing is concentrated on weekdays may have relatively abundant bike parking space. And these popular gathering places such as shopping malls, scenic spots, parks, hospitals, etc., may have a shortage of parking space. However, although there are sufficient parking conditions in some areas, due to guidance and planning problems, random parking can still occur.

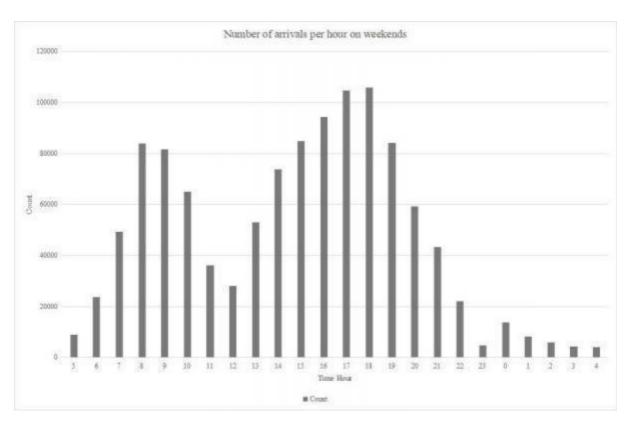


Figure 4.4 Number of arrivals per hour on weekends. Source: Author.

The analysis of dockless bicycle usage patterns reveals distinct temporal signatures, with significant peaks during morning and evening rush hours on weekdays. On weekends, usage is more evenly distributed throughout the day, with a notable increase in late evening trips. These findings suggest that dockless bikes are primarily used for commuting on weekdays and for leisure activities on weekends.

4.4.2 Spatial signatures of Bicycle Usage

4.4.2.1 Travel Spatial Distribution Characteristics Based on OD Data

As mentioned earlier, the GPS data of dockless bikes contains the latitude and longitude coordinates of the departure point and the latitude and longitude coordinates of the arrival point. However, it fails to store the coordinates of each point in the process, so observing the exact route of each trip is impossible, such as whether they are legally ridden, whether they are unreasonably parked in the roadside flower pool. Yet, through the analysis of the starting point-ending point, a insightful and impressive analysis can still be deducted. For example, the combination of regional characteristics and usage frequency can reveal the user's riding behavior pattern, regional demand distribution, and potential high incidence areas of irregular parking. Such analysis can provide reliable data support for planning parking areas

and guiding user behavior, so as to rationally plan the use of shared bicycles from the overall planning level. In addition, observation experiments or interviews can also be used to make up for the lack of data, directly record the specific behavior of cyclists, and understand the logic and reasons behind it. Through the combination of these means, the status quo can be integrated and analyzed to provide more comprehensive guidance for non-standard problems, and promote the optimization and sustainable development of dockless shared bicycles.

First of all, this study uses a remote sensing map of Shanghai with an accuracy of 30 meters. As shown in Figure 4.4, this map accurately shows the administrative divisions of Shanghai at the street network level and popular POI spots in the city, such as subway stations, shopping centers, high-end hotels, residential quarters and so on. Figure 4.7 is a screenshot of the map magnified 18 times, where it shows the street information (the two different colors are different levels of the road network), the red subway station logo on the left, the logo of the residential area above with the enlarged pixels. Urban building outline data is also needed, which is obtained from urban aerial orthographic images. Then, urban road network data and urban rail transit data are obtained from the latest updated Shanghai intersection vector map. A map of the Shanghai administrative region is shown in Figure 4.6. Figure 4.5 Shanghai's densely divided urban-rural boundary map is also the densely populated POI location. The basis for the urban-rural division of Shanghai can be obtained from the division of urban and rural physical areas in Shanghai. From the comparison of the divided urban and rural physical areas of various precision and types, it can be seen that, from the first precision to the fourth precision, the smaller the spatial unit is, the greater the workload of urban entity region determination is, so as the results and recommendations. Therefore, where the number of POIs gathers is also where the area division is dense.

Combing thermodynamic diagram of 4.8 dockless bicycles in the morning rush hour data, this survey can show that the main gathering places of this population are Xuhui District, Changning District, Yangpu District and Pudong New Area. These areas are concentrated in schools, commercial centers, office buildings and residential areas. Most of these travel destinations have good infrastructure conditions and are close to more bustling areas, and dockless bicycles are mostly distributed around rail transit stations, business office areas and residential buildings in these bustling areas. This shows that the use of dockless shared bicycles may be a fixed demand of some fixed people, mostly used for commuting, going to and from school, from school, company to home or bus, 1-3km from the subway station, and short-distance travel behaviors of users seeking efficient and economical travel tools. At the

same time, it also reflects that the main users of DB are students and office workers, and their behavior characteristics and needs should be fully considered in the setting of DB infrastructure. With the increase of the frequency of use, there will also be some temporary needs of users, mainly manifested in the increase of temporary routes, such as shopping, parks, emergencies and other scenes. Users will also mix some concepts of convenient, efficient and economical travel in their leisure and random behaviors.

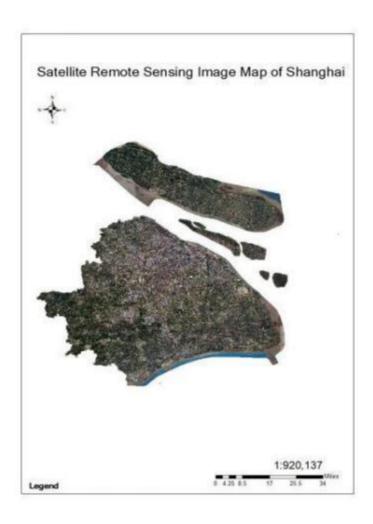


Figure 4.5 Shanghai remote sensing satellite map. Source: Author.



Figure 4.6 Remote sensing satellite map magnified 20 times Shanghai. Source: Author.

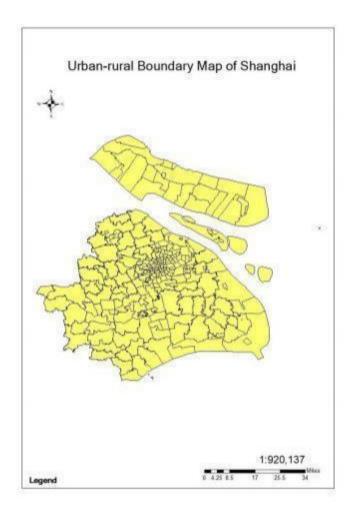


Figure 4.7 Urban–rural boundary map of Shanghai. Source: Author.

4.4.2.2 Density Characteristics of Spatial Distribution

The above paragraphs discussed the basic of spatial travel regional destination characteristics of dockless bike trips. This section will explore more specific travel destination characteristics, surrounding population needs, and infrastructure distribution. The travel volume on weekdays was found to be higher than that on weekends. Moreover, there are two peaks in dockless bike trips on weekdays, mornings and evenings, which have the highest number of dockless bike trips. Here, for the analysis of spatial characteristics, the morning and evening peaks of the working day, which have the largest amount of data for analysis, are directly chosen. First of all, gridding the bicycle data in Shanghai, extracting the arrival point data from the GPS data of Shanghai dockless bikes, and drawing a hot spot map, in which the grids are quantitative, of urban cycling according to the repetition times for arrival points in the satellite map. For the morning rush hour of a working day: for example, from 8: 00 to 9: 00 on May 11th, this research calculates the active bicycle density in different

areas by using the special raster attributes of raster data. The fields added during data preprocessing represent each bicycle. Using the Point-to-Grid tool, the next step is to select the SUM pixel allocation type to get the bicycle activity heat map (Figure 4.9).

After hotspot extraction, data classification and verification are carried out based on the matching of OD line radiation and absorption models, in which the data comes from the connection starting from the same name and reaching the bicycle point in unit time. Considering that the bicycle may be used many times, it can still be used to evaluate the activity trend in a short time.

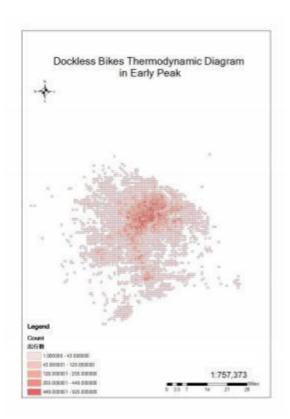
Here, the natural discontinuous segmentation method of 100m grid and Jenk is adopted. Although it only takes one hour, but the following findings are still confirmed. Firstly, it can be seen that there are obvious advantages to using non-stop bicycles DB in urban areas (areas within Shanghai Central). Also, from the perspective of shared bicycle parking spots, more and more citizens are inclined to choose the "shared bicycle subway" way to travel. Preliminary analysis can find that this is because in the central area of the city, dockless shared bicycles are more flexible than private cars and other public transportation, and it is easier to find bicycles that can be ridden or parked in the central area according to the indicating facilities, etc. The perfect types of facilities further strengthen the use of DB.

Secondly, Songjiang District and Yangpu District are the areas where the morning peak of cycling occurs, which is related to the concentration of colleges and universities and the early travel time of students in this area. As an area where education resources are concentrated, the student groups in these two areas are the main dockless shared bike users, and their travel needs are mainly short trips from home to school or nearby subway or bus transportation hubs. Compared with adults, the DB facilities here take more into account the characteristics of students, pay more attention to the construction of safety and humanization, and improve the road infrastructure and traffic management facilities, so the riding here is more intensive. For example, road transportation facilities will take into account the needs of students to ensure their safe riding and personal safety. The road infrastructure here has clear traffic signs and reminders to pay attention to students to ensure the safety of students. Some of these areas are also set up parking Spaces, using a combination of technology and manual methods to guide the correct parking of shared bicycles. This also shows that at the policy

level, we can gradually improve the construction and guidance of bike lanes, add special channels, and improve the safety of riders.

Thirdly, and most importantly, during the morning rush hour, more than half of the nonstop bicycles stop within 500m of a rail transit station. It can be seen from the distribution chart for the total frequency of days of loan and repayment that the parking frequency of non-stop bicycles is mostly concentrated around rail stations, business offices and residential areas. During the morning and evening peak hours, the demand for shared bicycles and parking at many popular subway stations, such as Shiguang Road Station, Lianhua Road Station, and Jiuting Station, increased significantly. This is because with the development of urban transportation systems, dockless bikes integrated with urban transportation systems are more popular because they do not need to return the bike to the designated location. The bustling urban rail transit station has a large demand for DB, complete parking facilities and sound cycling facilities, so DB is also used in agglomeration. In addition, it can also be found that the characteristics of cycling sites are mainly divided into the following categories. The first is the concentrated area of business and office. The cycling behavior in the morning and evening rush hours has different flow directions. The subway stations in the morning and evening rush hours are mostly the starting point of cycling, and the subway stations in the evening rush hour are mostly the end point of cycling. On the contrary, in the residential areas, the flow of cycling behavior in the morning and evening rush hours is opposite, and the subway stations in the morning rush hour are mostly the end of cycling, and the subway stations in the evening rush hour are mostly the starting point of cycling. This also explains the travel characteristics of residential or commercial office land in TOD mode, which are mostly commuter riding. There are also some scenic spots or commercial services that have the same morning and evening peak characteristics, subway stations are mostly the starting point for cycling, and passenger flow enters the area through rail transit.

Spatial analysis indicates that dockless bicycle usage is highly concentrated in the city center, particularly around subway stations and commercial areas. The density of usage decreases significantly in suburban areas. This spatial distribution highlights the importance of integrating dockless bikes with existing transportation hubs to enhance urban mobility.



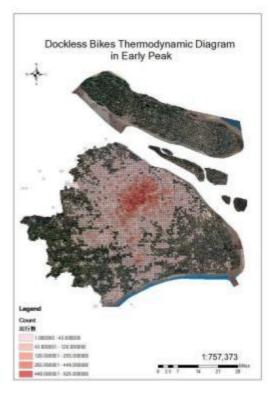


Figure 4.8 Dockless bikes thermodynamic diagram for the early peak. Source: Author

Up to now, this study has identified the temporal and spatial patterns of the dockless bike trip. However, there are still several questions to be answered:

- 1. How can we tell where people riding in the morning rush hour in downtown Shanghai want to go? Is the number of rides different for different types of destinations?
- 2. The riding destination for dockless bikes must have different time characteristics. For example, there may be a relatively large number of people riding to subway stations in the morning rush hour, and there will be more riding demand for dining at noon. How can we judge the travel characteristics of different types of places at different times?
- 3. OD data does not describe the behavior on the path. How can we learn about the riding behavior of the rider during riding? The accuracy of GPS data is also limited, and the riding behavior and parking behavior are unknown.

4. The first two questions will be addressed using the time-space analysis method. In regard to the latter question, I will make up for the shortage of GPS data by applying the observation method.

4.4.3.1 Distribution of Travel Spatial Characteristics Based on POIs

Nowadays, with the increasing mobility of cities and the geometric explosion of urban data, geographical big data provides a new opportunity for complex urban research. It can realize the simulation and deduction of geographical system, explore the development law and trend of urban space, mine valuable spatial information at a deeper level and scale, and enhance the service value of geographical information. POI refers to the point data of landmarks and geographic entities that are closely related to people's lives, such as schools, hospitals, shopping malls, parks, and government agencies. Its data sample size is large, covering rich information, which can reflect various activities in the city to a certain extent. POI data covers the location and attribute information of various urban facilities, and is the basic spatial big data used in urban research. POI basically contains four attributes, such as name, address, coordinate and category, which can be abstracted into an object for management, analysis and calculation in GIS. Distribution density, agglomeration trends and other characteristics of POIs are also important technical means for identifying urban centers and evaluating urban functional areas. In particular, the use of POI data is closely related to the characteristics of urban spatial layout, which can carry out information statistics, geographical positioning and expression of various public service facilities in the city, which provides great convenience for users, and helps users feel the distribution of various geographical entities more intuitively, so as to better understand the urban structure.

The distribution density of POI data is a field expression of spatial phenomena. From countries, regions and even global systems to cities, streets and communities, in the actual geographical space, the social and economic activities of human beings often show an agglomeration of several nodes at different spatial scales. The agglomeration centers with different intensity levels are formed in different spatial statistical units. Wang et al (2022) used shared bicycle data with POI data of Shanghai as a data source for a case study to measure the characteristics of travel patterns. The results can effectively explore the travel patterns of Shanghai dockless bike. Therefore, the core idea of city center identification is to simulate the concentration intensity of urban geographic space by

using the spatial point information of massive city POI data and the spatial relationship between its neighboring points.

POI data is the basic data based on Location service (LBS). It can be obtained from Open platforms such as Baidu Map, Amap, Google Map, and Open Street Map through the Application Programming Interface (API). Based on the API interface, some platforms, professional mapping companies and individuals have developed software to obtain POI data, such as bit and intelligence, BigeMap, Geosharp, etc., which has become an effective way to obtain POI data because of its convenience. Although the acquisition of POI data is realized based on location information service, the information contained in POI data from different sources is different due to different expression and application emphasis. In this study, POI related data was obtained through Baidu map for relevant analysis.

4.4.3.1.1 Working day trips using dockless bikes: taking subway stations as an example

In this study, travel data for Shanghai dockless bikes and POIs is classified and discussed with the spatial distribution density of dockless bikes. For example, the above-mentioned arrival trips of Shanghai POI and Shanghai dockless bikes during working days are used for cluster analysis with grouping the arrival points as arriving at traffic stations or as destinations without supervision. Here, subway stations among traffic stations are as shown in Figure 4.9.



Figure 4.9 Dockless bikes arrive at Shanghai metro stations on weekdays. Source: Author.

Looking at the whole map here, enlarging the picture further, in fact there are records of arrival trips around every subway station, with these stations being the working day destination. As shown in Figure 4.10, Century Avenue Subway Station in Pudong New Area of Shanghai is a large subway station where many subway lines pass through, including Metro Line 2 (the green line in the figure), Metro Line 4 (the purple line in the figure), Metro Line 6 (the pink line in the figure), and Metro Line 9 (the blue line in the figure). The subway station is a red and white circle symbol in the middle (also the symbol of the Shanghai subway). The many dots distributed on this big circle sign in the picture are the travel signs of dockless bikes. Every little point is a trip by a dockless bike with Century Avenue Subway Station as the destination during the working day. Therefore, after data processing, dockless bike trips to Century Avenue Subway Station on weekdays can be reflected. It can be seen that in the subway station where the subway lines converge, the concentration of dockless shared bicycles to the station is also higher on weekdays. This also reflects people's commuting characteristics, which is consistent with previous analyses of time

characteristics. However, it is worth mentioning that here we can clearly see the disadvantages of the big data processing method: that is, the accuracy of GPS used for civil/scientific research is obviously insufficient and the base map is blurred.

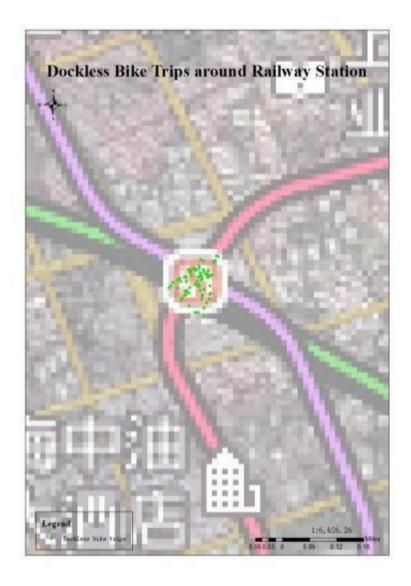


Figure 4.10 Dockless bikes arrive at Shanghai Century Avenue Subway Station on weekdays.

Source: Author.

Next, the nuclear density of these points is analyzed, meaning that subway stations will be selected to extract the heat of riding on working days, as shown in Figure 4.11. Note that there is no time feature here but only the feature of working days all day. This image already explains the spatial characteristics of the behavior of dockless bikes riding in Shanghai on weekdays, with subway stations as the destination. The heat map is made by means of stretching, a grading method of nuclear density analysis. The result of density analysis after stretching is graded in the heat map for dockless bike travel on weekdays.

Firstly, the thermal density in the downtown area is obviously greater than that outside the viaduct of Shanghai Outer Ring Road, which shows that the outer ring is the main area where

dockless bikes are used, and the arrival places of dockless bikes on working days are concentrated in the downtown area. This is also related to the gathering of people. As a firsttier city in China, the development of a city is similar to the outward expansion of a big pie. The central city has better resources and land, as well as more people. Therefore, the demand for traffic in central urban areas will be higher. According to incomplete statistics, Songjiang District gathers a large number of young people who are working hard in the city. They must go to the CBD every morning to start a day of hard work. Due to the high housing prices in the central areas of first-tier cities, although the central business district is located in the central urban area, young people will tend to rent in a far place, so young people working in the central business district will have more travel demand. Therefore, Songjiang District has become the earliest administrative district in the morning rush hour. The area of the evening peak is slightly different. Minhang District is the area where the evening peak occurs at the latest. 20% of users choose to travel between 17:00-17:30. As the central area between the middle and outer rings, Minhang District concentrates a large number of residents of Shanghai (Shanghai, 2020). Secondly, in the arrival areas in the downtown area, the subway stations along the Huangpu River is obviously hotter than dockless bikes, which shows that subway stations along the Huangpu River are areas where dockless bikes are parked intensively on weekdays. This may be because Huangpu River is the center river in Shanghai. Many people get off work at night from the North Bund CBD and Lujiazui CBD along Huangpu River, ride bicycles to subway stations along it, and then ride dockless bikes back to their places of residence. Besides, there may also be some residents living along riverside who set out from home in the morning working hours, ride a few hundred meters to a subway station, and take the subway to other places to work. It may also be that tourists ride dockless bikes to a subway station and take the subway back to their place of residence after visiting the riverside. While we can see the characteristics of the arrival points of dockless bikes on weekdays, we cannot know their specific travel purpose, which may be identified based on a study of the travel time and starting point.

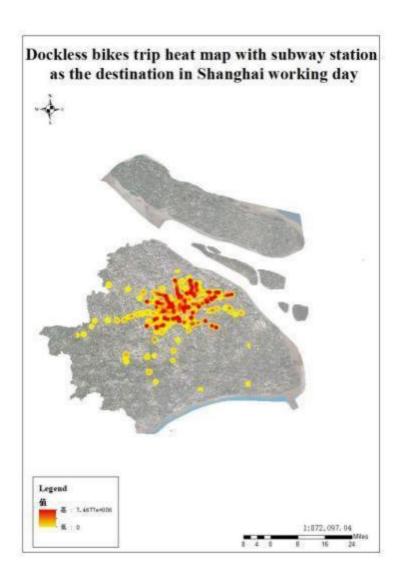


Figure 4.11 Dockless bikes trip heat map with subway station as the destination in Shanghai working day. Source: Author.

In particular, although the selection of clustering is carried out unsupervised, the distance is still a very important condition. First, POIs within 300 meters will be identified; otherwise, there may be a possibility that there is only one subway station within one kilometer, but clustering is forced. In order to verify people's travel mode on weekdays, each trip starting from the subway station with all the weekday riders departing there will be spatially analyzed this time. As shown in Figure 4.12 and Figure 4.13, trips starting from subway stations in Shanghai on weekdays are centered on subway stations in the downtown area and subway stations along Huangpu River, indicating that the demand for dockless bikes at the entrance of the subway stations in the downtown area and subway stations along Huangpu River on weekdays will be very large. On the one hand, it may be that the traffic with these subway stations is greater than that of dockless bikes in the surrounding subway stations, and, on the

other hand, it may also be that there is a destination that dockless bikes can reach that is not far from these subway stations. These destinations may be visited in the morning: people arrive at these subway stations by subway, choose this subway station as the starting point, ride a dockless bike to work in the downtown area. Alternatively, they may be visited at night, when people arrive at these subway stations by subway, choose to a ride dockless bike parked around this subway station and then ride home. This will depend on people's travel time. Similarly, before we can draw a conclusion we need to identify whether there is any change in the amount of travel on weekends. It is worth mentioning that downtown subway stations where dockless bikes arrive more on weekdays and subway stations along the Huangpu River have the same thermal density. This can be understood as reflecting the fact that subway stations where many dockless bikes are left are also popular subway stations where dockless bikes arrive. This is very consistent with the characteristics of people commuting to work: people take the subway to the vicinity of their place of employment, ride a dockless bike to get to the employment location, then leave from that location's gate at night, and ride a dockless bike back to the subway station to which they arrived in the morning. This daily commute will also ensure that dockless bikes are in the daily mode: commuting constitutes the distance of dockless bikes downtown subway station. Compared with arrivals of dockless bikes on weekdays, suburban subway stations often have more departure trips. So, on weekdays, many people choose to ride dockless bikes and set off for the last journey again after taking the subway to a suburban subway station. But these people do not ride back to this subway station in the same numbers. The same density of this activity pattern exists in many subway stations in the suburbs. From the perspective of commuting, the phenomenon that people only start at a subway station but do not ride back to the same subway station means that people arrive at a subway station in the morning not using a dockless bike, but they ride a dockless bike after work.

There is a very reasonable scenario to explain this: for many suburban families, in some families the father will drive the children to school in the morning and the mother will take the suburban subway to work in the urban area, because everyone's time for going to work and going to school is always the same; but when going to and from work at night, because of the uncertainty regarding when people finish work, mothers will often ride home directly after arriving at the subway station. In addition, this may also be because the morning work usually needs to arrive at the work place on time, so some people will choose to take a taxi and other ways to avoid the occurrence of late. People have more time off work and may prefer to use public transportation to get to their homes to save money or for other reasons.

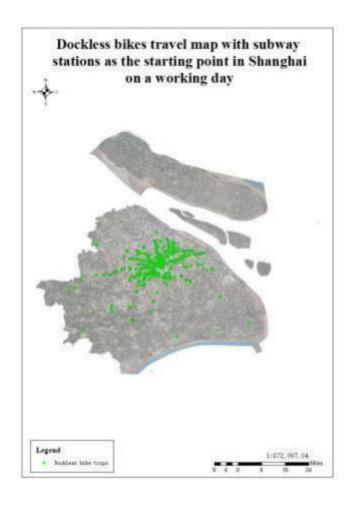


Figure 4.12 Dockless bikes travel map with subway stations as the starting point, in Shanghai on a working day. Source: Author.

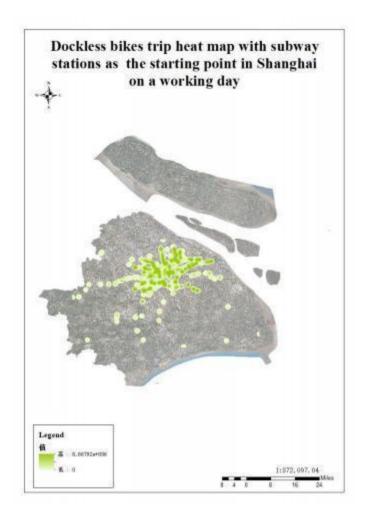


Figure 4.13 Dockless bikes trip heat map with subway stations as the starting point in Shanghai on a working day. Source: Author.

4.4.3.1.2 When we assume that all travel is for the purpose of connection

At present, the results of my research are based on all POI points in Shanghai: the transportation mobility system, such as subway stations and bus stops, as well as other types of building facilities, such as hotels, residential areas, restaurants, business districts, supermarkets, are considered in my research and analysis process.

In the process of the research, it was also considered whether all the trips of dockless bikes should be treated as connecting trips and calculated with the ratio of the connecting trips in all trips. Still, the analysis here omits the influence of all other building facilities, and assumes that all trips are destined for transportation mobility system.

Similarly, take Century Avenue Subway Station as an example, without considering the influence of restaurants, companies and residential areas around Century Avenue, all rides to Century Avenue are assumed to take the subway to Century Avenue Subway Station. After processing the data, the spatial analysis results for arrival trips on working days are shown in Figure 4.14. It can be seen that the number of trips has greatly increased, providing an analysis basis for comparison among various stations. At the same time, however, it can be noticed in the figure that many trips outside the distance of a traffic light are also regarded as trips relating to making a subway connection, which is obviously inappropriate.



Figure 4. 14 When only considering the spatial distribution of the connection function: arrival trips on weekdays at Century Avenue Subway Station. Source: Author.

Because of the difficulty to define all trips as the same travel mode in the city's dockless bikes, it is obviously inappropriate to assume that all trips are connecting trips. Therefore, this research method was discarded.

4.4.3.1.3 Weekend trips using dockless bikes, taking subway stations as an example

In this part of the chapter, trip data for dockless bikes with POI data for subway stations in Shanghai on weekends is chosen and conducted with a spatial analysis. First, similarly, rips to subway stations at the weekend are analyzed and then grouped weekend dockless bike trips into trips to subway stations by cluster analysis. The spatial distribution of these trips is shown in Figure 4.15, and a trip heat diagram after nuclear density analysis is shown in Figure 4.16. Secondly, for

weekend trips, trips with a subway station location as the starting point for dockless bikes are shown in Figure 4.17, while Figure 4.18 shows the weekend riding heat map with subway station locations as the starting point after nuclear density analysis. From Figure 4.15 and Figure 4.16, it can be seen that the main focus of travel is still the downtown location, and subway stations in the downtown location and subway stations on the west bank along the north bank of Huangpu River have obvious travel heat. This shows that the smaller downtown area still receives a larger number of trips, regardless of departures or arrivals. This also shows that the concentration of people affects the travel range of people. Central areas often gather more resources and activities, these factors affect people's travel demand, and also reflect that areas with high population concentration tend to become hot spots for travel, so it is necessary to deepen the construction of facilities and public transportation management in these areas.

It is worth mentioning that there are many stations on the north bank of Huangpu River where the subway station is the arrival point on the weekend, though this is less than arrival trips on weekdays. In other words, this shows that after the number of people who come to work on the north bank of Huangpu River on weekends decreases, volumes in these subway stations, which are mainly located in business districts, in terms of being the riding destination of dockless bike trips, also decrease accordingly. The number of people riding to subway stations is relatively reduced on weekends, so we can analyze that in the area on the north bank of Huangpu River, the main purpose of riding to the subway station is to commute to work. Weekend commuting is relatively rare, but the travel of surrounding residents still relies on public transportation and its station activities, so the guidance and planning of dockless shared bicycles around subway stations also need to be reasonably planned and set according to the common needs of working days and weekends.

According to the map of Shanghai, firstly, the subway stations near the Huangpu River span Hongkou District, Huangpu District, Pudong New Area, Xuhui District, Yangpu District, Baoshan District, and Songjiang District; while Yangpu District and Huangpu District, Pudong New Area and Xuhui District all belong to Shanghai's transportation network, places with high density and with a large number of POIs gather. Secondly, the map area of the popular areas of these POIs is only one-twentieth of the entire Shanghai. It is also the densely divided urban-rural boundary map of Shanghai. Due to the small area of these areas and the significant

traffic flow, dockless bicycle travel has also become one of the main ways for short-distance travel. Therefore, when office employees and students arrive at the subway station, using dockless bicycles as the last mile is the most reasonable way to travel during traffic congestion. This also shows the important role of dockless shared bicycles in channeling traffic demand, as a flexible and convenient mode of transportation, which can provide residents with fast passage services in subway stations and core areas of the city. The dockless shared bicycles in these key areas should be synchronized and reasonable planning by the government and the operator according to the gathering status quo and the characteristics of the use time, so as to achieve changes in the demand of different regions.

Judging from the time distribution characteristics of Mobike cycling users within a week, the total number of users on weekdays is more significant than on weekends, indicating that cycling traffic serves commuting traffic to a large extent. Among them, there are apparent peaks in the morning and evening on weekdays. The duration of the morning peak is short, and the increase in cycling volume is relatively rapid; the duration of the evening peak is long, and the increase in cycling volume is relatively gentle. In addition, there is a local noon peak, consistent with some users having meals nearby at noon and going out for errands. On weekends, cycling traffic is dominated by non-commuting traffic, and the distribution of periods is relatively balanced, with no apparent peaks in the morning and evening. The weekend peak usually gathers in the evening, mainly for rest, entertainment and leisure traffic. Judging from the spatiotemporal distribution characteristics of cycling traffic within a week, the most significant demand of shared bicycle users is mainly concentrated in the evening peak of working days, also the peak use of shared bicycles (Wu, 2020).

Guo Xinye (2019) evaluated 28 commercial circles in Shanghai and found that the commercial markets in Huangpu District and Pudong District on the north and west banks of the Huangpu River have huge potential, including shopping malls such as IFS International Financial Center and Yaohan. The total retail sales of social consumer goods in Pudong District still ranks the top among securities companies. It is equivalent to synthesising the four core commercial areas of Huangpu, Jing'an, Xuhui and Changning. Therefore, this also explains why the north bank of the Huangpu River and Xi'an also has apparent travel fever on weekends.

On weekends, the characteristics of cycling are mainly in the city center, but the relative proportion of cycling in the suburbs is higher, both in terms of departures and arrivals, suggesting that on weekends, dockless bikes can play a role in the suburbs of Shanghai. On weekends, people will take the subway to the suburbs and ride dockless bikes for fun. At the same time, this also shows that compared with the central area, the distribution density of the urban transportation network is different, the density of the suburb is low, the service radius of public transportation is large, and the frequency of traffic is also low, so the dockless shared bicycle is a better choice for suburban travel. You can travel immediately. At the same time, with the changes in the lifestyle of urban youth, cycling has also become a way for people to exercise on weekends. Dockless bike riding has gradually become one of the weekend life choices for young people. However, this kind of riding is mainly in one of the public places, such as parks, some attractions along the river and other leisure urban areas.

Comparing Figure 4.17 and Figure 4.18, namely comparing working days and weekends, it can clearly be seen that the travel density of several subway stations on the north side of Huangpu River has decreased. The number of subway stations that are travel destinations is relatively reduced. This shows that in the area on the north bank of the Huangpu River, weekend travel is more concentrated in the main POI area, rather than cross-regional flow. This is related to regional urban planning, construction and positioning. This positioning also affects the difference between people's travel on weekdays and weekends, providing a basis for transportation planning and management.



Figure 4.15 Dockless bike trip map with subway stations as the end point of cycling in Shanghai, on weekends. Source: Author.

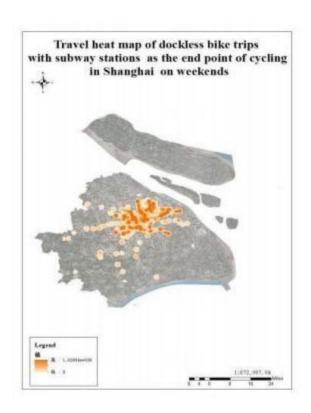


Figure 4.16 Travel heat map of dockless bike trips with subway stations as the end point of cycling, in Shanghai on weekends. Source: Author.

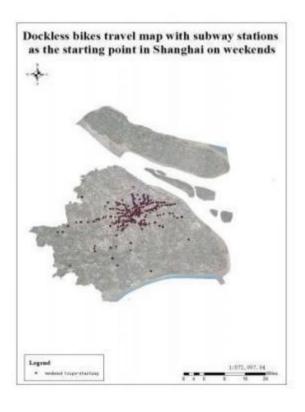


Figure 4. 17 Dockless bikes travel map with subway stations as the starting point in Shanghai, on weekends. Source: Author.

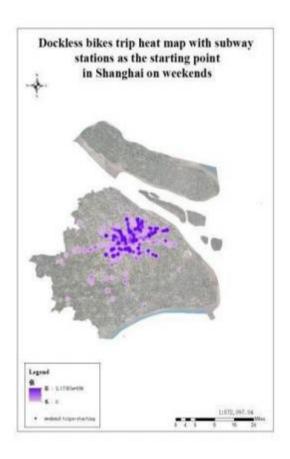


Figure 4.18 Dockless bikes trip heat map with subway stations as the starting point in Shanghai on weekends. Source: Author.

4.5.3.2 Travel Mode Analysis Based on Cluster Analysis: Taking Bus Stops as an Example

In the previous steps in the research, the spatial characteristics of various POIs are obtained. Now, combined with the GPS time information of each trip, according to POIs around the starting point and destinations of bike-sharing trips, cluster analysis is carried out on working days and non-working days (weekends) to find the time distribution of departure and arrival in bike-sharing under each travel mode.

Take the travel of tourist attractions as an example for analysis. The purpose of this trip is also summarized in Table 4.1. Obviously, places for dining are the most popular destinations for non-stop bike-sharing users, accounting for 22.53% of all trips. Transfer points for other public transport options and shopping locations follow closely behind, accounting for nearly 20%. Among the six most popular destination types, the least common use of dockless bicycle sharing is going home, accounting for about 10%.

Table 4. 1 Percentages of different trip purposes

Percentages of	different to	rip purposes.
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Bike-sharing trip purpose derived from different bike-sharing travel patterns	Percentage
Dining activity	22.53%
Transferring to other public transport modes	19.58%
Shopping activity	19.23%
Work-related activity	15.66%
Integrated location	12.15%
Going home	10.85%

According to the White Paper on Bike-Sharing and Urban Development 2017, about one-fifth of users in China ride bicycles to get to a subway or bus connection, and one-third of users ride bicycles for leisure-related activities. DBs have brought about significant changes in urban travel modes. Before dockless bikes became popular in China, bicycles only accounted for 5.5% of traffic mileage, while at present, the proportion of those undertaking trips by bicycles has increased to 11.6%. It should be noted that Shanghai residents are more inclined to use bicycles as an auxiliary tool for commuting, and the average riding distance is the shortest among the 36 cities surveyed in China, which leads to a slightly higher proportion of trips as against other public transportation systems, as compared to other cities. This is also deeply related to the wide coverage and high network density of Shanghai Metro. Therefore, more and more people use shared bicycles without stops to connect to the subway, and the usage of bicycles has thus increased significantly.

For bus stops, the core purpose of attending bus stops through DBs on weekdays is to commute. Both the number of trips to, and the number of public transportation shifts at, bus stops are much less than those on weekdays. For these POIs, weekdays and weekends have obviously different travel characteristics. On weekdays, similarly, the function almost refers to commuting. It also has the greatest impact on traffic stations. The morning and evening rush hours are the busiest time for subway stations. Songjiang District and Yangpu District are the areas where the morning cycling peak occurs first, which is related to the concentration of universities in this area and the early travel of students. The evening peak shows the characteristics of agglomeration towards the central city. The area where the evening peak of travel occurs the latest is Minhang District where 20% of users in this area choose to travel between 17:00-17:30. After 8:00 p.m., the most concentrated areas of cycling activities are mainly distributed in Daxue Road, Xujiahui, Tianzifang and other places in Yangpu District. These areas also have the highest concentration of business offices, attracting people to participate in various night activities (Shanghai, 2020). As can be seen above, the use of DB is mainly based on the use needs of the population, combined with the layout and context of urban construction and development, to form the purpose of travel, the

scope of travel and the time period. Therefore, when studying the impact of dockless shared bicycles on urban traffic, both users (crowd needs) and planners (urban construction, transportation system) should take into account.

When studying the mode of DBs trips and the influence of dockless bikes on the urban transportation system, subway stations, especially those with the subway mainly serving urban commuting, are a very good starting point to answer the question of how dockless bikes around subway stations are used differently during different time periods on weekdays and weekends and how people use dockless bikes in different time periods, which is of great significance for understanding how dockless bikes are used in Chinese cities. At the same time, it is also of great significance for how this travel mode can be used to better improve transportation mobility system in the city.

4.4.3.2.1 Analysis of travel mode through space-time analysis

In this part of the chapter, on the basis of the preceding time analysis and the preceding space analysis, all types of trip POIs in the city are clustered by cluster analysis, and time periods are divided and calculated in different places, so that the number of dockless bikes can be calculated starting or arriving during this time period around a given trip point type. Through the comparison of this data, the usage of these bicycles can then be analyzed during different time periods around these POIs. The cluster analysis reveals that the most common trip purposes on weekdays are commuting to and from work, with significant usage around subway stations. On weekends, leisure activities such as shopping and dining become more prominent. The results of the t-test indicate that there is a statistically significant difference in the number of dockless bike trips between weekdays and weekends (p < 0.05), suggesting that usage patterns are highly dependent on the day of the week.

The analysis involves clustering all subway stations in Shanghai into the same data model. The influence of this data model on dockless bike trips is also obtained by analyzing the trip volume. A few hypothetical cases are introduced to explain here.

The first case is the comparison in the same time period. Within a certain time period, the amount of departure data in the same time period is far greater than the amount of arrival data, which shows that this data type (that is, a POI in real life, which is only clustered into a data model in my research) is more of a destination for dockless bikes. In practical terms, in the actual planning process, the number of bicycles can be reduced for this point.

The second case is the comparison of different time periods. For example, on the same day, there is a period of time when the number of dockless bikes used around subway stations suddenly increases. On a working day, the reason for this situation can be the morning and evening peak times; yet, on weekends, further discussion should be introduced. There may be a policy of restricting private transportation, or public transportation may just stop or reduce operation at that time.

The third case is the comparison between working days and weekends. For each different POI, people's travel on weekdays and weekends is different. For example, the CBD of a city is the most intuitive example. However, many transportation mobility systems have not built different transportation supporting facilities according to different POI building types in cities. For example, around tourist attractions, the peak usage period for dockless bikes may not be the morning and evening peak on a working day but rather at the time with a good weather.

The fourth case is the comparison of the number of trips between different POI types. This shows where people are more willing to use this new way of travel. At the same time, for different modes of travel, more people use dockless bikes around this POI, which has different requirements for supporting the transportation mobility system of this POI-type building in the city. Maybe bicycle lanes and bicycle parking areas should be adjusted to match the use of both bicycles and motor vehicles. In addition, it may also explain the acceptance of dockless bikes by different income groups and age groups.

In this part, only the usage of dockless bikes around subway stations is analyzed. Here, subway stations are chosen as the typical representatives of urban transportation

mobility system. On the one hand, it is common for people to use subway stations in Shanghai, a city with the largest subway mileage and the most stations in the world, and people who use public transportation are often more willing to choose to use dockless bikes. On the other hand, compared with public transport buses, the requirements for urban mobility system construction are higher, and it is better to analyze how urban transport facilities can better integrate and absorb dockless bikes.

4.4.3.2.2 Analysis of travel modes used on working days: taking the vicinity of subway stations as an example

In this part, the time and space of bicycle travel around subways on the working days travel mode are analyzed. Working days are said to account for the most important challenge of transportation mobility system. The livability index of many cities and the happiness index of urban residents in many studies are closely related to commuting efficiency on working days. As a new type of travel mode, commuting efficiency on weekdays will also be the first major focus of research.

Dockless bikes trips around subway stations can be regarded as the purest way of commuting. An analysis of the departure itinerary around subway stations (Figure 4.19) on weekdays shows that there are two obvious peaks of travel on weekdays, which correspond to the morning and evening peak hours of weekday travel. In the morning rush hour, the number of urban residents riding from subway stations in Shanghai starts to increase significantly from 6:00 a.m., continues to increase through 7:00 a.m., reaches the highest value at 8:00 a.m., and then drops at 10:00 a.m.. The method of K-means cluster analysis is again used to calculate dockless bike trips around subway stations on weekdays and weekends. This was also divided into departure data and arrival data, and these data were analyzed as a whole. Based on the results of the spatial analysis, it can be concluded that dockless bike trips around subway stations during working days are concentrated in Puxi area in the city center, along Huangpu River and near subway stations near Shanghai Central. During the weekend, the downtown area of Puxi and Huangpu River are still important travel areas, but subway stations near Central, which is mainly a commuter station, are not so hot. This also proves that the use of dockless bikes in the downtown area is much higher than that in the surrounding areas. Dockless bikes are shown to be a mode of transportation for travel in cities, either on weekdays or weekends.

This part has provided a superposition analysis of time and space. In this part, based on spatial analysis, time travel was superimposed for further analysis. Finally, the travel time periods around subway stations on weekdays and weekends are obtained, as well as the travel situation in the morning and evening peaks. And through a differential comparison between the data volume of the travel times around subway stations and the data volume of the whole city in the same travel time, we finally investigated the influence and choice of dockless bikes in regard to urban public mobility system. This difference requires close attention to in further urban planning, especially the part that matches the development of dockless bikes.

It is worthy of recognition in this part of the research to focus on the relationship between transportation mobility system (subway stations) and dockless bikes. Meanwhile, it is the first research to think about the use of dockless bikes from the perspective of mobility system. There has been much research on dockless bikes in cities around the world, as mentioned above, but none of them focused on the urban mobility system. Transportation mobility system, as a very important development factor for urban construction, must be considered in future urban construction. Of course, the subway is not a broad sense of transportation mobility system but still a critical and representative one in the transportation mobility system, so studying the subway station as a narrow sense of mobility system gives insightful results.

Dockless bikes will be an indispensable part of the future city. The research fills the gap between them. However, there are still some shortcomings in this part of the data analysis. The biggest shortcoming is the lack of accuracy of GPS. In order to seek more accurate data, further observational research should be introduced. And because Shanghai has the largest subway mileage in the world, it cannot be said that the situation around the Shanghai subway will fully reflect the situation around subway stations in other cities around the world, a second-tier city, Xi'an, to compare and contrast with Shanghai, is included.

In regard to evening rush hour travel, Shanghai residents show an obvious increase in usage at 5:00 p.m., reaching a peak at 6:00 p.m.. There is an obvious data gap: travel data for the morning peak is much higher than that for the evening peak, suggesting that the number

of people riding from subway station to subway station in the morning rush hour is higher than the number of people riding from subway stations in the evening rush hour. The reasons why there are more people riding from subway stations in the morning rush hour may be that people live around subway stations located far from the city center, so the living cost will be lower. But for urban development, there are a large number of enterprises and employment opportunities in the city center. For most people, it is impossible to live within walking distance of their work location. People tend to live in the suburbs to reduce the cost of living, and choose jobs in the center of the city to get higher labor remuneration. In terms of subway distribution, subway stations in suburban areas are often located far apart, and subway stations in urban centers are often located closer together. In the morning rush hour on a working day, dockless bike cyclists start from their place of residence, ride to the subway station, change to the subway, take a bicycle from the subway station and finally reach their workplace. According to the daily total frequency distribution map, it can be seen that the surrounding areas of rail stations, commercial office areas, and residential areas are the areas where shared bicycles are most frequently parked and used. According to statistics, within the area of 500 m around the subway station, shared bicycle parking accounts for 51% of the total parking spots in Shanghai.

Chen Jie (1998), director of the Housing and Urban-Rural Construction Research Center of Shanghai Jiaotong University, found that nearly 83% of Shanghai's migrant population rented houses, and nearly 20% of the local population rented houses. The two figures together accounted for about one-third of the permanent population. He also found that the increase in housing in Shanghai in the past ten years was mainly concentrated in new cities and suburbs. Most of the existing young people in Shanghai will rent houses in the suburbs. Therefore, the demand for dockless bicycles in the suburbs increases on weekends because most of the population in the city centre has moved to the suburbs, resulting in a higher proportion of cycling in the suburbs (New Delhi, 2021).

The reasons why there are more people riding from subway stations in the evening rush hour may be various. First of all, dockless bikes in the downtown area are not adequately supplied in crowded spaces during the off-duty hours. Personally, it can be not very easy to ride a dockless bike during the evening rush hour in the downtown area. The supply

and demand situation of dockless bikes during the evening rush hour in the city is not very balanced. Although the city center has a small spatial scale, it has a large population. During the evening rush hour, a large number of people will suddenly appear in the downtown area. The insufficient number of bicycles will mean many people are unable to ride, which will eventually lead to the number of people riding from subway stations in the evening rush hour being significantly less than that in the morning rush hour. Secondly, for those who take the subway, the travel direction of people in the evening rush hour is from the company location to the subway station and then to their home, and the travel direction of people in the morning rush hour is from home to the subway station and then to the company. As just mentioned, the spatial scale of the city center is small, unlike in the suburbs, and most people cannot live in the core areas of the city. Therefore, in the trip from the subway station in the morning rush hour people take the subway from their suburban homes to subway station around the company and ride a short distance from the subway station to the company. However, by contrast, in the evening rush hour, when people take the subway to suburban subway stations, the distance to ride home often exceeds that for which people usually choose dockless bikes. Maybe the distance is the main reason why people choose dockless bikes. Of course, these analyses have to cooperate with the number of rides from subway stations on working days before the final conclusion can be drawn.

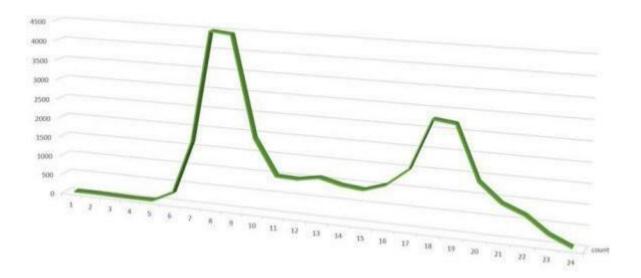


Figure 4. 19 Dockless bike trips from around subway stations on weekdays.

Therefore, it is also very important to ride dockless bikes to the subway station on weekdays. As shown in Figure 4.20, the number of first trips is within one day, and there are morning and evening rush hours. Different from trips from subway stations, the peak number for the morning and evening peaks of arrival trips is basically the same. This also confirms the conclusion mentioned earlier. Many people live in the suburbs, and there is no way to ride from their place of residence to the subway station in the morning rush hour, which results in the peak gap in dockless bike travel in the middle and morning rush hour in the city. However, in the evening rush hour, the basic number of trips and arrival trips is the same, which is probably caused by an insufficient supply of bicycles in the city center, as mentioned earlier. According to this finding, the supply of bicycles should take into account the characteristics of people's riding, and suppliers should reasonably launch and manage dockless shared bicycles to meet the needs of the population. This demand should be estimated according to the number of residents accommodated by the surrounding residential land and the population within the service radius of the subway station. In addition, dynamic research correction is also necessary. The number of dockless shared bicycles that need to be put into a subway station can only be roughly estimated according to the population residence, but the specific needs to be reasonably allocated and adjusted according to the actual situation. On weekdays, the morning and evening rush hours see the highest volume of dockless bike trips, with significant usage around subway stations. The data suggests that dockless bikes are primarily used for commuting purposes. This finding underscores the importance of providing adequate infrastructure to support high-demand periods and locations.

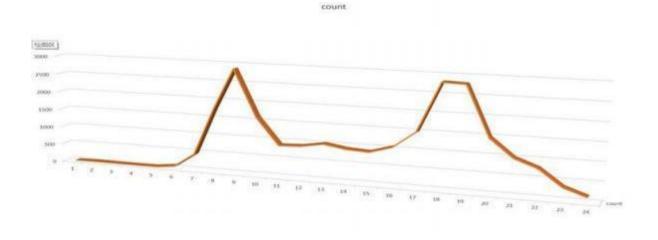


Figure 4.20 Dockless bikes trips to subway station on working day.

4.4.3.2.3 Differences in trips around subway stations on weekends

It has often been argued that dockless bikes, as a travel mode that is designed for urban commuting, solve the problem of people's travel within 1km after transferring from their main means of transportation in their daily commute. According to this main travel logic, the main travel mode should be obviously reduced from working days to weekends. Working days should be compared with weekends. First of all, the number of trips should be obviously more than that on working days. Weekend trips should have morning and evening peak performance that is different from that for working days. In Figure 4.21, the orange line is the number of rides departing from the vicinity of a subway station at each time on a working day, and the blue line is the number of rides departing from the vicinity of a subway station every hour from morning till night on a weekend day. The orange line is always higher than the blue line, and there is only a brief situation where they almost cross, at 3:00 p.m.. The working day has obvious morning and evening peaks. Relatively speaking, the number of morning peaks on weekends is obviously reduced, and people's trips in the afternoon, especially between 2:00 p.m. and 6:00 p.m., are obviously increased, which is also in line with the time rule regarding people going out to enjoy leisure activities on weekends. Many people prefer to have a rest rather than go out in the morning, and then go out in the afternoon. And starting from around the subway station, compared with other ways, it is not a very important travel proportion. It is worth mentioning that the total number of trips on a working day is 1.76 million. On a weekend day, the total number of trips is 1. 11 million. That is to say, the total number of trips is about 60% of the working day. Proportionally speaking, the morning and evening rush hour travel around subway stations is reduced by more than 30%. Therefore, when the overall travel proportion on weekends is expanded to start from around subway stations, travel in the afternoon on weekends is obviously greater than that on weekdays, but the function of commuting is obviously reduced. At the same time, as shown in previous section, trips along the river bank obviously increase on weekends, which means that many people turn their bicycles from subway stations to relaxing energy on weekends, instead of simply starting from subway stations and going to their work units. Judging from the time distribution characteristics of Mobike cycling users within a week, the total number of users on weekdays is more significant than on weekends, indicating that cycling traffic serves commuting traffic to a large extent. Among them, there are apparent peaks in the morning and evening on weekdays. The duration of the morning peak is short, and the

increase in cycling volume is relatively rapid; the duration of the evening peak is long, and the increase in cycling volume is relatively gentle. In addition, there is a local noon peak, consistent with some users having meals nearby at noon and going out for errands. On weekends, cycling traffic is dominated by non-commuting traffic, and the distribution of periods is relatively balanced, with no apparent peaks in the morning and evening. The weekend peak usually gathers in the evening, mainly for rest, entertainment and leisure traffic. Judging from the spatiotemporal distribution characteristics of cycling traffic within a week, the most significant demand of shared bicycle users is mainly concentrated in the evening peak of working days, which is the peak use of shared bicycles (MobiCASE, 2020). According to this finding, the release of dockless shared bicycles on weekends should take into account the nature of the land around the subway station, including the location of businesses, parks, waters, and people gathering places. Compared with the concentrated use on weekdays, weekends tend to be dispersed in some important nodes and lines and surfaces in cities. In addition, it can also be combined with big data analysis and dynamic changes in user behavior patterns to make appropriate dynamic adjustments to provide support for the construction of urban comprehensive public transportation.

Departure Riding on Weekday and Weekend

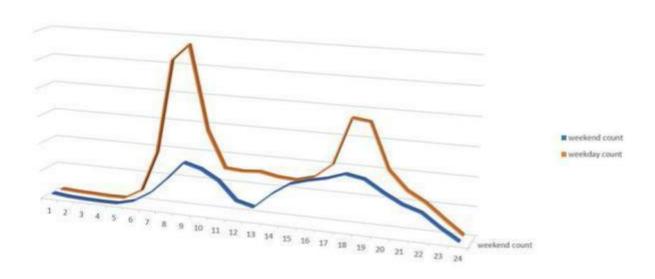


Figure 4.21 Comparison of departure trips around subway stations on weekends and

weekdays.

Similarly, a cluster analysis of other riding behaviors is conducted. Here, a cluster analysis chart of each POI starting on working days and arriving on working days, starting on weekends and arriving on weekends, displays that all the 14 POIs mentioned above are used for this analysis, with a total of 208 analysis charts and heat maps. Due to space limits, only tourist attractions are shown as an example. It is worth noting that, after clustering the spatial distribution of riding in these POIs, the time characteristics will be further analyzed to find out when people ride in these POIs in Shanghai.

Although there are not many rides in tourist attractions, the remaining 14 POIs at the same time with the same analysis show that, through a comparative analysis of each POI for weekend/working days and among different POIs, the following information can be found:

- 1. The spatial characteristics of dockless bikes riding in Shanghai which types of places are favorite parking places for dockless bikes and which types of places are favorite starting points for riding.
- The riding time period characteristics of dockless bikes in Shanghai in various types
 of places, and the differences between departures and arrivals in different time
 periods.
- 3. These two issues can be used to answer the big question of how dockless bikes are used in Shanghai, including when and where they are used.

Of course, following issues/questions remain unsolved:

- The accuracy of GPS data is insufficient, and further observation and research are still needed.
- 2. The unsupervised mode of cluster analysis makes it easier for it to fall into a local optimum, which will obviously affect the result.
- 3. Are there significant differences in riding characteristics between Xi'an and Shanghai two cities with different levels?

4.5 Summary

This chapter has conducted an in-depth empirical analysis to understand the interplay between Shanghai's transportation mobility system and the usage patterns of dockless bikes. It studied and analyzed when and where dockless bikes are used in Shanghai. The chapter focused on The spatial and temporal characteristics of the use of dockless bicycles in Shanghai are analyzed, and the distribution of dockless bicycles near subway stations is widely found. Therefore, the travel behavior of dockless bicycles around subway stations and the regional infrastructure environment are comprehensively analyzed. Subway stations, a kind of transportation mobility system that can best carry city commuting, are an obvious embodiment of the city's travel mobility system. By comparing the trips around subway stations on weekdays and weekends, combining temporal and spatial analysis, and focusing predominantly on dockless bike trips around subway stations, the study has offered valuable insights into urban mobility in one of the world's largest cities.

In the second part of this chapter, data analysis is carried out on the time characteristics of dockless bicycle travel in Shanghai, and it is concluded that in the time period of DB peak travel, that is, the morning and evening peak hours on weekdays, due to the impact of commuting time and other problems, the number of Dockless bicycles departing from subway stations in morning peak hours is more than that at night. The number of bicycles arriving at the subway station in the morning rush hour is basically the same as that in the evening rush hours (add it back up). Besides the reason of its own departure data, it is also due to the demand of this time period. In the morning rush hour, residents go to the central area for work and school, so the number of DB departing from the subway station in the morning rush hour is more. It also reflects the demand of the population to have a better layout of facilities, dynamic facilities and clear guidelines to help them more quickly commute and other activities.

In the third part, the spatial survey based on OD data shows that the probability of DB use is higher in the urban center area, especially in the area where schools and business offices are concentrated. The land use density in the central area is usually higher, and people's travel needs are more flexible, so the demand for DB is higher, and the higher demand and the design principle of the functional area promote the construction of a better cycling environment in

these areas, including flat roads, good lighting, safety protection measures and parking facilities, the two interact to jointly ensure the frequency and efficiency of cycling.

This chapter has provided a superposition analysis of time and space. In this part, based on spatial analysis, time travel was superimposed for further analysis. Finally, the travel time periods around subway stations on weekdays and weekends, as well as the travel situation in the morning and evening peaks, are obtained. And through a differential comparison between the data volume of the travel times around subway stations and the data volume of the whole city in the same travel time, the influence and choice of dockless bikes in regard to urban public mobility system is investigated. This difference deserves further attention to in urban planning and construction, especially the part that matches the development of dockless bikes. The study's time-space superposition analysis further refines these insights, allowing for a nuanced understanding of how dockless bikes are integrated into the city's broader public mobility system. By comparing travel volumes around subway stations against the city's overall travel patterns, it becomes evident that dockless bikes play a significant role in shaping urban travel behaviors.

It is worthy of recognition that besides focus on the relationship between transportation mobility system (subway stations) and dockless bikes, this research thinks about the use of dockless bikes from the perspective of mobility system that, as a very important development factor for urban construction, must be considered in future urban construction. At the same times, dockless bikes will be an indispensable part of the future city. Even though the subway is not a broad sense of transportation mobility system but still a critical and representative one in the transportation mobility system, studying the subway station as a narrow sense of mobility system gives insightful results and fill the gap between them.

The main conclusions of this chapter include the following aspects. First of all, in terms of time characteristics, the most intuitive conclusion is that there is a large amount of riding in the morning and evening peak hours on weekdays. Specifically speaking, working days show the characteristics of rapid growth in cycling volume during the morning peak period, while the evening peak period is long and the growth of cycling volume is relatively gentle. The weekday traffic is mainly commuting, and the non-weekday traffic is mainly non-commuting,

the distribution of time is relatively balanced, and the destinations are mostly leisure and entertainment. It can be seen that the morning and evening peak is the time when the traffic demand is the largest, at this time due to the increase in user demand and travel activities are in a hurry, hurry and other characteristics, the supply and demand carrying capacity of cycling facilities has a strong test. In this area of rail transit stations, especially near the rail transit stations in residential areas, parking conflicts often occur, such as random parking, taking cars across the road, parking in illegal areas and other irregular riding behaviors, at this time, cycling infrastructure is extremely important. Even though it is the same subway station, areas with better parking and road facilities reduce the probability of dangerous riding behavior during rush hour.

The second is the spatial characteristics. The spatial characteristics directly reflect the space needs of dockless shared bicycle riding facilities, and are an important reference for planning roads, parking facilities and other facilities. In terms of cycling traffic hotspots, cycling behavior mostly occurs in urban public activity centers, such as schools, business districts, business offices, etc., and more than 50% of dockless bicycles stay within 500 meters around rail transit stations. On the cycling road, most of the dockless shared bicycle travel routes are in the central urban area of Shanghai, and mainly on the roads with good non-motor vehicle traffic conditions, but there are still some vehicles riding on the road that prohibits non-motor vehicles, indicating that there are still shortcomings in road facilities. In terms of parking demand, there are more irregular behaviors such as random parking and random parking outside the rail transit station in the narrow residential area. Through spatial analysis, irregular parking behaviors can be effectively identified, and it is concluded that areas with better cycling facilities are more likely to have safe cycling behaviors.

The analysis of spatial and temporal superposition also proves the above conclusion. The urban public activity center is usually the earliest area of cycling morning peak. For example, Songjiang and Yangpu are concentrated areas of universities, and students' trips are mostly concentrated between 7:00 and 7:30 in the morning. The area of riding evening peak also occurs in the area with the most concentrated commercial office. In these periods, the phenomenon of disorderly parking and illegal riding in these areas is also the most prominent,

but the violations near the rail transit stations with reasonable surrounding, perfect guidance facilities and appropriate parking facilities are significantly reduced.

It can be seen that, as an important part of the urban transportation system, the standardized riding and good planning of dockless shared bicycles have an important impact on ensuring a sustainable bicycle passage network. In the longer term, due to the motor vehicle and non-motor vehicle road Settings without isolation belts, dockless shared bicycles can better ensure the smooth operation of the urban transportation system. The DB-related infrastructure is a key factor affecting the operation of dockless bicycles, and a smarter, clearer and more standardized infrastructure environment can better guarantee the norms of riding.

However, there are still some shortcomings in this part of the data analysis. The biggest shortcoming is the lack of accurate GPS information. In order to seek more accurate data, further observational research requires attention. And because Shanghai has the largest subway mileage in the world, it cannot be said that the situation around the Shanghai subway will fully reflect the situation around subway stations in other cities around the world, so a second-tier city, Xi'an, is then included. While this research is pioneering in its focus on the relationship between transportation mobility systems, particularly subway stations, and dockless bikes, it is not without limitations. The primary constraint is the reliance on GPS data, which, while useful, lacks the precision necessary for more granular analyses. This limitation suggests a need for supplementary research methods, such as direct observation or the use of more advanced tracking technologies, to validate and expand upon these findings. Additionally, the study's focus on Shanghai, with its unique urban layout and extensive subway system, may limit the applicability of its conclusions to other urban contexts, particularly those with differing public transportation infrastructures. As This chapter introduces the spatial and temporal characteristics of DB travel in Shanghai and the relationship between them and infrastructure. This exploration has uncovered significant insights, particularly in terms of temporal and spatial usage patterns, and the impact of these bikes on urban mobility and the impact of infrastructure on DB. However, this is just one facet of a broader picture.

This chapter provides a comprehensive analysis of the temporal and spatial characteristics of dockless bicycle usage in Shanghai. Key findings include significant peaks during morning and evening rush hours on weekdays, with usage concentrated in the city center and around subway stations. On weekends, usage is more evenly distributed, with a notable increase in leisure-related trips. The results highlight the need for targeted infrastructure improvements to support dockless bike usage and enhance urban mobility. These findings suggest that urban planners should consider both the temporal and spatial characteristics of dockless bike usage when designing and implementing transportation policies and infrastructure. The following chapter, "Chapter 5: Observation," aims to expand our understanding further by exploring behavioral factors that affect the safety of cyclists, particularly in relation to dockless bikes. It will utilize observational methods to compare cycling behaviors at various subway stations in Shanghai, providing a unique perspective on urban traffic management and mobility system construction. The chapter will specifically focus on the differences in riding and parking behavior of dockless bicycles between subway stations, using video observation to investigate whether a well-developed Infrastructure system can reduce dangerous cycling behavior and irregular parking. If so, what infrastructure is needed to regulate cycling? This study's findings are poised to offer invaluable insights into improving urban transportation safety and efficiency, bridging the gap between current practices and optimal urban mobility solutions.

Chapter Five: A Comparative Study of Cycling behavior between Shanghai and Xi'an: an Observation Approach

5.1 Introduction

The last chapter discusses the spatial and temporal distribution of DB behavior in Shanghai. Studies have shown that infrastructure and the spatial and temporal characteristics of DB interact with each other. However, due to the limitations of data analysis methods, it is easier to monitor behaviors such as retrograde and disorderly parking. Many dangerous riding behaviors cannot be observed due to the characteristics of the user's own needs, such as crossing the road, not wearing a helmet and so on. This needs to be further supplemented with observation methods and further analysis of which aspects of the infrastructure contribute to improving these dangerous riding behaviors. Based on the conclusions of the previous chapter, this chapter will find out how infrastructure can improve the riding environment of DB and mitigate the unplanned behavior through close observation and comparison of DB behaviors around subway stations in different cities.-There are a lot of results on the use of observation method to study DB in China, and most of the research focuses on the observation of irregular riding behavior. It is generally believed that irregular riding behavior will directly lead to the riding experience of DB, thus affecting the frequency and effect of DB use. Therefore, many studies on the use of infrastructure to increase cycling frequency have started with the improvement of irregular behavior. A study in Beijing found that 56% of bicycle riders (including electric and traditional bicycles) passed the red light signal (Wu et al., 2012; Fishman & Cherry, 2016). Another survey considered several unsafe behaviors of electric bicycle riders in Suzhou and reported riding on motor vehicle lanes (1.9%), and the rate of running red lights was worrying. (4.8%), riding in the opposite direction of traffic (3.4%), using mobile phones (0.4%), and not wearing helmets (91%) (Du et al., 2013; Jones et al., 2016). This study aims to observe the differences in riding and parking behavior of dockless bicycles between subway stations in Shanghai through video observation. Therefore, this study aims to illustrate advanced road mobility system to reduce dangerous riding behavior.

Observation method has obvious advantages in studying how infrastructure solves the irregular riding behavior of dockless bicycles. First of all, it can directly observe the rider's behavior, clearly distinguish and identify the type and frequency of irregular riding behavior,

such as speeding riding, reverse riding, etc., which effectively supplements the conclusions of space-time analysis. Secondly, when clarifying the relationship between infrastructure and irregular riding behaviors of dockless bicycles, researchers can clearly observe the direct relationship between irregular behaviors of dockless bicycles and the use of infrastructure. For example, researchers can observe whether bike-sharing parking facilities are properly set up. If the parking facility is far away from the subway station and bus station, riders may park the shared bikes at will, resulting in the shared bikes being parked randomly in the non-parking area. At the same time, the observation method can effectively match a variety of scenes, because of its intuitive observation characteristics, whether it is the downtown business district of the city, or relatively remote residential areas, as long as there is a shared bicycle riding and infrastructure, the observation method can be a good way to obtain first-hand data.

In this study, firstly, the observation method is used to compare the differences in cycling behavior at that subway station, which is conducive to promoting the urban traffic management system and improving the city's mobility system construction by how to improve the infrastructure. Secondly, the comparison between different subway stations in different cities can also focus on with different levels of development, which infrastructure has the most important impact on unregulated cycling behavior in cities. In this observation, dockless bikes will be observed near five subway stations in two cities, three subway stations in Shanghai will be used to observe infrastructure measures to improve dangerous dockless cycling in first-tier cities, and two subway stations in Xi 'an will be used to observe how dangerous dockless cycling can be improved in second-tier cities. The comparison between the two can intuitively see the focus of improving the non-standard riding behavior in the first and second tier cities. At the same time, each city has a comparison between the subway stations in the new urban area and the old urban area, and the solution of irregular cycling behavior in the new and old urban areas through infrastructure means will also be discussed.

This study analyzes the cycling and parking behavior of cyclists at three subway stations in Shanghai using the video recording observation method. According to the discussion in Chapter 4, the observation period is mainly in the morning and evening peaks, and the behavior difference between dockless bicycles and private bicycles is compared. In order to verify whether there is a significant difference between the two riding behaviors, this

article uses the T-test method for verification, and the results of the T-test will be placed behind each table. Through the above comparison, we can see that in first-tier cities like Shanghai, how infrastructure can reduce irregular cycling behavior.

This chapter also includes a detailed analysis of observations in Xi'an. In terms of the observations in Xi'an, this study encompasses an in-depth analysis of cycling and parking behaviors at the Beidajie subway station, which is representative of a new urban area. In addition to supplementing the observation of Shanghai subway station, this observation also aims to analyze the emphasis of infrastructure in cities with different levels of development in addressing irregular cycling behavior. This observational study was conducted in Shanghai, one of the largest tier-one cities in China, and Xi'an, a time-honored tier-two city in northern China. At the peak of cycling, three subway stations around Shanghai and two subway stations around Xi'an were selected, and observation and research were conducted on weekdays and weekends, to ensure more accurate results. The three stations in Shanghai are one in the old city centre, one in the new city centre and one in the suburbs. The two stations in Xi'an are one in the city centre and one in the suburbs. The observational data will be collected in the form of video. All irregular DB cycling around metro stations will be recorded, and the distribution of surrounding infrastructure will also be observed.

In this study, first of all, the regulation of irregular riding behavior includes both riding behavior and parking behavior. The five representative observation points mentioned above were selected, covering different types of traffic environments and bike-sharing usage scenarios. Through in-depth analysis of 103 hours of video data from the five observation points, data was collected on riding behavior and surrounding infrastructure. At the same time, two different groups of riding behavior were recorded at each observation point. The first group is the riding behavior of dockless bicycle. In this kind of behavior, riders show diversified behavior characteristics in the process of use. The other group is the riding behavior of private bicycles, and the behavior of such people often has their own fixed riding habits and parking ways, and there is a certain difference from the riding behavior of dockless bicycles. Parking behavior was also observed in detail. By repeatedly encoding and recording each hour of video, it is possible to accurately capture information such as the number of bikes parked in the area, where they are parked, and how regulated they are. After repeated playback and analysis, this paper recorded in detail the changes of riding behavior of dockless bicycles

and private bicycles in the recorded period, as well as the distribution and quality of surrounding infrastructure. This chapter hopes to fully reveal the complex relationship between the irregular riding behavior of shared bicycles and the infrastructure, and provide strong support for the subsequent traffic planning and management.

5.2 Analysis of Subway Stations in Shanghai

5.2.1 The 20-hour Video Observation at Century Avenue Underground Station (Representative of the New Downtown Area)

The following section will analyse 20 hours of video of the Century Avenue metro station observation point in the new downtown area of Shanghai over one month, starting with one hour of video from December 1, 2021 to December 30, 2021. As previously mentioned, the Century Avenue metro station is the central hub station in Shanghai's Pudong New Area, and therefore is a representative metro station in the new urban area of a first-tier metropolitan city, with a complete mobility system that is representative of a first-tier metropolitan area in China.

The videos contain 14 hours of weekday filming and 6 hours of weekend filming over the month, comprising 7 hours of weekday morning peak, 7 hours of weekday evening peak, 3 hours of weekend morning peak filming video and 3 hours of weekend evening peak filming video, respectively. These days also had relatively low temperature and also varying weather conditions in Shanghai in December, so the number of people riding dockless bikes was perceived overall to be lower than average. However, the riding patterns are still very much reflective and insightful in the content.

5.2.1.1 Weekday Morning and Evening Peaks at Century Avenue Metro Station

Firstly, this research will summarize the results of the weekday morning and evening peak data. In the 7-hour morning peak observation video, a total of 910 cyclists were captured during the 420 minutes of morning peak observation time, of which 832 rode dockless bikes and 78 rode private bikes, and 57 of these 78 rode private electric bikes (or e-bikes). The proportion of people riding dockless bikes was 91% of the total, and if personal electric bikes

are removed, it was 97% of the overall bicycle ridership. This shows that, all in all, dockless bikes are already a very mainstream mode of transport for cycling around metro stations. In the 7-hour video observation of the evening peak, from 5:30 to 6pm each day, 627 cyclists were captured, 483 of whom were on dockless bikes, 144 on personal bikes and 97 on personal e-bikes, most of whom were delivery workers as indicated by their clothing. The proportion of dockless bikes trips in the evening peak was 77%, a significant drop from the morning peak. Of the 315 parked bikes captured, 298 were parked dockless bikes and 17 were personal bikes, with dockless bikes accounting for 95% of the parked trips. This indicates that the evening peak is less concentrated than the morning peak, that people have sufficient time to choose when to ride, and that people tend to leave work at irregular times, and that Shanghai is a city that has some of the worst overtime in the world. So, while the morning rush may be an hour, the evening rush may be up to about three hours.

There were 249 bicycle parkers observed at this metro station observation point, where 221 parked dockless bikes and 28 parked personal bicycles, and 17 of these 28 parked personal e-bikes. Parked dockless bikes accounted for 89% of the total parked. The number of bicycle taken was much lower than those parked by people, with 144 bicycle pick-ups, of which 142 were dockless bikes, meaning that almost no personal bicycles parked in the morning peak were picked up. The number of dockless bikes taken during the morning peak is significantly lower than the number of dockless bikes parked, probably because the area around Century Boulevard is a concentrated CBD area and many people choose to walk directly to their workplace.

The observational study meticulously examines two key aspects: cycling behavior and parking behavior. Regarding cycling behavior, the focus will be on analyzing some of the more hazardous and frequently observed practices. These include behaviors such as cycling through a red light, riding in the wrong direction, riding without both hands on the handlebars, and cycling on lanes not designated for bicycles. Furthermore, this study will conduct a comparative analysis of the data gathered from riders of dockless bikes and those using personal bicycles. This comparison aims to address a critical research question that remains unanswered by large-scale data studies: how does the cycling behavior of individuals differ when using dockless bikes as opposed to private bicycles?

Firstly, look first at the data from the morning and evening peaks and compare the cycling data from dockless bikes with the cycling data between individual cyclists.

Table 5.1 Comparison of the number of dockless bikes and personal bicycle ridership data for

the morning and evening peaks at Century Avenue Metro Station.

	Bike rider type	Total amount	Riding a bike through a red light	Riding in the opposite direction	Do not hold the handlebar with both hands	Riding on a non-bicycl e lane
Morning peaks	Dockless bike riders	832	201 (24%)	171 (21%)	61 (7%)	294 (35%)
Morning peaks	Personal bike riders	78	7 (8%)	11 (14%)	0	21 (27%)
Evening peaks	Dockless bike riders	483	101(21%)	103(21%)	21(5%)	130(27%)
Evening peaks	Personal bike riders	144	3	2	0	3



5.1 Screenshot of observation video of century avenue subway station

Secondly, compare the parking data of dockless bikes with the parking data of personal bikes. For this section, four of the dangerous behaviors and common parking irregularities were selected, namely obstruction to passing pedestrians or passing bicycles, interference to surrounding merchants, not parking. These four types of behavior were also divided into two sections: personal bicycles and dockless bikes, which also answered the question of whether there is a difference between the behavior of people using dockless bicycles and personal bicycles, as well as whether there is a difference between the behavior of people using dockless bikes and personal bikes is also answered.

Table 5.2 Comparison of the number of morning and evening peaks dockless bikes and personal bicycle parking data at Century Avenue metro station.

Bike rider type	Total amount	Ī	Obstruct passing pedestrians or passing bicycles	Not parked upright	Has an impact on the surrounding green environment
Dockless bike riders	221	24 (11%)	11 (4%)	17 (7%)	20 (9%)
Personal bike riders	28	0	0	0	1 (3%)
Dockless bike riders	328	56 (17%)	20 (6%)	39 (12%)	49 (15%)
Personal bike riders	37	2 (5%)	0	0	1 (3%)

Given this complete set of one month's observations of the morning and evening peak dockless bikes and parking data from tier-one cities, a few simple summaries of the results are drawn as follows. Firstly, considering the riding and parking behavior of dockless bikes and personal bikes, it is clear that dockless bikes riders have a higher proportion of irregular behaviors in the process of riding, indicating that people are more casual when riding dockless bikes than when riding personal bikes. For evening peaks, of the four types of irregular cycling behavior, riding on a non-bicycle lane remains the highest at 27%, but this is somewhat lower than during the weekday morning peak. The other three types of irregular cycling behavior are also somewhat lower than in the morning peak, suggesting that people do not feel as anxious in the evening peak as they do in the morning peak.

Secondly, there are some riding behaviors that are more dangerous, with dockless bikes riders having a much higher incidence of riding through red lights than personal bicycle riders (24% vs 8%). In addition, the incidence of riding in the wrong direction was also

much higher for dockless bikes riders (21% vs. 14%), with dockless bikes riders being more likely to do this type of riding behavior than the average individual cyclist. Considering the next behavior of not riding in the cycle lane, dockless bikes riders were 35% more likely to do this in the morning rush hour, up from 27% for regular bikes. Finally, not holding the handlebar with both hands is a relatively high risk behavior, and fewer cyclists engage in this behavior than the other three, among which none of the individual cyclists are engaged in this behavior, but dockless bikes do. The four types of misplaced parking behaviors observed during the 30-minute counting period all increased in the evening peak, as compared to the morning peak, with the proportion of obstructing passing pedestrians or passing bicycles reaching 17%, a relative increase of 55% compared to the 11% in the morning peak (between 17%-11%) and 11%). This is still the most common of the four types of parking irregularities, but the increase in the proportion shows that not only is the amount of parking increasing in the evening peak, but the proportion of irregularities has also increased. The second most common misbehavior is damaging the surrounding green belt, at 15%. Then, causing interference to surrounding merchants is still the lowest but has increased from 4% in the morning peak to the second most common misbehaviors. Meanwhile, having an impact on the surrounding green belt reaches 15%.

Thirdly, in terms of parking behavior, there was very little unregulated parking by personal bicyclists, thanks to the fact that there was relatively ample parking space at the Century Avenue underground station during the morning rush hour. However, dockless bikes riders do not have this problem, with 11% of dockless bikes having the problem of obstructing passing pedestrians or passing bicycles, 4% of dockless bikes having the problem of causing interference to surrounding merchants, 7% of dockless bikes not parked upright and 9% of dockless bikes have an impact on the surrounding green belt. However, the characteristics of the evening peak parking behavior are completely different from those of the morning peak. In terms of parking behavior, it can be seen in Table 5.2 that there is a significant increase in parking behavior at the Century Avenue underground station during the weekday evening peak, with this increase only occurring in the parking of dockless bikes. In other words, the metro stations in the central business district in the city centre will have more parking behavior in the weekday evening peak, with 328 parkings of dockless bikes in the evening peak, far exceeding the

221 parkings in the morning peak amount. This suggests that people are more likely to ride dockless bikes to CBD stations in the evening peak than in the morning peak and then take the metro home instead. Of course, the large number of parkings occurring in the modest public space of the metro station entrance also leads to a higher proportion of incorrect parking behavior. This is also typical of evening peak parking behavior.

Through the T-test, it can be concluded that given P=0.012<0.05, the riding behavior of dockless bicycles is significantly different from that of private bicycles at a 5% confidence level. It can also be seen from the results that the dangerous riding behavior of dockless bicycles is higher than that of private bicycles. Through the comparison of the four dangerous riding behaviors, the results of the T-test can also verify that the data of the two groups were considered significantly different at 1% confidence level with P=0.007<0.01. It proves that between dockless bicycles and private bicycles, there is indeed a noticeable difference in riding behavior.

Chen et al (2022) believe that dockless bicycles are more casual than private bikes because dockless bicycles do not belong to the rider himself. Therefore, there is a lower sense of responsibility. For example, the cyclist will run a red light and go the other way. Secondly, there is a difference between dockless bicycles and private bicycles regarding parking behaviors. Private bicycles are owned by the cyclist, so the cyclist will pay more attention to property safety to avoid risk of damaging the property when parked near sidewalks, for example, knocking and scratching. Tan et al (2022) also verified that the morning rush hour has higher travel efficiency, so people don't have sufficient time to consider the right behavior and yet have to pursue the speed and efficiency. According to the data of Meituan Bike, the first wave of riding peaks of the day was ushered in from 7:00 a.m. to 9:00 a.m. on June 1. Compared with the same period in the previous week, the riding volume of the morning peak increased by 535%. Cui (2020) argues that most rush hours are mainly concentrated in subway hubs such as Century Avenue Subway Station of Line 6, Xintiandi Subway Station of Line 10, and Zhongshan Park Subway Station of Line 3, Xintiandi Commercial District, Zhongshan Park Commercial District, Xujiahui Commercial District. Therefore, it can be known that people indeed care more about travel efficiency during the morning rush hour and so become more unwilling to find parking spaces for dockless bicycles at that time. The lower travel efficiency demand in the evening rush hour suggests that people are less anxious after getting off work than in the morning but so many dockless bikes therefore no not willing to take the time to find a suitable parking spot. However, in contrast to the utilization rate of dockless bicycles, the parking space in the evening peak is significantly higher than that in the morning peak. Gao et al (2021) argue that from a spatial perspective, more developed areas in Shanghai usually have higher population densities and much higher environmental benefits. In terms of time, the environmental benefits of shared bicycles have obvious morning and evening peaks, and the evening peak is higher than the morning peak. It shows that the usage rate of dockless bicycles in the evening peak is also significantly higher than that in the morning peak.

It is worth noting that in these observations, while it appears that the morning peak is more anxious, the evening peak ends up with significantly more consecutive mis-parking. In the morning peak, there were already a large number of docklesss bikes and regular bikes parked in front of the Century Avenue metro station, but in the evening peak, just at the start of the observations, the existing parking situation was not sufficient for all bikes (either dockless bikes or personal bikes) to engage in incorrect parking behavior, as there still seemed to be enough space for parking. In the evening rush hour, the parking crowd seemed more willing to walk the extra 20 metres or take the extra 10 seconds to sort out a suitable space for a parking session; instead, the morning rush hour crowd was more anxious, which may also be related to the rush to get to work in the morning. But when there is a certain amount of parking, especially after a certain percentage of incorrect parking, it is clear that the subsequent parking behavior in the evening peak is continuously incorrect. This means that when the earliest incorrect parking behavior occurs, people subconsciously continue to follow this incorrect parking, and from an overall observation point of view, there is a succession of parking errors which are more likely to occur in the evening peak when the number of parking is higher.

The above observations show that during the morning peak on weekdays, the number of people using dockless bicycles is much more than that of private bicycles, and during the evening peak, the proportion of dockless bicycles is slightly reduced, but still more than twice that of private bicycles. The same is true for parking behavior. At the same time, users of dockless bikes have been shown to run red lights, drive the wrong way, damage green belts,

park and obstruct traffic during the busy midweek morning and evening rush hours in central urban areas, and much more. Moreover, it is worth noting that after reaching a certain proportion of wrong parking, there will be continuous wrong parking behavior in the evening rush hour. Combined with the distribution of DB-related infrastructure around the subway station, it is not difficult to find that because of the land price, the planning of parking facilities is very unreasonable, which directly affects irregular parking and running red lights and other car-hunting behaviors.

5.2.1.2 Weekend Observations at Century Avenue Metro Station

The second part of the observational study involves weekend observations of dockless bikes riding and parking behavior around the same metro station, Century Avenue, the metro station in the CBD area of the city centre, where most of the travel activities take place around business activities. The big data before the observation also illustrates that the difference between weekend and weekday dockless bikes parking, and pick-up behavior around the Century Avenue metro station is very significant.

The weekend observations were a 3-hour morning peak video and a 3-hour evening peak video observation, respectively. Based on the proportion of morning peak trips, the weekend morning peak should have reached around 350 trips in the 3 hour video, but in fact, there were only 103 dockless bikes trips, although it is worth noting that there was also a significant and large proportional drop in personal bicycle trips, suggesting that there are just very few trips in the downtown CBD during the weekend morning peak hours.

Table 5.3 Comparison of the number of weekend morning and evening peaks dockless bikes and personal bicycle rides at Century Avenue Metro Station

	Bike rider type	Total amount	Riding in the	Do not hold the handlebar	Riding on	
	JP -		opposite direction	with both hands	non-bicycl	
					e lane	

Morning peaks	Dockless bike riders	103	14 (13%)	10 (9%)	2 (2%)	17 (16%)
Morning peaks	Personal bike riders	16	1 (7%)	2 (14%)	0	1 (7%)
Evening peaks	Dockless bike riders	142	19 (14%)	16 (11%)	4 (3%)	24 (19%
Evening peaks	Personal bike riders	31	2 (6%)	4 (12%)	0	3 (9%)

Table 5.4 Comparison of weekend morning and evening peaks parking data for dockless bikes and personal bicycles at Century Boulevard Metro Station.

	Bike rider type	amount	Obstruct passing	Obstruct passing	Not parked upright	Has an impact on
			pedestrians or passing bicycles	or passing bicycles		the surrounding green environment
Morning peaks	Dockless bike riders	25	2 (8%)	1 (4%)	1 (4%)	2 (7%)
Morning peaks	Personal bike riders	4	0	0	0	1 (25%)

Evening peaks	Dockless bike riders	40	2 (5%)	2 (5%)	1 (2%)	6 (15%)
Evening peaks	Personal bike riders	8	0	0	0	0

The most typical feature of weekend morning peak dockless bicycle trips on Century Boulevard is the significant reduction in numbers, but, of course, this is not just a feature of weekend morning peak trips by dockless bikes. Overall, weekend morning peak trips are very low and the volume of traffic trips affects the travel behavior of everyone. The proportional reduction in all four types of irregular travel behaviors is related to the fact that, overall, road resources do not need to be competed for after the overall reduction in travel volume. Wider roads serve fewer vehicles and fewer dockless bikes, and cyclists have more room to adjust their riding behavior on weekdays even under the lack of mobility system when there is an adequate amount of mobility system. The cycling behavior is significantly more regulated.

During the weekend morning rush hour, all four types of irregular parking behaviors were observed to be less than 10%, with the not-parked-upright behavior occurring only once during the entire morning rush hour, and this was because the dockless bikes themselves were probably not very functional and therefore had to be parked against another wall. But the parking behavior and the riding behavior were uniformly characteristic.

Overall, the weekend morning rush had a sense that the whole city was asleep and the dockless bike riders were travelling less, as well as other riders and travelers, it is noticeable that when the trips were reduced, the overall percentage of unregulated trips was also much reduced.

This is followed by a look at dockless bikes trips during the weekend evening peak. Riding a bike through a red light and riding on a non-bicycle lane continue to be the two most prevalent types of irregular trips, at 15% and 19%, respectively. At the same time, the proportion of personal bicycle trips during the evening peak at weekends increased

significantly, reaching 13%, which is still higher than on weekdays, suggesting that many people also choose to ride their personal bicycles during the weekend evenings, indicating that the purpose of these trips may be more for non-work purposes such as recreation. Table 5.4 shows the parking situation at the Century Avenue underground station during the weekend evening peak.

Overall, there is not very much parking at the Century Avenue underground station during the evening peak at weekends, and there are not too many irregularities, and the proportion of the four irregularities is relatively much lower than that during weekdays, but it is worth mentioning that there is much more parking in the green belt during the weekend evening peak compared to other irregularities (15%), which may be due to the fact that many dockless bikes are parked in the green belt on weekends, causing later dockless bikes to follow this misbehavior.

On weekend nights, most of the private cyclists near the Century Avenue subway station belong to the residents near the Century Avenue subway station, and the dockless bicycles are for the last mile. Because e-bikes can be used for a limited distance, in an average of 5.1 kilometers trip, the overall number of trips in the morning on weekends is lower than in the evening. Gao (2021) believes that most weekend trips of shared bicycles show the features of non-commuting cycling patterns, meaning that more leisure activities occur during the week, and non-commuting pattern cycling behaviors mainly occur in residential areas, subway stations, public transportation as well as those between the station and entertainment facilities such as parks and playgrounds. This also shows that the travel needs of cyclists determine their use time and travel destinations.

The monitoring of dockless bicycles around Century Avenue subway station on weekends shows that there are significant differences in cycling and parking behaviors on weekends compared with weekdays. The amount of cycling during peak periods on weekends is greatly reduced, and irregular behaviors are also decreased. However, running red lights and occupying lanes are still the main irregular cycling behaviors. There is a decreasing trend of irregular behavior. It is not difficult to find that the decrease in irregular behavior on weekends is because the reduction in cycling makes the existing infrastructure more fully utilized, thus reducing the irregular parking behavior caused by inadequate facilities. In

addition to cyclists' weak awareness of traffic rules, cyclists cannot get effective guidance on standardized riding due to the blocking of many guiding facilities, resulting in unsafe behaviors.

5.2.2 The 20-hour Video Observation Video of the Old Ximen Metro Station (Representing the old town centre)

In the following, 20 hours of video from one observation point within one month, starting with a one-hour video from 1 October 2021 to 31 October 2021 for the Old Ximen Metro Station observation point in the new downtown area of Shanghai, will be analyzed. As previously mentioned, the Old Ximen Subway Station is a core hub station in the Huangpu District of Shanghai. The nature of the surrounding land is very complex, with residential, commercial and office functions in the area, and the road in front of the Old Ximen Subway Station is very narrow compared to the road in front of the Century Avenue Subway Station. In this study, the Lao Ximen metro station is a representative metro station in an old urban area of a first-tier city, with a large population but lacking new mobility system, and is a representative area of an old urban area of a first-tier city in China.

The videos consist of 14 hours of weekday filming over the month and 6 hours of weekend filming, comprising 7 hours of weekday morning rush, 7 hours of weekday evening rush, 3 hours of weekend morning rush filming and 3 hours of weekend evening rush filming. These days also had varying weather conditions, and it is worth noting that the overall weather in Shanghai in October was more pleasant, so the number of people riding dockless bikes in perception was overall a little higher than on average.

5.2.2.1 Video Analysis of Weekday Observations from the Old Ximen Metro Station

Firstly, the results of the weekday morning and evening peak data are summarized. In the 7-hour morning peak observation video, a total of 1,160 cyclists were captured in the 420 minutes of morning peak observation time, of which 1,085 rode dockless bikes and 75 rode personal bikes. The proportion of people riding dockless bikes was 94% of the overall total. This shows above all that dockless bikes are also already a very mainstream mode of transport for cycling around metro stations in older urban areas of first tier cities. At this metro station observation point 301 parked bikes were observed, 288 parked dockless bikes for

cycling and 13 parked personal bikes. Parked dockless bikes accounted for 96% of the total parking. Compared to the area around the Century Avenue MRT station, the Old Ximen MRT station, which is the old city centre MRT station, is equipped with less parking space but has more parked vehicles compared to the weekday morning peak around the Century Avenue MRT station. Even though it appears that more dockless bikes are taken out, the narrow pavements are still filled with dockless bikes. Probably because the Old West Gate is surrounded by a complex old town and there are so many destinations that people can go toafter exiting the metro station, many people choose to ride dockless bikes as their mode of transport. Given the morning rush hour data, firstly the cycling data of dockless bikes with the cycling data between individual cyclists will be compared.

Table 5.5 Comparison of the number of dockless bikes and personal bicycle ridership data for the weekday morning and evening peaks at Gao Xi Men MRT Station.

	Bike rider type	Total amount	bike	Riding in the opposite direction	Do not hold the handlebar with both hands	Riding on a non-bicycl e lane
Morning peaks	Dockless bike riders	1085	293 (27%)	347 (32%)	7 (1%)	467 (43%)
Morning peaks	Personal bike riders	75	17 (23%)	15 (20%)	0	23 (31%
Evening peaks	Dockless bike riders	608	164(27%)	164(27%)	21(8%)	130(35%)
Evening peaks	Personal bike riders	102	3 (3%)	2 (2%)	0	3 (3%)



Figure 5.2 Screenshot of observation video of Jiuting subway station

According to the statistics in Table 5.5, dockless bikes have a very high percentage of irregular behaviors during the weekday morning peak at the Old Westgate MRT station. The most surprising is Riding on a non-bicycle lane, which is 43%, compared to 35% at Century Avenue. In fact, 35% is already very high, but 43% means that almost half of all dockless bikes are ridden in unregulated areas, which is a direct indication that the bike lanes in the old city centre are woefully inadequate for the amount of dockless bikes being ridden. The same is true for 31% of personal bicycles, which of course firstly shows that people are indeed less aware of how to behave when riding dockless bikes, and secondly shows that there is a real need for wider cycle lanes in the old city centre to cope with the sudden influx of dockless bikes, and more generally that the mobility system in the old city centre is now not sufficiently built to cope with this new type of traffic. In a larger sense, the mobility system in the old city is now not sufficiently developed to cope with this new form of transport. It is also clear that the ridership data in the evening peak is significantly lower than that in the morning peak. Finally, the parking characteristics of dockless bikes and regular personal bikes during the evening peak hours are deducted. Secondly, the parking data for dockless bikes with that for personal bikes is compared. Four dangerous and common parking irregularities for this section are selected, namely obstructing passing pedestrians or passing bicycles, causing interference to surrounding merchants, not parking as required. These four types of behaviors were also divided into two sections: personal bicycles and dockless

bikes, which also answered the question of whether there is a difference between the behavior of people using dockless bicycles and personal bicycles.

Table 5.6 Comparison of weekday morning and evening peaks parking data for dockless bikes and personal bikes at Lao Xi Men MRT Station.

	Bike rider type	Total amount	Obstruct passing pedestrians or passing bicycles	Obstruct passing pedestrians or passing bicycles	Not parked upright	Has an impact on the surrounding green environment
Morning peaks	Dockless bike riders	275	143 (52%	88 (32%)	47 (17%)	91 (33%)
Morning peaks	Personal bike riders	35	11 (31%)	8 (23%)	0	1 (3%)
Evening peaks	Dockless bike riders	572	400 (70%	229 (40%	183 (32%)	257 (45%)
Evening peaks	Personal bike riders	66	3 (40%)	1 (33%)	2 (4%)	3 (5%)

From the observations in Table 5.6, the overall number of dockless bikes parked in the morning peak on weekdays is higher at Laoximen Metro than at Century Avenue Metro, although Laoximen Metro does not pass through as many underground lines as Century Avenue Metro, it is in the heart of the old city and the demand around it is still high on weekdays. And one very important point is that there are not as many entrances and exits to the Old West Gate Metro Station as there are to the Century Avenue Metro Station, which may also be a factor in the increase in parking figures.

Of the four types of parking irregularities, obstructing passing pedestrians or passing bicycles is a shocking figure, with a horrific 52% of such irregularities, meaning that more than half of all dockless bikes take up pedestrian space, which is of rather high frequency of misbehaviors and is often done with a very high frequency of dockless bikes being picked up. This is direct evidence of the need for more space for dockless bikes at the entrances and exits of metro stations in the old city, during the morning rush hour on weekdays. The narrow and inadequate parking areas are filled up before the morning peak has even fully started, so unregulated parking becomes the preferred option.

It is not difficult to see that in the bicycle travel in the old city, dockless bicycle travel is still the mainstream mode of transportation. Due to the greater road density and narrower road width in the old city, and the numerous travel destinations around, dockless bicycles have become a more convenient way to travel. Although the old West Gate subway station has less parking space than the Century Avenue station, the number of parking is more, and irregular riding behavior is more likely to occur. According to the data, the proportion of non-bicycle lane riding in Laoximen Station is 43%, which is much higher than 35% in Century Avenue station, indicating that the cycling facilities in the old city are seriously insufficient. And the lack of parking facilities has increased the rate of irregular parking.

5.2.2.2 Weekend Observations at Old Ximen Metro Station

The second part of the observation study is to observe the riding behavior and parking behavior of dockless bikes around the same subway station on weekends. Laoximen is a subway station in the old city center, and most of the travel activities here have been moved out and yet to places within daily travel. The big data before the observation also shows that the parking and pick-up behavior of dockless bikes around Laoximen subway station is very different on weekends and weekdays.

The weekend observations are 3 hours of morning peak video and 3 hours of evening peak video observation. According to the travel ratio of the morning rush hour, the weekend morning rush hour should reach about 350 vehicles in the 3-hour video. Like the Century Avenue subway station, the Laoximen subway station also has a large number of trips on weekends. It has fallen, but it is still normal compared to Century

Avenue. In fact, there are 234 dockless bikes traveling, and the same is true for personal bicycle trips, which also have a large and large proportion of the decline, which shows that the trips in the old city center during the morning rush hour on weekends are also reduced compared to weekdays.

Table 5.7 Comparison of the number of riding data of dockless bikes and personal bicycles in Laoximen subway station on weekend morning and evening peaks.

	Bike rider type	Total amount	bike	Riding in the opposite direction	Do not hold the handlebar with both hands	Riding on a non-bicycl e lane
Morning peaks	Dockless bike riders	234	40 (17%)	30 (13%)	14 (6%)	51 (22%
Morning peaks	Personal bike riders	22	3 (14%)	3 (14%)	0	3 (14%)
Evening peaks	Dockless bike riders	441	19 (14%)	16 (11%)	4 (3%)	24 (19%
Evening peaks	Personal bike riders	55	2 (6%)	4 (12%)	0	3 (9%)

As shown in Table 5.7, the most typical characteristic of dockless bikes in the morning rush hour in Laoximen is that the number is significantly reduced. Of course, this is not only the travel characteristics of dockless bikes in the morning rush hour on weekends. There is very little overall travel in the morning rush hour on weekends, and the traffic volume will affect everyone's travel behavior as a whole. The four types of non-standard travel behaviors have all decreased proportionally, which is related to the fact that the overall road resources do not need to compete after the overall travel volume is reduced. Wide roads serve fewer vehicles and fewer dockless bikes In the case of sufficient mobility system, cyclists have more room to adjust their riding behavior than those with insufficient mobility system on weekdays, so the riding behavior of cyclists is clearly regulated. For the travel data of Laoximen Subway Station in the weekend evening peak has increased compared with the morning peak, and the proportion of four kinds of illegal travel behaviors has also increased. Riding a bike through a red light and riding on a non-bicycle lane are still the two types of irregular trips with the highest proportion, reaching 15% and 19% respectively. At the same time, the proportion of personal bicycle trips in the weekend evening peak has increased significantly, reaching 13%, which is still higher than that on weekdays. The purpose may be more non-work purposes such as leisure and entertainment.

Table 5.8 Comparison of the parking data of dockless bikes and personal bicycles in Laoximen subway station on weekend morning and evening peaks.

	Bike rider	Total	Obstruct	Obstruct	Not	Has an
	type	amount	passing	passing	parked upright	impact on
			pedestrians or passing bicycles	pedestrians or passing bicycles	uprigiit	the surrounding green environment
Morning peaks	Dockless bike riders	38	6 (16%)	3 (8%)	2 (4%)	5 (13%)
Morning peaks	Personal bike riders	6	1 (17%)	0	0	1 (17%)

Evening peaks	Dockless bike riders	114	2 (5%)	2 (5%)	1 (2%)	6 (15%)
Evening peaks	Personal bike riders	8	0	0	0	0

As shown in Table 5.8, in the observation of parking behaviors in the morning rush hour on weekends, the proportions of the four types of irregular parking behaviors have all decreased by a lot but not very high. In the 3 hours of observation video, many of the irregular behaviors only appeared in single digits throughout the morning rush hour. As for the parking situation of the Century Avenue subway station during the weekend evening peak, overall, the Century Avenue subway station during the weekend evening peak does not have a lot of parking behaviors, and there are not too many violations. Relatively speaking, the proportion of the four irregular behaviors is much lower than that of weekdays, but it is worth mentioning that parking in green belts in the evening rush hour on weekends is much more than other irregular behaviors (15%), which may be because many dockless bikes are originally parked on weekends. In the green belt, the parking of dockless bikes will follow this wrong behavior to park if there has been a dockless bike wrongly placed there.

Generally speaking, the morning rush hour on weekends has a feeling that the whole city is sleeping. Not only the travel volume of dockless bikes has decreased, but the travel volume of the entire city has also decreased significantly. But the more obvious feature is that when the travel volume decreases After that, the overall proportion of irregular travel has also decreased a lot. However, it is very strange that the evening peak on weekends is higher than it should be, probably because there are a large number of restaurants, bars and other places in the old town on weekend nights to supply people with a large number of leisure needs after a week of work.

The typical feature of the weekend morning peak of pileless shared bicycles in Old Ximen Station is that the number is significantly reduced, and the reduction of the overall travel volume makes the proportion of irregular riding behavior also decrease. Similarly, due to its location in the central city and abundant surrounding attractions and entertainment venues, the irregular riding behavior of Laoximen subway station during the weekend evening peak is still showing an upward trend, and the lack of obvious guidance infrastructure is still the main reason for their irregular riding behavior.

5.2.3 The 20-hour Video Results for Jiuting Metro Station

103 hours of video at 5 different observation points are each performed with a classification analysis of the two groups of cycling behavior and parking dockless bikes behavior. For the following 5 observation points, the capture of people riding bicycles and people parking dockless bikes at the entrances and exits of subway stations at each observation point and every hour through repeated coding and recording has been obtained.

5.2.3.1 Observation Results of Morning and Evening Peak Hours of Jiuting Subway Station on Weekdays

First, a general analysis of the observation results of the morning and evening peak is performed. In the 6-hour observation video of the morning peak, a total of 1,324 cyclists were captured during the 360-minute morning peak observation time, of which 1,162 rode dockless bikes, 145 rode personal bicycles, and among the 145, only 34 people rode personal e-bikes. The proportion of riding personal bikes accounted for 94% of the total, and if the personal bicycles were removed, it accounted for only 28% of the overall bicycle riding. It shows that for the suburbs, dockless bikes are a mainstream mode of transportation for everyone.

178 bicycle parkers were observed in suburban subway stations, including 104 personal bikes and 74 dockless bikes, among whom 64 were parked as personal electric bicycles. Parking personal bikes accounted for 91% of the total parking. The removal of bicycles corresponds to an increase in the number of people parked, and the number of removals is 59. The other analytical feedback is that bicycles parked in the morning peak will continue to be taken away. In the morning rush hour, the number of personal bikes taken away is obviously more than that of dockless bikes. This is probably because the suburban roads are wide, there are few vehicles, and the work path is short. Most people choose

personal bicycles to commute to work, which improves convenience and efficiency. The proportion of parking in the evening peak has been greatly reduced, and the proportion of people leaving the station is high, accounting for as much as 72%. From the perspective of clothing, most of them are white-collar and blue-collar workers. If they choose to leave the station that is closely connected, they will also follow the off-duty rush hour.



Figure 5.3 Screenshot of observation video of Laoximen subway station

Table 5.9 Comparison of the number of riding data of dockless bikes and personal bicycles in the morning and evening rush hour of suburban subway stations.

	Bike rider type	Total amount	Riding a bike through a red light	Riding in the opposite direction	Do not hold the handlebar with both hands	Riding on a non-bicycl e lane
Morning peaks	Dockless bike riders	1324	307 (23%)	459 (34%	156 (12%)	402 (30%)

)		
Morning peaks	Personal bike riders	145	36 (24%)	33 (22%	19 (13%)	57 (39%)
Evening peaks	Dockless bike riders	327	120(37%)	26(8%)	19(6%)	9(3%)
Evening peaks	Personal bike riders	228	1	0	3	2

Through continuous observation, I selected 4 more dangerous parking irregularities: stopping in the middle of the sidewalk, stopping at the entrance of the subway, placing at random in the electric vehicle charging station and crossing the line in the scoring range, which are observed with high frequency. Here, four behaviors are used to give feedback. People treat the difference between personal bicycles and electric bicycles.

Table 5.10 Comparison of the parking data of dockless bikes and personal bicycles in suburban subway stations during the morning rush hour.

	Bike rider type	amount		•	Place at random in the elecctric vehicle charging	Crossing the line in the scoring range
Morning peaks	Dockless bike	1236	398 (32%)	354 (28%	station 221 (16%)	263 (21%)

	riders					
Morning peaks	Personal bike riders	475	99 (26%)	184 (18%	146 (10%)	46 (9%)
Evening peaks	Dockless bike riders	178	28 (16%)	8 (5%)	30 (17%)	16 (9%)
Evening peaks	Personal bike riders	112	6 (6%)	3 (3%)	0	4 (4%)

Through the observation of the riding data and parking data of the first-tier cities in the morning rush hour of this group in January, the analysis results of the morning rush hour in the suburbs will be reported.

First of all, judging from the data on parking behavior and riding behavior, personal bikes actually have fewer irregular behaviors in the riding process. It can show that people are extremely responsible when riding personal bikes, and it is also closely related to the low cost of using personal bikes.

Secondly, compared with the urban area, personal bikes parked in the suburbs beyond the fixed area are much less than dockless bikes (9% vs. 21%). At the same time, the proportion of parking in the middle of the sidewalk is relatively lower than that of dockless bikes riders (18% vs. 28%).

Most of the reasons for the cycling behavior of personal bikes cyclists in this situation are that, firstly, the routes have standardized bicycle lanes and eye-catching regulatory riding signs, which can regulate the behavior of cyclists invisible at all times. Secondly, from the perspective of parking behavior, individual cyclists have high irregular parking behaviors and

strong randomness. It may be because the parking space is too wide that it is easy for cyclists to park as if they want to put it away or throw it away psychologically. 9% of personal bikes riders have the problem of crossing the line in the scoring range, 10% of personal bikes parked have the problem of placing at random in the electric vehicle charging station, and 18% of personal bikes stopping at the entrance of, say, subway, and 26% of personal bikes have the problem of stopping in the middle of the sidewalk.

Next, a general description of the behavioral content of the suburban weekday evening rush hour is provided. In the 3-hour observation video of the evening peak, 327 cyclists were obtained from 5:30 p.m. to 6:00 p.m. every day, of which 228 rode personal bikes and 99 rode electric bicycles. According to the analysis, most of them are blue and white-collar workers and piecework workers. The parking ratio of personal bikes in the evening peak is only 34%, and the travel ratio is 66%. Compared with the morning peak, its parking ratio has dropped significantly. This shows that the evening peak has no fixed interval for everyone, and there is an irregular trend. In addition to working overtime, each person even has some other problems such as their own special circumstances, so everyone chooses different parking times when they come back.

Next, the corresponding irregularities during the evening peak hours is counted, and the morning peak hours on weekdays in the suburbs to draw the following conclusions are compared.

Among the four types of non-standard riding behaviors, Riding a bike through a red light is still the highest, reaching 19%, which is slightly higher than the morning and evening peaks on weekdays. It shows that people feel more anxious in the weekend evening peak than in the morning peak; their corresponding parking characteristics and behaviors are indeed reduced compared with the morning peak. From Table 5.10, the parking behavior of subway stations in the suburban weekend evening peak has decreased significantly. This reduction temporarily appears on personal bikes. This shows that compared with the morning peak, the evening peak has more freedom for individuals to arrange their time. Some groups may not choose to go home after the evening peak and may have other arrangements on their own. This is also a notable changeable feature of the weekend evening peak. It is noted that

although the parking data during the evening peak is even lower, it can also be seen that the parking errors are correspondingly reduced at the same time. Even if the number of parking lots is small and the area is open during the evening rush hour, there may not be related misbehaviors such as crossing the line and crossing the line. The reason for this is that after everyone came back from the evening rush hour, there was no additional target plan. Naturally, subconsciously, they began to pay attention to quality behaviors such as parking regulations, and there were very few consecutive parking errors. It was also related to weekend rest, not so strong, work and rest pressure.

There are more dockless cyclists in the suburbs. Random lane occupation is the main irregular riding behavior, which is compared with the spacious suburban roads and the lack of standardized bike lanes and striking riding facilities because they are far away from the city, resulting in irregular riding behavior.

5.2.3.2 Weekend Observations of Suburban Subway Stations

The second part of the observation study is to observe the cycling behavior and parking behavior of personal bikes around the same subway station on weekends. The suburban subway station is the travel area of urban residents, and most of the travel activities here are carried out around personal life. The big data before the observation shows that the difference between the parking and pickup behavior of personal bikes around suburban subway stations is not obvious on weekends and weekdays.

The weekend observations are 4 hours of morning peak video and 4 hours of evening peak video observation. According to the travel ratio of the morning rush hour, the morning rush hour on weekends should reach about 420 trips in the 4-hour video, but in fact there are also 203 personal bikes trips, so personal bicycle trips also have a certain degree of change.

Table 5.11 Comparison of the number of riding data of dockless bikes and personal bicycles

in suburban subway stations on weekend morning and evening peaks.

	Bike rider type	Total amount	Riding a bike through a red light	Riding in the opposite direction	Do not hold the handlebar with both hands	Riding on a non-bicycl e lane
Morning peaks	Dockless bike riders	420	58 (14%)	37 (9%)	4 (1%)	46 (11%
Morning peaks	Personal bike riders	203	24 (12%)	16 (8%)	0	6 (3%)
Evening peaks	Dockless bike riders	174	20 (12%)	10 (6%)	7 (4%)	12 (7%)
Evening peaks	Personal bike riders	33	23 (7%)	1 (3%)	0	16 (5%)

Table 5.12 Comparison of parking data of dockless bikes and personal bicycles in suburban subway stations on weekend morning and evening peaks.

	Bike rider	Total	Obstruct	Obstruct	Not	Has an
	type	amount	passing	passing	parked upright	impact on
			pedestrians or passing bicycles	pedestrians or passing bicycles	uprignt	the surrounding green environment
Morning peaks	Dockless bike riders	21	14 (7%)	6 (3%)	2 (1%)	2 (1%)

Morning peaks	Personal bike riders	2	0	0	0	1 (50%)
Evening peaks	Dockless bike riders	51	2 (4%)	3 (6%)	1 (2%)	6 (13%)
Evening peaks	Personal bike riders	13	0	0	0	0

The most notable travel feature of personal bikes in the suburban morning rush hour on weekends is that the number of trips is relatively less than that on weekdays, which has something to do with not having to work on weekends. The overall travel trend and changes remain relatively stable. The proportion of the four kinds of irregular behaviors is also relatively reduced. The roads are spacious and the traffic is smooth. The average road width in Songjiang District is 38m, and the road width in Shanghai as a whole is 32m to 40m. From the above data, the overall road width in Songjiang District has a riding advantage compared with other roads in Shanghai. Compared with the suburban morning rush hour on weekdays, there is more time to go on. With enough time, the riding behavior will be able to and then tend to become standardized thereby.

In the observation of parking behavior in the morning rush hour on weekends, the four types of irregular parking behaviors are all declining, and the proportion has dropped to 7%. Not parked upright did not appear in the morning peak for the first time.

Generally speaking, compared with weekday morning rush hours in suburban areas, the morning rush hour is slightly dormant, and the changes in travel and parking are relatively small. This is also related to the living habits of suburban residents who get up early to buy vegetables and take walks.

As shown in Table 5.11, the travel data of the suburban subway stations in the evening rush hour on weekends has dropped to 174 compared with the morning rush hour, and the proportion of four violations is also on the decline, Riding a bike through a red light and Riding on a non-bicycle lane It is the two types of irregular travel with the highest proportion among the four, reaching 6% and 7% respectively. This is also related to the end of the weekend. At the same time, the proportion of bicycle trips in the evening peak of the weekend is also decreasing, and the parking rate is more. The proportion is 9%.

Table 5.12 shows the parking situation of suburban subway stations in evening peak hours on weekends. On the whole, there are not many irregular parking behaviors in suburban subway stations during weekend evening peak hours, and the trend continues to remain stable and normal. The proportion of parking in the green belt with a higher occurrence rate in the urban area is also declining, to 5%. It also has to do with people having a good weekend mood.

On weekends, the number of dockless bicycle trips in the suburbs is reduced, the proportion of irregular behavior is also reduced, and the usual parking facilities can be fully used, so the proportion of violations is also showing an overall downward trend. At the same time, it can also reflect that in the case of smaller traffic flow, cyclists have more time and space to comply with traffic rules, which reduces the occurrence of violations such as running red lights and riding in non-bike lanes.

5.3 Analysis of Xi'an Results

5.3.1 The 20-hour Video Observation at Beidajie Subway Station (Representative of New Urban Area)

Next, 20 hours of video footage captured over a month from a surveillance camera at the Beidajie subway station will be analyzed. This analysis will begin with the one-hour video recorded in March 2022. Beidajie Station is situated in the Lianhu District of Xi'an City; it is a transfer point for Xi'an Rapid Transit Lines 1 and 2 and the first station of Xi'an MRT, featuring the city's first underground shopping district (Beidajie Station, 2022). As such, this study presents a representative example of a subway station in the new first-tier city of Xi'an, with a well-developed mobility system indicative of China's rapidly expanding first-tier metropolises.

Over this month, the video footage captured 14 hours of weekdays and 6 hours of weekends. Specifically, 7 hours of footage were obtained during weekday mornings, 7 hours in the evenings, and 3 hours each weekend morning and evening. Furthermore, the video was captured under varying weather conditions. It is worth noting that Xi'an's weather was generally cold throughout March, leading to a low volume of cyclists riding without designated parking areas. However, these relative figures will still primarily reflect the main features of Xian's riding behavior.

5.3.2 Morning and Evening Peak of Beidajie Subway Station on Weekdays

To begin with, the weekday morning and evening peak data results are summarized. During the 7-hour morning peak observation period, 735 riders were captured on video, with 610 riding dockless bikes and 125 riding personal bikes. This means that dockless bikes have become a prevalent mode of transportation around the subway, comprising 83% of the total number of people riding bicycles.

At the subway station observation point, 207 bicycles were recorded, among which 170 dockless bikes and 37 personal bikes. Dockless bikes accounted for 82% of the parking volume. The number of bicycle pick-ups was notably lower than the number of parking, indicating that personal bikes parked during the morning peak were rarely taken away. However, the number of dockless bikes during the morning peak was significantly lower than the number of parked bikes.

The observational research will analyze two aspects: riding behavior and parking behavior. Concerning riding behavior, more dangerous and common scenarios will be focused on, such as running red lights, riding in the opposite direction, not using both hands to hold the handlebars, and riding on a non-bicycle lane. The observation data of dockless bikes with private bikes to answer the first research question that big data research cannot answer: how do cyclists behave when riding bikes and private cars or, are there differences in riding behavior between dockless bikes and personal bicycles?

First, the data of the morning and evening peak will be studied, starting with the data of dockless bikes with the individual bikes.



Figure 5.4 Screenshot of observation video of Beidajie subway station

Table 5.13 Comparison of Number of dockless Bicycles and Private Bicycle Travel Data at Beidajie Station in Morning and Evening Peaks.

	Bike rider type	amount	Riding a bike through a red light	Riding in the opposite direction	Do not hold the handlebar with both hands	Riding on a non-bicycl e lane
Morning peaks	Dockless bike riders	610	201 (33%)	177 (29%)	85 (14%)	256 (42%)
Morning peaks	Personal bike riders	125	15 (12%)	23 (18%	6 (5%)	21 (30%

Evening peaks	Dockless bike riders	411	107(26%)	115(28%)	37(9%)	123(30%)
Evening peaks	Personal bike riders	171	15	14	3	20

It can be seen from table 5.13 that the overall travel volume of dockless bicycles is greater than that of private bicycles, and the riding volume of dockless bicycles is about 5 times that of personal bicycles. This shows that the sorted dockless bicycles are more popular with cyclists. At this stage, shared cycling has become a "just need" for people's livelihood, which greatly facilitates residents' daily travel (Li, 2022). Therefore, dockless bicycles have become one of the main ways of cycling in Xi'an. one. Through the T-test, it can be seen that there are obvious differences in the riding behavior of dockless bicycles and private bicycles. Among them, the data with the largest difference is riding under traffic lights, and the most obvious violation is riding on non-motorized lanes. Both dockless bicycles and private bicycles have high violation data, 42% and 30% respectively.

First of all, the riding behavior of dockless bicycles and private bikes running red lights is quite different because of responsibility. Yang (2022) shows that the traffic lights on Xi'an North Street are relatively complete and have now entered the level of intelligence. Xian (2021) also mentioned that in recent years, nearly 2,000 signal lights at intersections in Xi'an have been intelligently transformed, and gradually realize the coordinated timing of signal lights in the city based on the "smart platform". The efficiency of vehicles passing through key intersections. At the intersection where intelligent signal lights are set, traffic flow monitoring equipment is installed in all directions, and the intelligent signal lights can adjust the duration of traffic lights according to the traffic flow in each direction. For example, if there are many vehicles queuing up for a red light in a certain direction, the green light in this direction will be intelligently increased to allow the queuing vehicles to pass quickly, eliminate invalid waiting time, and meet the traffic demand in all directions to the maximum extent which do not need to wait for the second red light (Huashang, 2020).

Therefore, the riding behavior under red lights is completely different from individual behavior differences. Chen & Ettema (2020) believe that the reason for the higher rate of illegal riding behaviors of dockless bicycles than private bicycles is the cyclists of dockles bicycles because dockless bike riders do not think that dockless bicycles belong to them, therefore riders do not have a sense of responsibility for property that do not belong to them. The above behaviors are reflected in the fact that riders of dockless bicycles may have the behavior of riding under red lights or not wearing behavior such as helmets. Therefore, the difference about red lights is the behavioral difference caused by the psychological difference between dockless bicycles and private bicycles (Chen & Ettema, 2022). However, when riding on motorized lanes, the ratios of dockless bicycles and personal bicycles are 42% and 30%, respectively. The percentage of illegal riding of dockless bikes is not much different from that of private bikes. There is indeed a problem of insufficient facilities in Beidajie station. For example, She (2022) mentioned that the blowout growth of motor vehicles has severely compressed the space of nonmotorized lanes and the non-motorized lanes are too narrow to meet the needs of nonmotorized vehicles, and the non-motorized lanes are discontinuous and incoherent. The phenomenon of street vendors and illegal parking is prominent. Therefore, the problem of non-motorized lanes leads to the problem that both dockless bicycles and private bicycles cannot ride on bicycle lanes, and the two ratios are similar.

For evening peak, among the four kinds of irregular riding behaviors, the proportion of riding on non bicycle lanes is still the highest, at 30%, but it is lower than the early peak on weekdays. The other three types of irregular riding behaviors are also lower than those in the morning peak, which means that people are not as anxious in the evening peak as in the morning peak. However, the parking behavior characteristics are quite different from those of the morning peak. Dockless cyclists riding in the non-cycling lanes in the evening rush hour can also well explain the defects of the bicycles in the North Street, especially the North Street is located in the Ming Dynasty City Wall in the old city of Xi'an. It has a total length of about 2.2 kilometers to the East Gate. It used to be the most prosperous and main commercial area in Xi'an (Huayu, 2022). Publishing (2019) shows that since Xi'an decided to renovate East Avenue in 2008, the area along East Avenue has been fenced intermittently for many years. Therefore, even in the evening rush hour, there are still many dockless bicycles riding on non-bicycle lanes.

Secondly, the parking data of dockless bikes with personal bicycles will be compared. In this part, four more dangerous and common parking violations are also selected: obstructing pedestrians, causing interference to surrounding businesses, not parking, and affecting the surrounding green environment. These four behaviors are divided into two parts: personal bicycles and dockless bikes, which also answers the question of whether there are differences in the behavior of people using dockless bikes and personal bicycles.

Table 5.14 Comparison of Number of Pileless Bicycles and Individual Bicycle Parking Data at Beidajie Metro Station in Morning and Evening Peaks.

	Bike rider type	Total amount	Obstruct passing pedestrians or passing bicycles	Obstruct passing pedestrians or passing bicycles	Not parked upright	Has an impact on the surrounding green environment
Morning peaks	Dockless bike riders	170	29 (17%)	14 (8%)	20 (12%)	24 (14%)
Morning peaks	Personal bike riders	37	2 (5%)	4 (11%)	2 (5%)	3 (8%)
Evening peaks	Dockless bike riders	287	51 (18%)	27 (9%)	44 (15%	50 (17%)
Evening peaks	Personal bike riders	21	6 (29%)	1 (5%)	0	1 (5%)

From this set of one month's morning peak dockless bikes of riding and parking data in first tier cities, I can make some simple conclusions about the results as follows.

First of all, by observing the riding and parking behavior of dockless bikes and private bikes, it can be clearly seen that the proportion of irregular behaviors of dockless bicycle riders is higher, which indicates that people ride dockless bike more freely than private cars.

Secondly, some cycling behaviors are more dangerous. The incidence of dockless bike riders running red lights is much higher than that of private bicycle riders (33% vs. 12%). In addition, the incidence of wrong direction riding by dockless bike is much higher (29% vs. 18%), and dockless bikes are more likely to make this type of riding behavior than ordinary cyclists. Considering the next behavior of not riding on the bicycle lane, dockless bike riders are 42% more likely to do so in the morning peak hours, which is 30% higher than ordinary bicycles. Finally, not holding the handlebars with both hands is a high-risk behavior, and fewer cyclists have this behavior than the other three. 5% of cyclists overall have this behavior, but dockless bikes reach as many as 14%.

Third, in terms of parking behavior, there are relatively enough parking spaces in Beidajie subway station in the morning rush hour, so there are very few cases of individual cyclists parking without standards. Xi'an's North Street has recently set up 2,000 parking spaces near the subway entrance, and the design of the parking spaces on North Street has greatly reduced the illegal parking of bicycles without docks. The design of bicycle spaces not only alleviates traffic congestion but also facilitates the parking of bicycles for citizens (Xinhua, 2022). However, dockless bikes riders still have this problem. 17% of dockless bike riders have the problem of impeding pedestrians or passing bicycles, and 8% of dockless bike riders have the problem of interfering with surrounding businesses. 12% of dockless bikes are parked improperly, and 14% of dockless bikes have an impact on the surrounding green environment.

For evening peak, in terms of parking behavior, it can be seen from Table 5.14 that the parking behavior of Beidajie subway station increases significantly during the evening peak on weekdays, and this increase only occurs in the parking of dockless bikes. In other

words, there will be more parking at the subway station in the city center during the evening peak on weekdays. There are 411 dockless bikes parking without piles at the evening peak, which is far lower than the 611 parking at the morning peak. This shows that people are more likely to ride dockless bikes to the station in the morning peak than in the evening peak.

The four misplaced parking behaviors observed by the author during the 30 minute statistical period have all increased in the evening peak and the early peak, among which the proportion of pedestrians or bicycles obstructing passing has reached 17%, which is the same as that in the morning peak. This is still the most common of the four types of parking violations, but the increase in the proportion shows that not only the number of late peak parking increases, but also the proportion of illegal parking increases. The second most common misconduct is the impact on the surrounding green environment of 15%, and the interference to surrounding businesses is still the lowest, which has been reduced from 8% to 6% in the morning peak. The second highest number of misconduct is the impact on the surrounding green belt of 15%. In fact, no matter whether it is the morning peak or the evening peak, the impact of dockless bicycles on bicycle lanes and pedestrians has a great negative impact. Wei (2022) reported the situation of dockless bicycles "enclosing" bus stops and subway entrances in Xi'an. Although the phenomenon of indiscriminate parking of dockless bike on Xi'an North Avenue has improved, the problem of parking dockless bike on non-arterial roads has not improved significantly. A large number of dockless bike is still in a mess, and some bicycles parked in disorder occupy the non-motorized lanes, affecting traffic. Xi'an Transportation Bureau (2022) integrates parking resources, dynamically adjusts the balance of parking supply and demand, improves the pedestrian and bicycle traffic signs and identification systems in Xicheng District, and expands sufficient parking spaces, but there are still insufficient parking spaces on North Street. For example, the division of bicycle parking spaces on North Street is unreasonable. Although there are enough parking spaces, most of the parking spaces are arranged in multiple rows. Yuan (2022) also shows that multi-row parking is more likely to cause confusion than single-row parking spaces, because single-row parking spaces are set according to the length of bicycles, while multi-row parking spaces need to be parked according to the voluntary parking of bike riders without docks, so single-row parking spaces are more restrictive than multi-row parking spaces and will reduce disorderly parking.

It is worth noting that in my observation, the number of wrong berthing at night peak is significantly reduced. In the morning rush hour, there are already a large number of dockless bikes and ordinary bicycles parked in front of the Beidajie subway station. In the evening rush hour, when the observation is just started, there is still enough parking space. The parking crowd seems to be more willing to walk 20 meters or spend 10 seconds more to sort out a suitable parking space during the evening rush hour. The people in the morning rush hour are more anxious, which may also be related to the rush to work in the morning. From the overall observation, continuous wrong parking is more likely to occur, and there are more parking times in the morning peak. The 2022 urban travel report (2023) shows that it has become the most congested city in the morning peak after Beijing, Shanghai and Shenzhen, and Xi'an is an important city in the central and western regions of my country. The rapid growth of private cars has exposed many problems within the city, such as urban unreasonable planning, insufficient public transportation channels, inadequate priority public transportation policies, low efficiency of traffic management policies, lack of strategic position in comprehensive transportation development, all these aspects have aggravated the problem of traffic congestion to a certain extent (Yang, 2013). Therefore, people in the morning peak when the traffic network is congested are more willing to ride on the last mile because of the tight time to go to work.

In the morning and evening peak periods in second-tier cities, the proportion of dockless bicycles is still much higher than that of private bicycles. Moreover, due to the combination of parking facilities around subway stations, the phenomenon of indiscriminate parking is significantly reduced. However, the lack of corresponding management facilities, random lane occupation, lack of management and other irregular riding behaviors are still serious.

5.3.3 Weekend Observation of Beidajie Subway Station

Weekend observation includes 3 hours of morning peak video observation and 3 hours of evening peak video observation. From the perspective of the proportion of morning peak travel, the weekend morning peak in the 3-hour video should reach about 116 vehicles, and the number of trips of dockless bikes should account for 87 vehicles, although it is worth noting that a large proportion of private bicycle trips have declined, indicating that the number of trips in the city center during the weekend morning peak hours is very small.

Table 5.15 Comparison of pileless bike and individual bike rides at Deidajie metro station on weekend morning and evening peaks.

	Bike rider type	amount	Riding a bike through a red light	Riding in the opposite direction	Do not hold the handlebar with both hands	Riding on a non-bicycl e lane
Morning peaks	Dockless bike riders	87	16 (18%)	12 (14%)	6 (7%)	18 (21%)
Morning peaks	Personal bike riders	29	3 (10%)	6 (20%)	0	2 (6%)
Evening peaks	Dockless bike riders	127	23 (18%)	20 (15%	10 (8%)	32 (25%
Evening peaks	Personal bike riders	40	4 (10%)	4 (10%)	0	3 (8%)

Table 5.16 Comparison of weekend morning and evening peaks parking data of dockless bikes and individual bicycle at Beidajie subway station.

	Bike rider type	Total amount	Obstruct passing pedestrians or passing bicycles	Obstruct passing pedestrians or passing bicycles	Not parked upright	Has an impact on the surrounding green environment
Morning peaks	Dockless bike riders	20	3 (15%)	1 (5%)	1 (5%)	2 (10%)
Morning peaks	Personal bike riders	8	1 (13%)	0	0	1 (13%)
Evening peaks	Dockless bike riders	37	5 (14%)	3 (8%)	2 (6%)	9 (25%)
Evening peaks	Personal bike riders	13	1 (8%)	0	0	0

The most typical feature of the weekend morning peak bicycle free travel on North Street is the sharp reduction in the number, but this is certainly not just the feature of weekend morning peak bicycle free travel. The overall weekend morning peak travel volume is very low, and the traffic travel volume affects everyone's overall travel behavior. The four types of abnormal travel behaviors are reduced in proportion, and there is no need to compete for the overall road resources after the overall travel volume is reduced. The wider the road, the fewer vehicles, the fewer bicycles, and the larger the space for

cyclists. It is related to adjusting their riding behaviors according to the lack of mobility system on working days with sufficient mobility system. Cycling is clearly more regulated. First of all, comparing the riding behavior of the morning rush hour on weekends, the riding behavior of dockless bicycles and private bicycles has obvious differences. Although the sample is small, it can still represent the riding behavior. As mentioned earlier, there are behavioral differences between private bicycles and dockless bicycles. From the data point of view, the most obvious one is still riding on non-bicycles. Xian (2022) explained that non-motorized lanes were originally set up in the road planning of North Street, but some road sections and traffic arteries "disappeared" during the road reconstruction and expansion process due to the surge in the number of motor vehicles and heavy traffic pressure up. The existing North Street roads are mainly divided into three types. The first type is to set up special non-motor vehicle lanes on roads with wide road width and low traffic saturation, and use isolation guardrails to isolate them as much as possible; the second type is the road width. On narrower roads with high traffic saturation, non-mixed traffic lanes for vehicles are set up without guardrails. Third, mixed traffic lanes for pedestrians and non-traffic lanes are set up on some roads without guardrails for separation. According to the relevant national regulations, according to road traffic conditions, it is possible to set up non-machine mixed traffic and pedestrian non-mixed roads (Shanxi, 2022). During the morning peak at the weekend, 15% of pedestrians or bicycles obstructing the passing were observed, and the other three irregular parking behaviors were all less than 10%. The standing behavior without parking only occurred once in the whole morning peak, accounting for 5%. This is because the dockless bikes may not be very practical, so it must be parked against another wall. But parking behavior and riding behavior have unified characteristics.

In general, there is a feeling that the whole city is sleeping at the weekend until the next morning peak. Not only are there fewer trips for dockless bikes, but there are fewer trips in the whole city. What's more noteworthy is that when the number of trips decreases, the overall percentage of uncontrolled trips also decreases significantly. The travel data of AutoNavi Maps (2023) shows that there are more choices of travel destinations and travel methods on weekends, and people do not pursue travel efficiency too much on weekends. In contrast, travels on weekdays are mainly rigid travels (such as

commuting, going to school). The purpose of non-working days is not a rigid demand, so it is not necessary to cause traffic jams and the travel time is relatively scattered.

For weekend evening, running red lights by bicycle and riding on non-bicycle lanes are still the two most common types of abnormal travel, accounting for 18% and 25% respectively. At the same time, it shows that many people also choose to ride bicycles to run red lights on weekends. Weekend nights indicate that the purpose of these trips may be more for entertainment and other non-work purposes. The travel purposes of AutoNavi map (2022) shows that 32% of the travel destinations of the people traveling in the evening peak on weekends are supermarkets, and 43% of people travel destinations are bathing, KTV, restaurants and other leisure and entertainment places. Table 5.16 shows the peak parking at Beidajie subway station on weekends. In general, there are not many parking spaces at the subway station on North Street of Gaofeng on the weekend night, and there are not too many violations. The proportion of the four major violations is much lower than that on weekdays, but it is worth mentioning that compared with other violations, the parking volume in the green belt of the peak on the weekend night is much more (25%), which may be because there are many dockless bikes parked in the green belt on weekends. As a result, the dockless bikes later stopped on the green belt, following this misconduct.

However, regarding the parking behavior of dockless bicycles, it can be found that as long as there are enough bicycle parking spaces and the distance is relatively close, most cyclists will park in a suitable location. Especially on weekends, it can be seen that no matter it is the morning peak or the evening peak, the behavior of illegal parking is less, of which the morning peak accounts for 26%, while the evening peak only accounts for 8%.

On weekends, the rate of parking violations in the new urban areas of second-tier cities is also significantly increased, and bicycles running red lights and occupying lanes are still the most common violations, but the amount of parking in the green belt during the weekend evening peak is higher than that in first-tier cities, because there are many dockless bicycles parked in the green belt at weekends, leading to subsequent vehicles to imitate.

5.4 T-test result analysis

5.4.1 Analysis on riding and parking behavior of people in different urban areas

Here are the results of the T-test for riding behavior in the old and new urban areas. According to t-test, it can be seen that among the riding behaviors of dockless shared bicycles and private bicycles in the new and old urban areas, there is a significant difference in the non-standard riding behaviors of the two in the new urban area. Combined with the data of observation method, the irregular riding behavior is less in the new urban area. This is because the urban planning concept and design strategy in the new urban area will pay more attention to the construction of modern infrastructure, and the concept of the last mile will be better integrated. For example, new urban areas will have more good bike lanes and better connections with other public transport as much as possible, reducing the cost and time of cyclists. At the same time, the supporting facilities in the new urban area also provide a good space and environment for cycling, making people tend to regulate their own behavior. However, the specification of dockless shared bicycles is still relatively poor, which may be due to the fact that even if the new urban area considers the demand for bicycles, there is still less consideration for dockless shared bicycles. Even with fewer overall irregularities, there is still a difference between the two approaches. In addition, the residents of new urban areas are usually young people who want to stay in the city. In China, if you want to settle in big cities, the high cost of housing is a relatively big burden for the young generation. When it comes to transportation, they tend to use economical and flexible modes of transportation compared to public transportation such as cars. At the same time, the younger generation in the city has generally received higher education and has its own restrictions on riding behavior. However, for shared bicycles and their own bicycles, they will be more binding on their own cars, after all, it is the private property of individuals.

Figure 5.2 T-test result of riding behavior in new urban areas

Group Statistics

	VAR00001	N	Mean	St d.	Deviation	St d.	Error Mean
VAR00021	Dockl ess	8	. 7087		. 21879		. 07735
	Per sonal	8	. 3225		. 14704		. 05199

Independent Samples Test

Levene's Test for Equality
of Variances

t-test for Equality of Means
Sig.

F Sig. t df (2-tailed)

VAR00021 Equal variances
assumed
Equal variances not
assumed

4. 144 12. 252 . 001

Independent Samples Test

t-test for Equality of Means 95% Confidence Interval of Std. Error the Difference Mean Difference Difference Lower VAR00021 38625 Equal variances assumed . 09320 . 18635 58615 Equal variances not . 38625 . 09320 . 18365 . 58885 assumed

Independent Samples Effect Sizes

					95% Confiden	ce Interval
		St andar di zer ª	Poi nt	Estimate	Lower	Upper
VAR00021	Cohen's d	. 18640		2. 072	. 809	3. 289
	Hedges' correction	. 19719		1. 959	. 765	3. 109
	Gass's delta	. 14704		2. 627	. 933	4. 263

a. The denominator used in estimating the effect sizes.

Cohen's duses the pooled standard deviation.

Hedges' correction uses the pooled standard deviation, plus a correction factor.

Glass's delta uses the sample standard deviation of the control group.

In terms of parking behavior, the difference between the two types of riders' irregular behavior is more significant in the new urban area than in the old urban area, and the irregular parking behavior is less in the new urban area. The reason is closely related to the rationality of construction. The planning, capacity design and guidance of the shared bicycle parking space in the new urban area take more into account the needs and use of the crowd, which can meet people's parking of shared bicycles as far as possible from the planning, and also show the level of modern urban construction. When there is a reasonable design, it can greatly improve the convenience and safety of riding. The location of its layout is also often

closely integrated with crowded public transport stations or crowded areas, which can reduce disorderly parking caused by insufficient parking Spaces. In addition, ease of use is also an important factor. Eye-catching signage systems and ground guidance allow people to quickly find parking spaces and avoid irregular parking due to time constraints. In terms of private and shared bicycles, in some major traffic nodes and commercial gathering areas, although there are some parking spaces for private bicycles, there is a lack of a sufficient number of shared bicycle parking spots, resulting in shared bicycle riders needing to spend extra time looking for shared bicycle parking Spaces during use.

Figure 5.3 T-test result of parking behavior in new urban areas

Group Statistics

	VAR00001	N	Mean S	Std. Deviation	Std. Error Mean
VAR00002	Dockl ess	8	. 4200	. 12375	. 04375
	Per soanl	8	. 1725	. 13926	. 04924

Independent Samples Test

Levene's Test for Equality
of Variances
t-test for Equality of Means
Sig.

		F	Sig.	t	df	(2- t ai I ed)
VAR00002	Equal variances assumed	. 335	. 572	3. 758	14	. 002
	Equal variances not assumed			3. 758	13. 809	. 002

Independent Samples Test

t-test for Equality of Means

95% Confidence Interval of Std. Error Mean the Difference Difference Difference **Upper** VAR00002 . 24750 Equal variances assumed . 06587 . 10623 . 38877 Equal variances not . 24750 . 06587 . 10605 . 38895 assumed

Independent Samples Effect Sizes

95% Confidence Interval

		St andar di zer a	Point Estimate	Lower	Upper
VAR00002	Cohen's d	. 13173	1. 879	. 658	3. 055
	Hedges' correction	. 13936	1. 776	. 622	2. 887
	Gass's delta	. 13926	1. 777	. 406	3. 084

a. The denominator used in estimating the effect sizes.

Cohen's duses the pooled standard deviation.

Hedges' correction uses the pooled standard deviation, plus a correction factor.

Glass's delta uses the sample standard deviation of the control group.

For the old urban area, it has no significant impact on the riding behavior of shared bicycles and private bicycles. This shows that due to the early construction of the old urban area, the road design and planning of the bicycle planning is insufficient, mostly considering the travel demand of motor vehicles. At the same time, the roads in some old urban areas are relatively narrow, and motor vehicles will also stop at the roadside, which brings a lot of obstacles to the passage of all kinds of bicycles. In this case, due to the chaotic nature of the traffic, it is difficult for riders to restrain their own behavior, resulting in irregular riding. In addition, due to the convergence of a large number of people and vehicles in the old city, the traffic situation is usually congested. In order to make their own smooth passage, some riders will choose to take the motor road, resulting in a lot of cycling violations.

Figure 5.4 T-test result of riding behavior in old urban areas

Group Statistics

	VAR00001	N	Mean	St d.	Deviation	St d.	Error	Mean
VAR00021	Dockl ess	4	. 6125		. 34789		. 17	7394
	Per sonal	4	. 3450		. 29263		. 14	4632

Independent Samples Test

Levene's Test for Equality

of Variances t-test for Equality of Means Sig.

		F	Sig.	t	df	(2-tailed)
VAR00021	Equal variances assumed	. 056	. 821	1. 177	6	. 284
	Equal variances not assumed			1. 177	5. 829	. 285

Independent Samples Test

t-test for Equality of Means

95% Confidence Interval of

		Mean	Std. Error the Diffe		f er ence
		Difference	Difference	Lower	Upper
VAR00021	Equal variances assumed	. 26750	. 22730	28868	. 82368
	Equal variances not	. 26750	. 22730	29266	. 82766
	assuned				

Independent Samples Effect Sizes

95% Confidence Interval

		St andar di zer ^a	Point Estimate	Lower	Upper
VAR00021	Cohen's d	. 32145	. 832	658	2. 262
	Hedges' correction	. 37007	. 723	572	1. 965
	Gass's delta	. 29263	. 914	692	2. 410

a. The denominator used in estimating the effect sizes.

Cohen's duses the pooled standard deviation.

Hedges' correction uses the pooled standard deviation, plus a correction factor.

Gass's delta uses the sample standard deviation of the control group.

For the parking behavior in the old urban area, the conclusions show consistency. The old area gathers more population than the new, so its land resources are relatively tight. Existing space tends to be used for other daily needs of residents, while land for transportation is relatively limited. Land coordination in the old urban area is very difficult, involving many departments and various interest groups. The location of the bicycle requires a relatively large land area, so the parking space for both shared bicycles and private bicycles in the old city is insufficient. Besides, motor vehicle parking in the old area is also experiencing the same problem, but due to the larger size of the motor vehicle, the parking space encroachment on non-motor vehicles is more serious. It is difficult for cyclists to find places and spaces to park, which leads to indiscriminate parking. They may park their bikes on other empty land that has other uses, such as sidewalks, green belts, etc. Moreover, the supervision of public transportation in the old urban area is poor, and the supervision of the parking of shared bicycles is also poor.

Figure 5.5 T-test result of parking behavior in old urban areas

	VAR00001	N	Mean	St d.	Deviation	Std. Error Mean
VAR00002	Dockl ess	4	. 6025		. 41748	. 20874
	Per sonal	4	. 2600		. 24698	. 12349

Independent Samples Test

Levene's Test for Equality

of Variances t-test for Equality of Means

Sig.

		F	Si g.	t	df	(2-tailed)
VAR00002	Equal variances assumed	3. 025	. 133	1. 412	6	. 208
	Equal variances not assumed			1. 412	4. 871	. 218

Independent Samples Test

t-test for Equality of Means

95% Confidence Interval of

		Mean	Std. Error	the Diff	er ence
		Difference	Difference	Lower	Upper
VAR00002	Equal variances assumed	. 34250	. 24253	25096	. 93596
	Equal variances not	. 34250	. 24253	28596	. 97096
	assuned				

Independent Samples Effect Sizes

95% Confidence Interval

		St andar di zer a	Point Estimate	Lower	Upper
VAR00002	Cohen's d	. 34300	. 999	528	2. 456
	Hedges' correction	. 39487	. 867	459	2. 133
	Gass's delta	. 24698	1. 387	418	3. 066

a. The denominator used in estimating the effect sizes.

Cohen's duses the pooled standard deviation.

Hedges' correction uses the pooled standard deviation, plus a correction factor.

Gass's delta uses the sample standard deviation of the control group.

For the suburbs, there is no significant difference in the non-standard riding behaviors and parking behaviors of dockless shared bicycles and private bicycles. In the suburbs, urban construction and public transportation system planning are relatively backward, and the coverage rate of bicycles is low. Less attention is paid to travel by public transport. Although dockless shared bicycles exist in the suburbs, they may have little impact on irregular behaviors due to their small distribution points and relatively dispersed distance. It is also related to the distribution of people and the nature of land use and other related factors. The distance between POI points in the suburbs is also longer, and the frequency of bicycle use is lower. In this case, whether it is a dockless shared bike or a private bike, the difference in their irregular riding behavior will not be too great.

Figure 5.6 T-test result of riding behavior in sub-urban areas

	VAR00001	N	Mean	St d.	Deviation	Std. Error Mean
VAR00021	Dockl ess	4	. 5275		. 30071	. 15035
	Per sonal	4	. 4650		. 39946	. 19973

Independent Samples Test

Levene's Test for Equality

 VARO0021
 Equal variances assumed
 1.495
 .267
 .250
 5.574
 .812

 Equal variances assumed
 .250
 .574
 .812

Independent Samples Test

t-test for Equality of Means

95% Confidence Interval of

		Mean	Std. Error	the Dif	f er ence
		Difference	Difference	Lower	Upper
VAR00021	Equal variances assumed	. 06250	. 25000	54922	. 67422
	Equal variances not	. 06250	. 25000	56074	. 68574
	assumed				

Independent Samples Effect Sizes

95% Confidence Interval

		St andar di zer a	Point Estimate	Lower	Upper
VAR00021	Cohen's d	. 35355	. 177	- 1. 220	1. 559
	Hedges' correction	. 40702	. 154	- 1. 059	1. 354
	Gass's delta	. 39946	. 156	- 1. 247	1. 535

a. The denominator used in estimating the effect sizes.

Cohen's duses the pooled standard deviation.

Hedges' correction uses the pooled standard deviation, plus a correction factor.

Glass's delta uses the sample standard deviation of the control group.

Figure 5.7 T-test result of parking behavior in old urban areas

	VAR00001	N	Mean	St d.	Deviation	St d.	Error Mean
VAR00002	Dockel ss	4	. 5250		. 29011		. 14506
	Per sonal	4	. 3625		. 37757		. 18878

Independent Samples Test

Levene's Test for Equality

of Variances t-test for Equality of Means

) /AFT00000		F 700	Si g.	t	df	(2-t ai l ed)
VAR00002	Equal variances assumed	. 799	. 406	. 683	6	. 520
	Equal variances not assumed			. 683	5. 627	. 522

Independent Samples Test

t-test for Equality of Means

95% Confidence Interval of

		Mean	Std. Error	the Difference	
		Difference	Difference	Lower	Upper
VAR00002	Equal variances assumed	. 16250	. 23808	42006	. 74506
	Equal variances not	. 16250	. 23808	42955	. 75455
	assumed				

Independent Samples Effect Sizes

					95% Confidence	e Interval
		St andar di zer ^a	Poi nt	Estimate	Lower	Upper
VAR00002	Cohen's d	. 33669		. 483	948	1. 875
	Hedges' correction	. 38762		. 419	823	1. 629
	Glass's delta	. 37757		. 430	- 1, 026	1. 823

a. The denominator used in estimating the effect sizes.

Cohen's duses the pooled standard deviation.

Hedges' correction uses the pooled standard deviation, plus a correction factor.

Glass's delta uses the sample standard deviation of the control group.

5.4.2 Analysis on riding and parking behavior of people on weekends and weekdays

For the analysis of the weekend, the difference in riding behavior between dockless shared bicycles and private bicycles was not significant. Compared with weekdays, the purpose of travel on weekends is more diverse, so that the difference in the frequency and location of use between dockless shared bicycles and private bicycles is not obvious. On weekends, whether using dockless shared bikes or private bikes, the main purpose is to travel within a short distance, rather than commuting needs, so the difference in cycling use between the two is relatively small. For shared bicycles, his distribution is mainly concentrated in areas

such as transportation transfer stations and POI. On weekends, there is less demand for shared bikes in these areas, so that the riding of shared bikes is more in line with that of private bikes. Besides, private bike users usually ride familiar routes around their homes or ride to fixed locations on weekends, which complements the random cycling needs of shared bike users on weekends, thus making the difference between the two insignificant. The regular places they go to may be similar on weekends, such as shopping malls, parks, etc. This also shows that there is less difference in riding behavior in the weekend situation.

Figure 5.8 T-test result of riding behavior on weekends

Group Statistics VAR00001 N Mean St.d. Deviation St.d. Error Mean VAR00011 Dockless 8 .4350 .17809 .06296 Per sonal 8 .3412 .17618 .06229

Levene's Test for Equality of Variances F Sig. t df (2-tailed) VARO0011 Equal variances assumed Equal variances not assumed 1.059 13.998 .308

Independent Samples Test t-test for Equality of Means

		1 1001 10. =					
		95% Confidence Interval of					
		Mean Std. Error		the Difference			
		Difference	Difference	Lower	Upper		
VAR00011	Equal variances assumed	. 09375	. 08857	09621	. 28371		
	Equal variances not	. 09375	. 08857	09621	. 28371		
	assumed						

Independent Samples Effect Sizes

					95% Confiden	ice Interval
		St andar di zerª	Poi nt	Estimate	Lower	U pper
VAR00011	Cohen's d	. 17714		. 529	479	1. 519
	Hedges' correction	. 18739		. 500	453	1. 436
	Gass's delta	. 17618		. 532	503	1. 532

a. The denominator used in estimating the effect sizes.

Cohen's duses the pooled standard deviation.

Hedges' correction uses the pooled standard deviation, plus a correction factor.

Glass's delta uses the sample standard deviation of the control group.

For parking behavior, the difference between dockless shared bikes and private cars is also not significant. Many of the parking areas of both are close to each other on weekends, mainly concentrated in crowded areas to meet their use needs. Crowded areas often have a certain amount of bicycle parking space, so the difference in behavior between the two is not very big. There is little difference in the management of weekend bicycles in cities, and there will be management and restrictions in the gathering places, so that the parking behaviors of the two tend to be consistent. Also, parking is also about people's awareness, whether it is dockless shared bikes or private bikes, riders tend to park in areas with planning and clear guidelines. In conclusion, there is little difference in parking behavior between shared bicycles and private bicycles on weekends.

Figure 5.9 T-test result of parking behavior on weekends

Group Statistics							
	VAR00001	N	Mean	St d.	Deviation	St d.	Error Mean
VAR00002	Dockl ess	8	. 3313		. 13442		. 04753
	Per sonal	8	. 1763		. 18585		. 06571

	l r	ndependent S Levene's Test	-			
		of Var	t-test	t-test for Equality of Means		
						Sig.
		F	Sig.	t	df	(2-t ai I ed)
VAR00002	Equal variances assumed	1. 694	. 214	1. 911	14	. 077
	Equal variances not assumed			1. 911	12. 750	. 079

Independent Samples Test t-test for Equality of Means 95% Confidence Interval of Std. Error Mean the Difference Difference Difference Lower **Ubper** VAR00002 . 15500 . 08109 - . 01893 32893 Equal variances assumed . 15500 . 08109 - . 02054 . 33054 Equal variances not assumed

Independent Samples Effect Sizes

05% Confi donos Interval

				95% Will I del	ice Tillervai
		St andar di zerª	Point Estimate	Lower	Upper
VAR00002	Cohen's d	. 16219	. 956	100	1. 982
	Hedges' correction	. 17158	. 903	095	1. 873
	Gass's delta	. 18585	. 834	260	1. 879

a. The denominator used in estimating the effect sizes.

Cohen's d uses the pooled standard deviation.

Hedges' correction uses the pooled standard deviation, plus a correction factor.

Glass's delta uses the sample standard deviation of the control group.

In terms of riding behavior on weekdays, there is a significant difference between dockless shared bikes and private bikes. On weekdays, due to commuter demand, the frequency of use of shared bikes will increase, especially at public transport interchange stations. This kind of usage has a strong characteristic and concentration. At the same time, due to the flexibility of the use of shared bicycles, users can access them at any time, so the frequency of use will increase. The use of private bikes will be less than that of shared bikes. The users of private bicycles are mostly long-term users of bicycles. For riding behavior, because riding shared bikes is to catch up on the commute, some people may not pay attention to irregular behaviors when riding. And a large number of people ride in the same time frame, so the number and frequency of irregularities will be higher. This difference is mainly due to the ripple effect of the change in the purpose of commuting.

Figure 5.10 T-test result of riding behavior on weekdays

	VAR00001	N	Mean	St d.	Deviation	St d.	Error Mean
VAR00011	Dockl ess	8	. 8288		. 14307		. 05058
	Per sonal	8	. 3863		. 32018		. 11320

Independent Samples Test

Levene's Test for Equality

 VARO0011
 Equal variances
 Tequal ty of Means Sig.

 Equal variances
 7.600
 .015
 3.569
 14
 .003

 Equal variances not assumed
 3.569
 9.688
 .005

Independent Samples Test

t-test for Equality of Means

95% Confidence Interval of

		Mean	Std. Error	the Difference	
		Difference	Difference	Lower	Upper
VAR00011	Equal variances assumed	. 44250	. 12399	. 17657	. 70843
	Equal variances not	. 44250	. 12399	. 16503	. 71997
	assumed				

Independent Samples Effect Sizes

95% Confidence Interval

		St andar di zer a	Point Estimate	Lower	Upper
VAR00011	Cohen's d	. 24797	1. 784	. 584	2. 941
	Hedges' correction	. 26233	1. 687	. 552	2. 780
	Gass's delta	. 32018	1. 382	. 141	2. 561

a. The denominator used in estimating the effect sizes.

Cohen's duses the pooled standard deviation.

Hedges' correction uses the pooled standard deviation, plus a correction factor.

Glass's delta uses the sample standard deviation of the control group.

For the parking behavior on weekdays, the difference is also significant. Due to the limitation of the parking location of private bicycles, their parking use is not as convenient as that of shared bicycles. Shared bikes can be parked where users feel they can. Due to inadequate facilities or unclear guidelines, users of shared bikes can take advantage of their flexibility and park in areas they find empty, such as blind lanes, street sides or building entrances, thereby saving time for quick transfers. Although this kind of random parking behavior meets the convenient needs of users, it also puts forward higher requirements for

the planning and construction of public space. The difference in parking behavior may also be due to the fact that bike-sharing users also rely on guidance from the program, but sometimes this guidance is inconsistent with the use of space in the city, leading users to park the shared bikes in non-parking areas. Private bikes are more likely to have fixed parking Spaces, which regulate their behavior. This different car properties and the flexibility of the parking area lead to the difference between the two. This also shows that it is necessary to consider the characteristics and nature of the use of transportation to plan the urban public transport system.

Figure 5.11 T-test result of parking behavior on weekdays

Group Statistics

	VAR00001	N	Mean	St d.	Deviation	Std. ⊟	rrorMean
VAR00002	Dockl ess	8	. 6525		. 25013		. 08843
	Per sonal	8	. 3075		. 27613		. 09763

Independent Samples Test

Levene's Test for Equality of Variances

t-test for Equality of Means

						Sig.
		F	Sig.	t	df	(2- t ai I ed)
VAR00002	Equal variances assumed	. 000	. 985	2. 619	14	. 020
	Equal variances not assumed			2. 619	13. 865	. 020

Independent Samples Test

t-test for Equality of Means

95% Confidence Interval of

		Mean	Std. Error	the Diff	er ence
		Difference	Difference	Lower	Upper
VAR00002	Equal variances assumed	. 34500	. 13173	. 06248	. 62752
	Equal vari ances not	. 34500	. 13173	. 06222	. 62778
	assumed				

Independent Samples Effect Sizes

95% Confidence Interval

		St andar di zer a	Point Estimate	Lower	Upper
VAR00002	Cohen's d	. 26345	1. 310	. 199	2. 382
	Hedges' correction	. 27870	1. 238	. 188	2. 252
	Gass's delta	. 27613	1. 249	. 048	2. 391

a. The denominator used in estimating the effect sizes.

Ohen's duses the pooled standard deviation.

Hedges' correction uses the pooled standard deviation, plus a correction factor.

Glass's delta uses the sample standard deviation of the control group.

5.4.3 Analysis on riding and parking behavior in morning and evening peak hours

During the morning rush hour, there was no significant difference in the irregular behavior between dockless bike users and private bike users. According to the analysis of the results of the T-test, this is because in the morning peak period, both of them have the need to commute and rush time, so despite the infrastructure, the irregular behavior of both of them still occurs. Combined with the observation conclusions, a deeper analysis can be found that this is because of the imperfect road infrastructure and signage facilities in the morning rush hour when people are in a hurry. Both do not have dedicated bicycle riding roads, so there will be irregular behavior of occupying the road and retrograde. At the same time, there is no clear traffic sign to guide the ride, resulting in the phenomenon of lane occupation because of unclear norms. This shows that reasonable guidance facilities and good traffic facilities are very necessary during the morning rush hour.

Figure 5.12 T-test result of riding behavior in morning peak

	VAR00001	N	Mean	St d.	Deviation	Std. Error Mean
VAR00011	Dockl ess	8	. 7000		. 24213	. 08561
	Per sonal	8	. 4863		. 22251	. 07867

Independent Samples Test

Levene's Test for Equality of Variances t-test for Equality of Means Sig. (2-tailed) VAR00011 . 638 . 438 1.838 . 087 Equal variances assumed 1.838 Equal variances not 13. 901 . 087 assumed

Independent Samples Test

t-test for Equality of Means 95% Confidence Interval of Mean Std. Error the Difference Difference Difference Lower Upper VAR00011 -. 03561 . 21375 . 11627 . 46311 Equal variances assumed Equal variances not . 21375 . 11627 -. 03578 . 46328 assumed

Independent Samples Effect Sizes

				95% Contider	ice interval
		St andar di zer ª	Point Estimate	Lower	Upper
VAR00011	Cohen's d	. 23253	. 919	132	1. 941
	Hedges' correction	. 24599	. 869	125	1. 835
	Gass's delta	. 22251	. 961	163	2. 031

a. The denominator used in estimating the effect sizes.

Cohen's duses the pooled standard deviation.

Hedges' correction uses the pooled standard deviation, plus a correction factor.

Gass's delta uses the sample standard deviation of the control group.

As far as parking behavior is concerned, there is no significant difference between them. This is also due to the fact that people are in a hurry during the morning peak hour. In the morning peak hour, those who go to work early will give priority to parking spaces, and those who go to work later may not be able to park their cars just because of a five-minute gap. In this case, it is not difficult to find that in the morning peak hour, the way to control irregular parking behavior is to set up enough and flexible parking facilities and areas.

Figure 5.13 T-test result of parking behavior in morning peak

	VAR00001	N	Mean	Std. Deviation	Std. Error Mean
VAR00002	Dockl ess	8	. 5337	. 27082	. 09575
	Per sonal	8	. 3838	. 24237	. 08569

Independent Samples Test

Levene's Test for Equality of Variances t-test for Equality of Means Sig.

F Sig. t df (2-tailed)

VAR00002 Equal variances assumed 1.167 13.831 .263 assumed

Independent Samples Test

t-test for Equality of Means 95% Confidence Interval of Mean Std. Error the Difference Difference Difference Lower VAR00002 . 15000 . 12849 Equal variances assumed - . 12559 . 42559 Equal variances not . 15000 . 12849 - . 12590 . 42590 assumed

Independent Samples Effect Sizes

					95% Confider	nce Interval
		St andar di zer ª	Poi nt	Estimate	Lower	Upper
VAR00002	Cohen's d	. 25698		. 584	429	1. 577
	Hedges' correction	. 27186		. 552	406	1. 491
	Gass's delta	. 24237		. 619	431	1. 630

a. The denominator used in estimating the effect sizes.

Cohen's duses the pooled standard deviation.

Hedges' correction uses the pooled standard deviation, plus a correction factor.

Glass's delta uses the sample standard deviation of the control group.

The T-test results of the two riding behaviors during the evening rush hour show that there are significant differences between the two behaviors. The reason is that although the two travel to the same destination during the evening peak, they are both residential areas. However, most of the routes of private cyclists are fixed, and the roads and other non-marked facilities can be easily found. Users of dockless bikes may choose to pick up their bikes elsewhere within walking distance due to a lack of vehicles near the starting point, leading to partial changes in the cycling route and more violations. This shows that for dockless bicycles, more number and route guidance facilities are needed to regulate their behavior in the evening peak.

Figure 5.14 T-test result of riding behavior in evening peak

	VAR00001	N	Mean	St d.	Deviation	St d.	Error Mean
VAR00011	Dockl ess	8	. 5638		. 26747		. 09457
	Per sonal	8	. 2413		. 22561		. 07976

Independent Samples Test

Levene's Test for Equality

 VARO0011
 Equal variances
 658
 . 431
 2.607
 13.613
 . 021

 Equal variances assumed
 2.607
 13.613
 . 021

Independent Samples Test

t-test for Equality of Means

95% Confidence Interval of

		Mean	Std. Error	the Difference	
		Difference	Difference	Lower	Upper
VAR00011	Equal variances assumed	. 32250	. 12371	. 05716	. 58784
	Equal variances not	. 32250	. 12371	. 05645	. 58855
	assumed				

Independent Samples Effect Sizes

95% Confidence Interval

		St andar di zer ª	Point Estimate	Lower	Upper
VAR00011	Cohen's d	. 24743	1. 303	. 194	2. 375
	Hedges' correction	. 26175	1. 232	. 184	2. 245
	Gass's delta	. 22561	1. 429	. 174	2. 623

a. The denominator used in estimating the effect sizes.

Cohen's duses the pooled standard deviation.

Hedges' correction uses the pooled standard deviation, plus a correction factor.

Glass's delta uses the sample standard deviation of the control group.

There is still a strong difference between the two parking behaviors in the evening peak. The same reason as riding behavior, parking behavior is more concerned with the situation of parking facilities at the end. Many private cyclists have fixed parking facilities near their homes for choice and use. And these facilities are to some extent under their personal ownership. However, there is no corresponding parking facility for dockless bicycle riding, so it will produce non-standard parking behavior. This also shows that in the destination

area of the evening peak, it is reasonable and necessary to ensure a sufficient number of parking facilities.

Figure 5.15 T-test result of parking behavior in evening peak

Group Statistics

	VAR00001	N	Mean	St d.	Deviation	St d.	Error Mean
VAR00002	Dockl ess	8	. 4500		. 24951		. 08822
	Per sonal	8	. 1000		. 12604		. 04456

Independent Samples Test

Levene's Test for Equality

of Variances t-test for Equality of Means

Sig.

		F	Sig.	t	df	(2-t ai I ed)
VAR00002	Equal variances assumed	2. 390	. 144	3. 541	14	. 003
	Equal variances not assumed			3. 541	10. 354	. 005

Independent Samples Test

t-test for Equality of Means

95% Confidence Interval of

		Mean Std. Error the Differer		f er ence	
		Difference	Difference	Lower	Upper
VAR00002	Equal variances assumed	. 35000	. 09883	. 13803	. 56197
	Equal variances not	. 35000	. 09883	. 13080	. 56920
	assumed				

Independent Samples Effect Sizes

95% Confidence Interval

		St andar di zer a	Point Estimate	Lower	Upper
VAR00002	Cohen's d	. 19766	1. 771	. 573	2. 925
	Hedges' correction	. 20911	1. 674	. 542	2. 765
	Gass's delta	. 12604	2. 777	1. 021	4. 477

a. The denominator used in estimating the effect sizes.

Cohen's d uses the pooled standard deviation.

 $\label{thm:ledges'} \textit{Ledges' correction uses the pooled standard deviation, plus a correction factor.}$

Glass's delta uses the sample standard deviation of the control group.

5.4.4 Infrastructure Possible measures to reduce irregular cycling behaviours

The above results show that infrastructure can effectively address irregular cycling and parking behaviors in new urban areas, old urban areas and suburbs, weekends and weekdays, morning and evening peak, especially in new urban areas, evening peak and midweek areas and times.

Specifically, infrastructure can first reduce irregular cycling and parking by installing enough road infrastructure. There are enough road facilities with clear bike lanes to ensure that cyclists can ride properly on the road, avoiding the phenomenon of peak hour and occupying the road in the center of the new city. Secondly, by setting up sufficient number and route guidance facilities, in the evening peak and weekday when guidance facilities are very needed, the best route should be planned according to the number of dockless bikes and possible routes to facilitate riders to find the bikes and ride without detour, thus reducing violations such as reverse traffic. Urban centres that do not have the conditions for a dedicated bike lane can follow the example of setting up a "green wave bike pass", giving priority to bicycle right of way when necessary. Finally, the number and flexibility of parking facilities are also essential. With enough dockless bike parking areas and the flexibility to change certain road boundaries to parking facilities during peak hours in key areas, riders can view and receive notifications of temporary adjustments on the app to regulate parking violations. All in all, infrastructure can reduce the occurrence of irregular behaviors by setting up road facilities, guidance facilities and parking facilities.

5.4.5 Analysis of T-Test Results: Insights into Dockless Bike and Private Bike Behavior

The T-test results offer a comprehensive analysis of the differences in riding and parking behaviors between dockless bike users and private bike users across various scenarios. These findings highlight the impact of infrastructure and other factors on the observed behaviors.

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
Frequency	Dockless bike riders	4	181.75	96.033	48.016
	Personal bike riders	4	9.75	8.770	4.385

Independent Samples Test

Levene's Test for Equality

of Variances t-test for Equality of Means

										95% Confidence	e Interval of
							Sig. (2-	Mean	Std. Error	the Diffe	erence
			F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal va	riances	4.066	.090	3.567	6	.012	172.000	48.216	54.019	289.98
	assumed										
	Equal va	riances not			3.567	3.050	.037	172.000	48.216	19.969	324.03
	assumed										
Independen	t Samples	Test									
			Levene's Test for	or Equality							
			of Varia	nces			t-	test for Equality	of Means		
										99% Confidence	e Interval o
							Sig. (2-	Mean	Std. Error	the Diffe	erence
			F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal va	riances	4.066	.090	3.567	6	.012	172.000	48.216	-6.758	350.75
	assumed										
	Equal va	riances not			3.567	3.050	.037	172.000	48.216	-105.093	449.09
	assumed										
Group Si	tatistics										
		Group		N		Mean	Std. 1	Deviation	Std. Erro	r Mean	
Frequenc	су	Dockless b	ike riders		4	18.	00	5.477		2.739	
		Personal bi	ke riders		4	•	25	.500		.250	
Independen	t Samples	Test								_	
	-		Levene's Test fo	or Equality							
			of Varia				t-i	test for Equality	of Means		
										95% Confidence	e Interval o
							Sig. (2-	Mean	Std. Error	the Diffe	
			F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal va	riances	6.021	.050	6.455	6	.001	17.750	2.750	11.021	24.47
	assumed		****					2,,,,			,
		riances not			6.455	3.050	.007	17.750	2.750	9.079	26.42
	assumed							2,,,,			
Independen											
p chach			Levene's Test fo	or Equality							
			of Varia				t-	test for Equality	of Means		
			or varia	20				tor Equality	-11.104110	99% Confidenc	e Interval a
							Sig (2	Mass	Std. Error	the Diffe	
			F	Sia	•	df	Sig. (2-	Mean			
F	E 1			Sig.	t		tailed)	Difference	Difference	Lower	Upper
Frequency	-		6.021	.050	6.455	6	.001	17.750	2.750	7.555	27.94
	assumed										

	Equal variances not assumed			6.455	3.050	.007	17.750	2.750	1.946	33.55
	assumed									
Group Sta	utisties									
Отоир зи	Group		N		Mean	Std.	Deviation	Std. Erro	r Mean	
Frequency		ike riders		4	88.	75	47.063		23.531	
	Personal bi	ke riders		4	2.0	00	1.414		.707	
Independent	Samples Test									
		Levene's Test f	or Equality							
		of Varia	nces			t-	test for Equality	of Means		
									95% Confidence	e Interval
						Sig. (2-	Mean	Std. Error	the Diffe	
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
	Equal variances	6.306	.046	3.685	6	.010	86.750	23.542	29.145	144.3
	assumed Equal variances not			3.685	3.005	.035	86.750	23.542	11.905	161.5
	assumed			3.063	3.003	.033	80.730	23.342	11.903	101.5
	Samples Test									
		Levene's Test f	or Equality							
		of Varia				t-	test for Equality	of Means		
									99% Confidence	e Interval
						Sig. (2-	Mean	Std. Error	the Diffe	erence
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal variances	6.306	.046	3.685	6	.010	86.750	23.542	531	174.0
	assumed									
	Equal variances not			3.685	3.005	.035	86.750	23.542	-50.512	224.0
	assumed									
Group Sta	ntistics									
Group Sid	Group		N		Mean	Std.	Deviation	Std. Erro	r Mean	
Frequency		ike riders		4	41.0		15.642		7.821	
ricquency	Personal bi			4		75	.957		.479	
Trequency										
	Samples Test									
		Levene's Test f	or Equality							
		Levene's Test f				t-	test for Equality	of Means		
						t-	test for Equality	of Means	95% Confidence	ee Interval
						Sig. (2-	test for Equality Mean	of Means Std. Error	95% Confidence	

_	al variances not			5.137	3.022	.014	40.250	7.836	15.418	65.082
assu										
Independent Sam	ples Test									
		Levene's Test f	or Equality							
		of Varia	nces			t-1	test for Equality	of Means		
									99% Confidence	e Interval of
						Sig. (2-	Mean	Std. Error	the Diffe	erence
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Group Statist										
	Group		N		Mean	Std. 1	Deviation	Std. Erro	r Mean	
Frequency	Dockless b	ike riders		4	10.	75	6.500		3.250	
	Personal bi	ke riders		4	1.0	00	.816		.408	
Independent Sam	ples Test									
		Levene's Test f	or Equality							
		of Varia	nces			t-i	test for Equality	of Means		
									95% Confidence	e Interval of
						Sig. (2-	Mean	Std. Error	the Diffe	erence
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency Equa	al variances	5.780	.053	2.977	6	.025	9.750	3.276	1.735	17.765
assu	med									
Equa	al variances not			2.977	3.095	.057	9.750	3.276	496	19.996
assu	med									
Independent Sam	ples Test									
		Levene's Test f	or Equality							
		of Varia	nces			t-1	test for Equality	of Means		
									99% Confidence	e Interval of
						Sig. (2-	Mean	Std. Error	the Diffe	erence
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency Equa	al variances	5.780	.053	2.977	6	.025	9.750	3.276	-2.394	21.894
assur										
Equa	al variances not			2.977	3.095	.057	9.750	3.276	-8.813	28.313
assu										
Group Statist	ics									
over province	Group		N		Mean	Std. 1	Deviation	Std. Erro	r Mean	
Frequency	Dockless b	ike riders		4	1.:		.577	2210	.289	
- 10-1401103	Personal bi			4		25	.500		.250	
Independent Sam				•			.500		.255	
тмерениет зит	pics 1631	Levene's Test f	or Equality							
							test for E1'	of Mann		
		of Varia	nces			t-i	test for Equality	of infearis		

									95% Confidence	e Interval o
						Sig. (2-	Mean	Std. Error	the Diffe	rence
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal variances assumed	1.000	.356	3.273	6	.017	1.250	.382	.316	2.18
	Equal variances not			3.273	5.880	.017	1.250	.382	.311	2.18
Indonondor	assumed at Samples Test									
тиерениен	i sumpres Test	Levene's Test f	or Equality							
		of Varia	nces			t-	test for Equality	of Means		
									99% Confidenc	e Interval o
						Sig. (2-	Mean	Std. Error	the Diffe	rence
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal variances	1.000	.356	3.273	6	.017	1.250	.382	166	2.66
	assumed									
	Equal variances not			3.273	5.880	.017	1.250	.382	178	2.6
	assumed									
Group Si	tatistias									
Group Si	Group		N		Mean	Std.	Deviation	Std. Erro	r Mean	
Frequenc		oike riders		4	15.		8.500		4.250	
	Personal bi			4	2.:	25	1.708		.854	
Independen	nt Samples Test									
-		Levene's Test f	or Equality							
		of Varia	nces			t-	test for Equality	of Means		
									95% Confidence	e Interval o
						Sig. (2-	Mean	Std. Error	the Diffe	rence
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
		1	Sig.							
Frequency	Equal variances	3.162	.126	3.114	6	.021	13.500	4.335	2.893	24.10
Frequency	•		-		3.242	.021	13.500 13.500	4.335	2.893	
Frequency	assumed		-	3.114						
	assumed Equal variances not		-	3.114						
	assumed Equal variances not assumed		.126	3.114						
	assumed Equal variances not assumed	3.162	.126	3.114		.047		4.335		
	assumed Equal variances not assumed	3.162 Levene's Test f	.126	3.114		.047	13.500	4.335		26.73
	assumed Equal variances not assumed	3.162 Levene's Test f	.126	3.114		.047	13.500	4.335	.269	26.73
	assumed Equal variances not assumed	3.162 Levene's Test f	.126	3.114		.047	13.500	4.335	.269 99% Confidence	

	Equal variances not assumed			3.114	3.242	.047	13.500	4.335	-10.035	37.035
Group St	tatistics									
	Group		N		Mean	Std.	Deviation	Std. Erro	r Mean_	
Frequenc	cy Dockless b	oike riders		4	2.7	75	2.217		1.109	
	Personal b	ike riders		4	.(00	.000		.000	
Independen	t Samples Test									
		Levene's Test fo	or Equality							
		of Varia	nces			t-	test for Equality	of Means		
									95% Confidence	ce Interval of
						Sig. (2-	Mean	Std. Error	the Diffe	erence
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal variances assumed	7.567	.033	2.480	6	.048	2.750	1.109	.037	5.463
	Equal variances not assumed			2.480	3.000	.089	2.750	1.109	778	6.278
Independen	t Samples Test									
		Levene's Test for	or Equality							
		of Varia				t-	test for Equality	of Means		
									99% Confidence	ce Interval of
						Sig. (2-	Mean	Std. Error	the Diffe	erence
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	the Diffe	erence Upper
Frequency	Equal variances	F 7.567	Sig. .033	t 2.480	df 6					Upper
Frequency	assumed					tailed)	Difference	Difference	Lower	Upper 6.860
Frequency				2.480	6	tailed)	Difference 2.750	Difference	Lower -1.360	Upper 6.860
Frequency Group St	assumed Equal variances not assumed			2.480	6	tailed)	Difference 2.750	Difference	Lower -1.360	Upper 6.860
	assumed Equal variances not assumed			2.480	6	.048 .089	Difference 2.750	Difference	-1.360 -3.726	Upper 6.860
	assumed Equal variances not assumed Satistics Group	7.567	.033	2.480	3.000	.048 .089	2.750 2.750	1.109 1.109	-1.360 -3.726	Upper 6.860
Group St	assumed Equal variances not assumed Satistics Group	7.567	.033	2.480	6 3.000 Mean		2.750 2.750 Deviation	1.109 1.109	-1.360 -3.726	Upper 6.860
Group St	assumed Equal variances not assumed eatistics Group Ey Dockless b	7.567	.033	2.480	6 3.000 Mean 278.5		2.750 2.750 Deviation 195.062	1.109 1.109	-1.360 -3.726 r Mean 97.531	Upper 6.860
<i>Group St</i> Frequenc	assumed Equal variances not assumed Eatistics Group Ey Dockless by Personal by	7.567	.033 N	2.480	6 3.000 Mean 278.5		2.750 2.750 Deviation 195.062	1.109 1.109	-1.360 -3.726 r Mean 97.531	Upper 6.860
<i>Group St</i> Frequenc	assumed Equal variances not assumed Eatistics Group Ey Dockless by Personal by	7.567 Dike riders Dike riders	.033 N or Equality	2.480	6 3.000 Mean 278.5		2.750 2.750 Deviation 195.062	1.109 1.109 Std. Erro	-1.360 -3.726 r Mean 97.531	Upper 6.860
<i>Group St</i> Frequenc	assumed Equal variances not assumed Eatistics Group Ey Dockless by Personal by	7.567 Dike riders Levene's Test for	.033 N or Equality	2.480	6 3.000 Mean 278.5		2.750 2.750 Deviation 195.062 9.777	1.109 1.109 Std. Erro	-1.360 -3.726 r Mean 97.531	Upper 6.860 9.220
<i>Group St</i> Frequenc	assumed Equal variances not assumed Eatistics Group Ey Dockless by Personal by	7.567 Dike riders Levene's Test for	.033 N or Equality	2.480	6 3.000 Mean 278.5		2.750 2.750 Deviation 195.062 9.777	1.109 1.109 Std. Erro	Lower -1.360 -3.726 r Mean 97.531 4.888	Upper 6.860 9.226

	Equal variances not			2.711	3.015	.073	264.750	97.653	-45.149	574.649
	assumed									
Independen	nt Samples Test									
		Levene's Test for	or Equality							
		of Varia	nces			t-	test for Equality	of Means		
									99% Confidence	ce Interval of
						Sig. (2-	Mean	Std. Error	the Diffe	erence
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal variances	4.917	.068	2.711	6	.035	264.750	97.653	-97.292	626.792
	assumed									
	Equal variances not			2.711	3.015	.073	264.750	97.653	-302.816	832.316
	assumed									
Group St	tatistics									
	Group		N		Mean	Std.	Deviation	Std. Erro	r Mean	
Frequenc	cy Dockless b	ike riders		4	92.	25	39.339		19.670	
	Personal b	ike riders		4	5.0	00	5.354		2.677	
Independen	nt Samples Test									
		Levene's Test fo	or Equality							
		of Varia	nces			t-	test for Equality	of Means		
									95% Confidence	ce Interval of
						Sig. (2-	Mean	Std. Error	the Diffe	erence
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal variances	2.524	.163	4.395	6	.005	87.250	19.851	38.676	135.824
	assumed									
	Equal variances not			4.395	3.111	.020	87.250	19.851	25.333	149.167
	assumed									
Independen	nt Samples Test									
		Levene's Test for	or Equality							
		of Varia	nces			t-	test for Equality	of Means		
									99% Confidence	ce Interval of
						Sig. (2-	Mean	Std. Error	the Diffe	erence
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal variances	2.524	.163	4.395	6	.005	87.250	19.851	13.654	160.846
	assumed									
	Equal variances not			4.395	3.111	.020	87.250	19.851	-24.686	199.186
	assumed									
Group Si	tatistics									
Group St	Group		N		Mean	Std 1	Deviation	Std. Erro	r Mean	
	LOTOUP		11		ivicali	Siu.	De viailUli	Sid. EHO	1 WICHII	

Frequency Dockless bike riders

119.75

67.756

33.878

	Personal b	ike riders		4	2.	00	1.414		.707	
Independen	t Samples Test									
		Levene's Test f	or Equality							
		of Varia	nces			t-	test for Equality	of Means		
									95% Confidence	e Interval o
						Sig. (2-	Mean	Std. Error	the Diffe	erence
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal variances	6.980	.038	3.475	6	.013	117.750	33.886	34.835	200.66
	assumed									
	Equal variances not			3.475	3.003	.040	117.750	33.886	9.964	225.53
	assumed									
Indenenden	at Samples Test									
тиерениен	i sumpres Test	Larranala Taat f	an Eassalites							
		Levene's Test f of Varia					test for Equality	y of Moons		
		OI Valia	nces			<u> </u>	test for Equanty	of Means	000/ G . C 1	T . 1
									99% Confidence	
						Sig. (2-	Mean	Std. Error	the Diffe	
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal variances	6.980	.038	3.475	6	.013	117.750	33.886	-7.878	243.37
	assumed									
	Equal variances not			3.475	3.003	.040	117.750	33.886	-80.002	315.50
	assumed									
Group St	tatistics									
	Group		N		Mean	Std.	Deviation	Std. Erro	r Mean	
Frequenc	by Dockless b	oike riders		4	267.	25	93.610		46.805	
	Personal b	ike riders		4	2.	25	.957		.479	
Independen	nt Samples Test									
		Levene's Test f	or Equality							
		of Varia	nces			t-	test for Equality	of Means		
									95% Confidence	e Interval o
						Sig. (2-	Mean	Std. Error	the Diffe	erence
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal variances	5.963	.050	5.661	6	.001	265.000	46.808	150.466	379.53
1)	assumed				*					3,,,,,
	Equal variances not			5.661	3.001	.011	265.000	46.808	116.055	413.94
	assumed			2.001	5.001	.011	203.000	10.000	110.055	113.74
Indonoudo	at Samples Test									
<u> 1пиерепиеп</u>	a sumples Test	Lovernot- T 6	or Equality							
		Levene's Test f					taat fan EU	v of Mo		
		of Varia	nces				test for Equality		000/ 0 7:	T : .
		_				Sig. (2-	Mean	Std. Error	99% Confidence	
		F	Sig.	t	df	tailed)	Difference	Difference	the Diffe	erence

									Lower	Upper
Frequency	Equal variances	5.963	.050	5.661	6	.001	265.000	46.808	91.464	438.536
	assumed									
	Equal variances not			5.661	3.001	.011	265.000	46.808	-8.343	538.343
	assumed									

	Group	N	Mean	Std. Deviation	Std. Error Mean
Frequency	Dockless bike riders	4	33.75	15.714	7.857
	Personal bike riders	4	2.25	1.500	.750

Independent Samples Test

Levene's Test for Equality
of Variances

									95% Confidence	e Interval of
						Sig. (2-	Mean	Std. Error	the Diffe	erence
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal variances	7.123	.037	3.991	6	.007	31.500	7.893	12.188	50.812
	assumed									
	Equal variances not			3.991	3.055	.027	31.500	7.893	6.635	56.365
	accumad									

t-test for Equality of Means

t-test for Equality of Means

t-test for Equality of Means

Independent Samples Test

Levene's Test for Equality of Variances

									99% Confidence	e Interval of
						Sig. (2-	Mean	Std. Error	the Diffe	erence
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal variances	7.123	.037	3.991	6	.007	31.500	7.893	2.239	60.761
	assumed									
	Equal variances not			3.991	3.055	.027	31.500	7.893	-13.791	76.791
	assumed									

Group Statistics

•	Group	N		Mean	Std. Deviation	Std. Error Mean
Frequency	Dockless bike riders		4	4.00	1.826	.913
	Personal bike riders		4	.50	.577	.289

Independent Samples Test

Levene's Test for Equality

of Variances

							95% Confiden	nce Interval of
				Sig. (2-	Mean	Std. Error	the Dif	ference
F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper

Frequency	Equal variances	12.000	.013	3.656	6	.011	3.500	.957	1.157	5.843
requency	assumed	12.000	.015	3.030	Ü	.011	3.300	.931	1.137	3.043
	Equal variances not			3.656	3.594	.026	3.500	.957	.719	6.281
	assumed									
Independer	nt Samples Test									
		Levene's Test fo	r Equality							
		of Varian	ces			t-1	test for Equality	of Means		
									99% Confidence	e Interval of
						Sig. (2-	Mean	Std. Error	the Diffe	rence
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal variances	12.000	.013	3.656	6	.011	3.500	.957	050	7.050
	assumed									
	Equal variances not			3.656	3.594	.026	3.500	.957	-1.267	8.267
	assumed									
Group S	tatistics									
	Group		N		Mean	Std. l	Deviation	Std. Erro	r Mean_	
Frequen	cy Dockles	s bike riders		4	15.	75	8.500		4.250	
	Personal	bike riders		4	2.:	25	1.708		.854	
Independer	nt Samples Test									
		Levene's Test fo	r Equality							
		of Varian	ces			t-1	test for Equality	of Means		
									95% Confidence	e Interval of
						Sig. (2-	Mean	Std. Error	the Diffe	rence
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal variances	3.162	.126	3.114	6	.021	13.500	4.335	2.893	24.107
	assumed									
	Equal variances not			3.114	3.242	.047	13.500	4.335	.269	26.731
	assumed									
Independer	nt Samples Test									
		Levene's Test fo	r Equality							
		of Varian	ces			t-1	test for Equality	of Means		
									99% Confidence	e Interval of
						Sig. (2-	Mean	Std. Error	the Diffe	rence
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal variances	3.162	.126	3.114	6	.021	13.500	4.335	-2.571	29.571
	assumed									
	assumed Equal variances not			3.114	3.242	.047	13.500	4.335	-10.035	37.035

	Group		N		Mean	Std.	Deviation	Std. Erro	r Mean	
Frequen	cy Dockless	bike riders		4	331.0	00	132.446		66.223	
	Personal	bike riders		4	36.2	25	15.692		7.846	
Independer	nt Samples Test									
		Levene's Test f	or Equality							
		of Varia	nces			t-	test for Equality	of Means		
									95% Confidence	e Interval o
						Sig. (2-	Mean	Std. Error	the Diffe	rence
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal variances	7.149	.037	4.420	6	.004	294.750	66.686	131.575	457.92
	assumed									
	Equal variances not			4.420	3.084	.020	294.750	66.686	85.765	503.73
	assumed									
Independer	nt Samples Test									
		Levene's Test f	or Equality							
		of Varia	nces			t-	test for Equality	of Means		
									99% Confidence	e Interval o
						Sig. (2-	Mean	Std. Error	the Diffe	rence
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal variances	7.149	.037	4.420	6	.004	294.750	66.686	47.515	541.985
	Equal variances not			4.420	3.084	.020	294.750	66.686	-84.399	673.899
	assumed			4.420	3.004	.020	294.730	00.080	-04.399	073.69
Group S	tatistics									
	Group		N		Mean	Std. 1	Deviation	Std. Erro	r Mean	
Frequenc		bike riders		4	309.0	00	81.253		40.626	
•		bike riders		4	118.		59.673		29.837	
Independer	nt Samples Test									
<u>F</u>	,	Levene's Test f	or Equality							
		of Varia				t-	test for Equality	of Means		
									95% Confidenc	e Interval of
						Sig. (2-	Mean	Std. Error	the Diffe	
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	•	1.299	.298	3.774	6	.009	190.250	50.406	66.912	313.58
	assumed						46			
	Equal variances not			3.774	5.507	.011	190.250	50.406	64.185	316.31

Independent Samples Test

assumed

Equal variances Equal var			Levene's Test f	or Equality							
Figure			of Varia	nces			t-	test for Equality	of Means		
Equal variances not assumed Equal variances not assumed Std. Deviation Std. Error Mean Std. Error							Sig. (2-	Mean	Std. Error		
Equal variances not			F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Second Statistic Second Statistic Second Statistic Second Statistic Second Statistic Second Statistic Statistic Second Statistic	Frequency		1.299	.298	3.774	6	.009	190.250	50.406	3.375	377.125
Frequency Dockless bike riders 4 43.50 51.475 25.737					3.774	5.507	.011	190.250	50.406	-3.696	384.196
Frequency Dockless bike riders 4 43,50 51,475 25,737	Group S	tatistics									
December 1.291		Group		N		Mean	Std.	Deviation	Std. Erro	r Mean	
	Frequenc	cy Dockless b	oike riders		4	43.	50	51.475		25.737	
Levene's Test for Equality of Variances Page 1		Personal b	ike riders		4	1.	50	1.291		.645	
Frequency Equal variances not assumed Equal var	Independer	nt Samples Test									
Frequency Equal variances Fre			Levene's Test f	or Equality							
Frequency Equal variances not assumed			of Varia	nces			t-	test for Equality	of Means		
F Sig. t df tailed Difference Difference Lower Upper										95% Confidence	e Interval of
Frequency Equal variances 7.937 0.030 1.631 6 0.154 42.000 25.746 -20.997 104.55 assumed Equal variances not assumed Equal variances not assumed							Sig. (2-	Mean	Std. Error	the Diffe	erence
Equal variances not assumed			F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Independent Samples Test	Frequency		7.937	.030	1.631	6	.154	42.000	25.746	-20.997	104.993
Levene's Test for Equality Of Variances Levene's Test for Equality Of Variances Levene's Test for Equality Of Variances Sig. (2- Mean Std. Error Equality Of Means Of Means Of Means Std. Error Equality Of Means					1.631	3.004	.201	42.000	25.746	-39.876	123.876
Of Variances Frequency Equal variances Page Frequency Equal variances Page Frequency Equal variances Page	Independer	nt Samples Test									
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Position							t-	test for Equality	of Means		
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assumed Equal variances not 1.631 3.004 .201 42.000 25.746 -108.190 192.1 assumed Group Statistics Group N Mean Std. Deviation Std. Error Mean			F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Equal variances not assumed 1.631 3.004 .201 42.000 25.746 -108.190 192.1 Group Statistics Group N Mean Std. Deviation Std. Error Mean	Frequency	-	7.937	.030	1.631	6	.154	42.000	25.746	-53.450	137.450
Group N Mean Std. Deviation Std. Error Mean		Equal variances not			1.631	3.004	.201	42.000	25.746	-108.190	192.190
· ·	Group S	tatistics									
Frequency Dockless bike riders 4 20.50 10.376 5.188		I -								_	
		Group		N		Mean	Std.	Deviation	Std. Erro	r Mean	

Independent Samples Test

Personal bike riders

3.25

2.500

1.250

		Levene's Test f	or Equality							
		of Varia	nces			t-	test for Equality	of Means		
						Sig. (2-	Mean	Std. Error	95% Confidence	
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal variances	13.500	.010	3.232	6	.018	17.250	5.337	4.192	30.30
	Equal variances not assumed			3.232	3.347	.041	17.250	5.337	1.221	33.27
Independer	nt Samples Test									
		Levene's Test f	or Equality							
		of Varia	nces			t-	test for Equality	of Means		
						Sig. (2-	Mean	Std. Error	99% Confidence	
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal variances	13.500	.010	3.232	6	.018	17.250	5.337	-2.535	37.03
	Equal variances not assumed			3.232	3.347	.041	17.250	5.337	-10.922	45.42
Group S										
_	Group		N		Mean		Deviation	Std. Erro		
Frequenc				4	36.		23.157		11.579	
	Personal b	ike riders		4	11.:	50	10.630		5.315	
Independer	nt Samples Test									
		Levene's Test f	or Equality							
		of Varia	nces			t-	test for Equality	of Means		
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ъ	- ·	F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal variances assumed	1.128	.329	1.943	6	.100	24.750	12.740	-6.424	55.92
	Equal variances not assumed			1.943	4.211	.120	24.750	12.740	-9.936	59.43
Independer	nt Samples Test									
		Levene's Test f	or Equality							
		of Varia	nces			t-	test for Equality	of Means		
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						Sig. (2-	Mean	Std. Error	unc Dillic	

tailed)

Frequency	Equal variances	s	1.128	.329	1.943	6	.100	24.750	12.740	-22.483	71.983
	assumed										
	Equal variances	s not			1.943	4.211	.120	24.750	12.740	-31.951	81.45
	assumed										
Group S											
	Grou			N		Mean		Deviation	Std. Erro		
Frequen		kless bike			4	6.0		5.657		2.828	
	Perso	onal bike	riders		4	.2	25	.500		.250	
Independer	nt Samples Test										
			Levene's Test for	or Equality							
		_	of Varia	nces			t-	test for Equality	of Means		
										95% Confidence	
							Sig. (2-	Mean	Std. Error	the Diffe	erence
			F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal variances	s	4.899	.069	2.025	6	.089	5.750	2.839	-1.198	12.69
	assumed										
	Equal variances	s not			2.025	3.047	.135	5.750	2.839	-3.208	14.70
	assumed										
Independer	assumed nt Samples Test										
Independer			Levene's Test fo								
Independer			Levene's Test for				t-	test for Equality	of Means		
Independer		_						test for Equality		99% Confidence	
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	nt Samples Test	_	of Variai		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	the Diffe	Upper
	nt Samples Test Equal variances	_	of Varia	nces	t 2.025	df 6	Sig. (2-	Mean	Std. Error	the Diffe	Upper
	nt Samples Test Equal variances assumed	S	of Variai	Sig.	2.025	6	Sig. (2-tailed)	Mean Difference 5.750	Std. Error Difference 2.839	Lower -4.777	Upper 16.27
	Equal variances assumed Equal variances	S	of Variai	Sig.			Sig. (2-tailed)	Mean Difference	Std. Error Difference	the Diffe	Upper
	nt Samples Test Equal variances assumed	S	of Variai	Sig.	2.025	6	Sig. (2-tailed)	Mean Difference 5.750	Std. Error Difference 2.839	Lower -4.777	Upper 16.27
Frequency	Equal variances assumed Equal variances assumed	S	of Variai	Sig.	2.025	6	Sig. (2-tailed)	Mean Difference 5.750	Std. Error Difference 2.839	Lower -4.777	Upper 16.27
	Equal variances assumed Equal variances assumed	s s not	of Variai	Sig069	2.025	3.047	Sig. (2- tailed) .089	Mean Difference 5.750 5.750	Std. Error Difference 2.839 2.839	the Diffe Lower -4.777 -10.585	Upper 16.27
Frequency Group S.	Equal variances assumed Equal variances assumed Equal variances assumed tatistics Grou	s s not	of Varian	Sig.	2.025	6 3.047 Mean	Sig. (2- tailed) .089 .135	Mean Difference 5.750 5.750 Deviation	Std. Error Difference 2.839	the Diffe Lower -4.777 -10.585	Upper 16.27
Frequency Group S.	Equal variances assumed Equal variances assumed tatistics Groupey Dock	s not ip kless bike	of Varian	Sig069	2.025	6 3.047 Mean 12.2	Sig. (2- tailed) .089 .135	Mean Difference 5.750 5.750 Deviation 5.560	Std. Error Difference 2.839 2.839		Upper 16.27
Frequency Group S Frequence	Equal variances assumed Equal variances assumed Equal variances assumed Equal variances assumed	s s not	of Varian	Sig069	2.025	6 3.047 Mean	Sig. (2- tailed) .089 .135	Mean Difference 5.750 5.750 Deviation	Std. Error Difference 2.839 2.839	the Diffe Lower -4.777 -10.585	Upper 16.27
Frequency Group S Frequence	Equal variances assumed Equal variances assumed tatistics Groupey Dock	s not ip kless bike onal bike	of Varian	Sig069	2.025	6 3.047 Mean 12.2	Sig. (2- tailed) .089 .135	Mean Difference 5.750 5.750 Deviation 5.560	Std. Error Difference 2.839 2.839		Upper 16.27

Sig. (2-

tailed)

Mean

Difference

Std. Error

Difference

the Difference

Upper

Lower

Frequency	Equal variances	6.582	.043	.356	6	.734	2.250	6.316	-13.205	17.705
	assumed									
	Equal variances not			.356	4.363	.738	2.250	6.316	-14.726	19.226
	assumed									
Independer	nt Samples Test									
		Levene's Test f	or Equality							
		of Varia				t-1	test for Equality	of Means		
									99% Confidenc	e Interval of
						Sig. (2-	Mean	Std. Error	the Diffe	erence
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	Equal variances	6.582	.043	.356	6	.734	2.250	6.316	-21.167	25.667
	assumed									
	Equal variances not			.356	4.363	.738	2.250	6.316	-25.243	29.743
	assumed									
Group S	tatistics									
	Group		N		Mean	Std. 1	Deviation	Std. Erro	r Mean	
Frequen		ike riders		4	3.	00	2.160		1.080	
•	Personal bi			4		00	.000		.000	
Independe	nt Samples Test									
тисрение	n samples Test	Levene's Test f	or Equality							
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							iosi ioi ziquani)	or mound	95% Confidenc	e Interval of
						Sig. (2-	Mean	Std. Error	the Diffe	
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Fraguanay	Equal variances	5.400	.059	2.777	6	.032	3.000	1.080	.357	5.643
rrequency	•	3.400	.039	2.111	0	.032	3.000	1.080	.337	3.043
	assumed			2 777	2.000	060	2.000	1.000	427	6 427
	Equal variances not			2.777	3.000	.069	3.000	1.080	437	6.437
	assumed									
Inaepenaei	nt Samples Test	T 1 77 1 7								
		Levene's Test f						22.5		
		of Varia	nces			t-1	test for Equality	of Means		
									99% Confidenc	
						Sig. (2-	Mean	Std. Error	the Diffe	
		F	Sig.	t	df	tailed)	Difference	Difference	Lower	Upper
Frequency	-	5.400	Sig. .059	2.777	df 6	tailed)	Difference 3.000	Difference	-1.004	7.004
Frequency	Equal variances assumed		_							
Frequency	-		_							

During the morning rush hour, the T-test results indicate no significant difference in irregular riding behavior between dockless bike users and private bike users. This is attributed to the common need for commuting and time constraints faced by both groups. The analysis reveals that imperfect road infrastructure and signage contribute to irregular behaviors such as occupying the road and retrograde riding. The lack of dedicated bicycle lanes exacerbates these issues, leading to lane occupation due to unclear norms. Similarly, no significant difference was found in parking behavior during the morning peak. The urgency of the morning rush hour means that early commuters prioritize parking spaces, while those arriving later may miss out due to a five-minute delay. This suggests that controlling irregular parking behavior during the morning peak requires sufficient and flexible parking facilities.

The T-test results show significant differences in riding behavior between the two groups during the evening peak. While both groups travel to residential areas, private cyclists tend to follow fixed routes and can easily find unmarked facilities. In contrast, dockless bike users may choose to pick up their bikes from locations within walking distance due to a lack of available bikes near their starting points. This leads to partial changes in their cycling routes and more violations. This highlights the need for more numerous and route guidance facilities to regulate dockless bike behavior during the evening peak. A significant difference is also observed in parking behavior during the evening peak. Many private cyclists have fixed parking facilities near their homes, which are to some extent under their personal ownership. However, dockless bike users lack corresponding parking facilities, resulting in non-standard parking behavior. This underscores the importance of ensuring a sufficient number of parking facilities in the destination areas of the evening peak.

The findings suggest that improving infrastructure, such as dedicated bike lanes, clear signage, and sufficient parking facilities, is crucial for regulating the behavior of dockless bike users and enhancing overall urban mobility and safety. Dockless bike users exhibit more irregular behaviors due to the lack of dedicated facilities and clear guidance. This highlights the need for more comprehensive infrastructure planning to accommodate the growing use of dockless bikes. The results imply that policymakers should focus on providing more flexible and accessible parking areas, especially during peak hours, to reduce irregular parking and improve traffic flow.

5.5 Summary

This chapter provides a comprehensive analysis of cycling and parking behavior around subway stations in Shanghai and Xi'an, utilizing video observations as its primary methodology. The findings align closely with the research objectives outlined in the introduction, specifically addressing the impact of infrastructure on cycling behavior and the differences between dockless bikes and private bicycles. The study aimed to explore how urban infrastructure influences the riding and parking behavior of dockless bikes and private bicycles, and the results clearly demonstrate that well-designed infrastructure can significantly reduce irregular cycling behaviors. This chapter highlights the importance of integrating cycling infrastructure with public transportation systems to promote sustainable urban development.

In this chapter, observation method is the main research method. By comparing the relationship between the irregular riding behavior and the surrounding infrastructure in the same time period of weekends and workdays in Shanghai and Xi'an, the following conclusions are drawn. In both cities, violations were significantly lower on weekends than on weekdays, indicating the importance of time-sharing dockless bike management facilities. Smarter and more visible guidance facilities should be used during normal morning and evening peak periods to increase the frequency of regular rides, and on weekends to reduce the frequency. At the same time, the frequency of violations in the old city is greater than that in the new city, so the facilities in the old city should also be equipped with more guiding and convenient facilities for riding. However, it can also be found that in Shanghai, more attention is paid to the intelligent management of existing infrastructure, while Xi 'an pays more attention to the improvement and standardization of facilities to reduce irregular riding behaviors.

In the comparative analysis of the two cities, it is not difficult to find that in cities with different levels of development, in order to improve the non-standard riding behavior of DB, the focus on infrastructure is different, which is mainly reflected in the following aspects. The first is the setting of road facilities, Shanghai and other first-tier cities pay attention to the optimization of existing infrastructure, including improving the continuity and coherence of bicycle lanes. Second-tier cities such as Xi 'an pay more attention to the

construction of road infrastructure, such as setting up more independent bicycle lanes and improving the density of the road network.

Secondly, in terms of parking facilities, first-tier cities pay more attention to the number and scope of parking facilities to meet the parking needs of crowded places, and pay attention to the application of intelligent parking piles to guide users to regulate parking. Second-tier cities pay more attention to the flexibility of parking facilities. Second-tier cities are more inclined to use facilities such as clear signs to guide residents to park in designated areas.

Third, in terms of transportation connection facilities, first-tier cities emphasize the use of flexible and convenient transportation connection facilities to open up the last kilometer of urban travel, and pay attention to the connection of subway stations and bus stations; As a key mode of travel in second-tier cities, dockless bicycles emphasize reducing irregular behaviors by increasing the connection to bus stations, railway stations and other transportation hubs.

Fourth, and finally, in terms of management and implementation, first-tier cities use refined management facilities to reduce irregular riding behaviors, such as analyzing riding data through the eye system and traffic brain, and optimizing vehicle deployment. Management facilities in second-tier cities pay more attention to helping residents identify routes and avoid riding risks through more guided management facilities to reduce unsafe riding behaviors.

The policy recommendations presented in this chapter, such as improving infrastructure and enhancing traffic management, are supported by the empirical findings of this study. For instance, the significant reduction in irregular cycling behaviors observed in areas with better infrastructure underscores the need for continued investment in cycling facilities. However, recommendations such as mandatory helmet laws should be reconsidered, as the current data does not provide sufficient evidence to support their implementation. Future research should focus on gathering more data to validate such policy measures. Specifically, while helmet use is generally considered a safety measure, the current study did not observe a significant correlation between helmet use and the overall safety of cyclists. Therefore, it

is recommended that further studies be conducted to explore the effectiveness of helmet laws in reducing cycling injuries and fatalities.

This study contributes to the existing literature by providing empirical evidence on the impact of urban infrastructure on cycling behavior. The findings suggest that well-designed infrastructure can significantly reduce irregular cycling behaviors, thereby enhancing urban mobility and safety. This chapter highlights the importance of integrating cycling infrastructure with public transportation systems to promote sustainable urban development. Future research should explore the long-term effects of infrastructure improvements on cycling behavior and urban sustainability. Additionally, the study underscores the need for more detailed and context-specific infrastructure planning, particularly in areas with high population density and significant transportation demand. The results also highlight the importance of continued monitoring and evaluation of cycling infrastructure to ensure its effectiveness and adaptability to changing urban conditions.

Chapter Six: Discussion and Conclusion

6.1 Overview of the Research and Its Importance

The current study provides essential insights into the transformation and formulation of urban infrastructure. It highlights the need for reasonable planning of dockless bicycle parking spaces at subway entrances, expanding the width of non-motor vehicle lanes, and addressing issues related to cycling behavior. The research indicates that the existing infrastructure cannot adequately meet the community's needs, particularly with the sharp increase in dockless bicycle (DB) trips. This study serves as a valuable reference for urban infrastructure construction plans. However, it lacks sufficient empirical evidence to support the effectiveness of mandatory helmet laws in reducing cycling injuries, suggesting that future research should focus on gathering more data to validate the impact of such regulations on cyclist safety. The study compares three subway stations in Xi'an and Shanghai, revealing that the level of infrastructure perfection significantly influences dangerous cycling and illegal parking behaviors. The comparison between Century Avenue Subway Station and Old Ximen Subway Station shows that continuous and intact cycling spaces can reduce cases of cycling in reverse and in non-bicycle lanes. Additionally, the study finds no major differences between private bike riders and DB riders in harsh riding environments, indicating that urban infrastructure conditions shape riding habits and impact the likelihood of dangerous riding or wrong parking.

6.2 Discussion of the Results

The findings of this study provide valuable insights into the impact of urban infrastructure on cycling behavior. The results highlight the significant role of well-designed infrastructure in reducing irregular cycling behaviors and enhancing urban mobility.

6.2.1 Comparison between Century Avenue Subway Station and Laoximen Subway Station

The comparative analysis of cycling behavior at Century Avenue Subway Station and Laoximen Subway Station reveals distinct differences in riding patterns, primarily due to the varying levels of infrastructure development.

6.2.1.1 Riding Behavior

The riding behavior observed at Century Avenue Subway Station, characterized by a higher incidence of cycling on non-bicycle lanes and in reverse directions, underscores the need for continuous and intact cycling spaces. First, compare Century Avenue Subway Station's working days and Laoximen Subway Station. Century Avenue Subway Station belongs to the new urban area, and its infrastructure is relatively complete, while Laoximen Subway Station belongs to the old urban area.

Century Avenue Station, adjacent to Lujiazui Station, is where four subway lines, with lines 2, 4, 6, and 9 crossing. After exiting Shanghai, it became the subway station with the most significant passenger flow. Almost every period of this station is peak time. Zhang (2022) reported that the Century Avenue Station has the most people disembarked, and basically, half of the people alighted every time. There are also many people getting off at Pudian Road Station in front and many financial institutions there (Wikimedia Foundation, 2023). After passing the Century Avenue Subway Station and Pudian Road Station, the subway congestion will be much reduced. Compared with the morning rush hour, if the change to Line 6 at Century Avenue subway station around 6:00 p.m., the passenger flow will be much higher than the morning rush hour (Wu, 2021). This also explains why there are more parking spaces for dockless bicycles in the evening than in the morning peak because the passenger flow is much greater than in the morning. Secondly, there is only one Lujiazui subway station that Line 2 passes through, and the "tidal" passenger flow is significantly reflected here. Most want to avoid squeezing the subway and take a taxi or drive by themselves.

Cycling behavior with a higher risk in Century Avenue Subway Station is riding on non-bicycle lanes, which 35% appear in Century Avenue Subway Station, and 43% in Laoximen Subway Station. Regarding riding in the opposite direction, 21% were at Century Avenue Subway Station and 32% at Laoximen Subway Station. Compared with the corresponding parking behaviors, the parking habits of Century Avenue Subway Station and Laoximen Subway Station differ. They have a greater impact on pedestrian lane parking and surrounding greening. First of all, the above comparative analysis analyses the difference between the cycling-related infrastructure of Century Avenue Subway Station and

Laoximen Subway Station. Shanghai Metro (2022) shows that Century Avenue Subway Station is located in the core business circle of Lujiazui Finance and Trade Zone on Century Avenue. It is a new landmark integrating commerce, shopping, and entertainment, directly connected to the transportation hub, with zero distance to Century Avenue Station where No. 2, No. 4, No. 6, and No. 9 subways meet. The above locations are all around the Century Avenue Subway Station, and the walking time is within 15 minutes. When the traffic situation is complicated in the morning, commuters at the Century Avenue Subway Station will choose to walk to work (Wang, 2016).

6.2.1.1.1 Limited Road Width for Non-Motorized Lanes

The Century Avenue Subway Station has a continuous cycling lane, with relatively broad and spacious cycling roads on both sides. The basic profile of a cyclist, generally defined in Western countries, requires 1.0 m (40 in) of basic maneuvering space, including the space required for handlebars and front wheel twisting. The measurement of the cycling lanes near the Century Avenue Subway Station shows that 95% of the lanes have a width that can accommodate two bicycles riding side by side simultaneously. The cut width is greater than three meters. Only some of the riding lanes have reduced riding width due to factors such as the increase in the number of motor vehicle lanes at traffic lights. However, most riding lanes can accommodate two bicycles riding side by side. The more prominent data of Laoximen Subway Station on weekends is cycling on non-bicycle lanes. Accounting for 22% of the total DBS riders are riders on non-motorized lanes caused by the lack of excellent infrastructure (Shanghai, 2022). Judging from the cycling environment near Laoximen Subway Station, the "narrowest" non-motorized lane outside Laoximen can only allow one electric vehicle to pass. Only one electric car can pass through the narrowest part of the non-motorized lane from west to east outside the old west gate. Pay the handlebars to avoid rubbing against the isolation guardrails or attention construction site fences on both sides.

The widest part can accommodate two bikes driving side by side, and the narrowest part is just at the protruding part of the construction site fence. Almost every electric vehicle has to slow down when driving here, and the rider passes slowly with his feet on the ground without paying attention. Shanghai Daily (2022) shows that the handlebars would rub against the

construction site fence. Many cyclists take the motorway to pass parallel to the car, which is dangerous. This non-motorized lane has been established for a while. There was no guardrail here before. Later, an isolation guardrail was set up because the traffic flow is relatively large during the morning and evening peak hours, and the mixed traffic of non-motorized and motorized vehicles is prone to danger. However, the isolation fence set-up's width differs from the fence on the construction site, which led to this situation (Shanghai, 2022).

6.2.1.1.2 Lack of Double-Sided Bike Lanes

The above-mentioned old Ximen Subway Station rides on non-bicycle lanes and reverse rides. From observing the bicycle lanes at Laoximen Subway Station, Laoximen Subway Station only has relatively continuous bicycle lanes on one side, and intermittent road sections on the other are under construction so that bicycles and motor vehicles are mixed. Chinese journal (2022) also proved that the old Ximen subway station will be under road construction throughout 2022, but there is no corresponding backup non-motorized lane in the direction of the construction. For example, due to renovation and road construction, the old Ximen Subway Station blocked the entire bicycle lane and part of the motorway. Therefore, by passing through the motor vehicle lane or going retrograde in the opposite

direction, some cyclists can only choose to go retrograde in the opposite direction because riding with a motor vehicle is too dangerous.

Lua & Li (2017) argue that many cities in China mistakenly use iron fences to separate bicycle lanes and motor vehicle lanes. However, this kind of brittle facility cannot be installed in the road space. The foot of the railing column is vast, which compresses the effective width of the bicycle lane. The width of the foot of this column should be removed and replaced. Draw a sideline outside the foot of the column, and people will choose to ride one meter from the foot of the railing, which underpins the decision by cyclists to ride in the motorway than in their lane as the outside is more spacious and inertial power and the continuity is better. Xiaoximen Subway Station is representative of the above problems. Sina (2016) shows that there is a cycling lane on one side, and the fence at the foot of the column makes the effective riding width too small. Although the Century Avenue Subway Station also has the above problems, the actual width of the Avenue subway station is large enough, so the narrow bicycle lanes are not shown in the Century Avenue Subway Station. However, compared with the old Ximen Subway Station, because the road infrastructure itself is not perfect, cyclists can only ride on non-bicycle lanes.

6.2.1.2 Parking Behavior

The parking behavior at Century Avenue Subway Station and Laoximen Subway Station shows significant differences, with Century Avenue having more organized parking areas and Laoximen experiencing higher rates of misplaced parking. There are increasingly erroneous riding behaviors in the evening rush hour, about why misplaced parking behavior appears. According to the distribution of dockless bicycles in Shanghai Century Avenue Subway Station, it can be known that dockless bicycles are usually placed vertically and parked in about three rows. CNN (2017) argues that if a dockless bicycle is wrongly parked, the impact is that at least three dockless bicycle follow, and if it will continue to be wrongly parked around it due to insufficient parking spaces. Second, the wrong parking behavior will mislead subsequent cyclists, making it difficult to distinguish the parking area. Difficulty in discerning and anxiety eventually lead to more misplaced parking habits.

Secondly, compare the parking behavior of Century Avenue Subway Station and Laoximen

Subway Station. The roads around Century Avenue Subway Station, including the intersection of Dongfang Road and Zhangyang Road, Weifang Road, and Fushan Road, have special bicycle parking racks for bicycles to park when traveling. However, compared with the old Ximen Subway Station, the latter has two main problems. One is the need for a fixed parking area for dockless bicycles. Since there is no designated fixed parking area, cyclists do not know where to park is "civilized" and where to park is "uncivilized". As long as there is no place marked "no parking of bicycles", users can choose to park according to their convenience. The existing parking areas of Erlaoximen Subway Station are unreasonably demarcated or distributed, which is inconvenient for most users. Most of the existing parking areas of Laoximen Subway Station are in smaller areas with multi-row parking area. Compared with the Century Avenue Subway Station, this parking area lacks convenience because many dockless bicycles are easy to get together. Each dockless bicycle in the parking space of Century Avenue Subway Station also has a fixed location, so no misplacement is prone to occur.

6.2.2 Comparison between Century Avenue Subway Station and Jiuting Subway Station

The comparison between Century Avenue Subway Station and Jiuting Subway Station highlights the impact of infrastructure differences on cycling behavior, with Jiuting showing higher rates of red light running and non-bicycle lane usage.

6.2.2.1 Riding behavior

6.2.2.1.1 Missing warning signs

Jiuting Subway Station is located in Songjiang District. The existing Songjiang District Traffic Construction Management Center has recently added danger warning areas at 18 intersections, including the Sixian Road and Dingyuan intersection, spraying warning signs to remind motor and non-motor vehicles when crossing the intersection (China Daily, 2022). Be vigilant and avoid in time. The danger warning areas at 18 intersections have been drawn up because sidewalks are prone to blind spots for driving vision, leading to traffic accidents. To further ensure the safety of road traffic, danger warning areas have been added at 18 intersections. A new batch of road traffic signs has been added at the subway entrance. Among them, the most eye-catching ones are the

"Pedestrian Waiting Area" in red paint and white characters on the sidewalk and the big words "Give way to pedestrians" next to the zebra crossing, making it safer for pedestrians to cross the street. In addition, the white words "Give way to pedestrians" on the side of the pedestrian crossing can remind cyclists to pay attention to their surroundings when approaching the area and stop in time if they encounter pedestrians. Xinhua Net (2022) shows that although some cyclists occasionally ignore it, the words in front of the crosswalk can be seen from a distance now, which also serves as a good reminder. Compared with Century Avenue Subway Station, Jiuting Subway Station has a much higher parking ratio on the sidewalk than Century Avenue Subway Station.

6.2.2.1.2 The traffic light setting is not obvious

Compared with dockless bicycles in Century Avenue Subway Station, the proportion of running red lights is more prominent, accounting for 19% of the overall data. The overall proportion is higher than that of working days. As a new street established for just over a year, Jiuliting Street covers an area of 6.79 square kilometers and has a permanent population of about 115,000. It has the characteristics of a large population density, which brings great pressure on traffic. The bearing pressure of Metro Line 9 is too high, especially in the morning rush hour, and it is difficult to get on and off; residents in the community far away from the subway station find it inconvenient to travel in the "last mile"; some bus lines are unreasonably set up, such as Ring Line 1840, Songjiang Road 42, etc. Only a one-way circle in one direction, commuting to and from work will always take a big circle once, which is a waste of time; in terms of the number of buses, the number of buses is relatively concentrated along Hunting North Road, and some other roads, such as Jiudu Road, west of Laifang Road, Laifang Road, and many more. The bus laying density in the east of Tingbei Road is low; the waiting time at the bus station needs to be fixed, and it is impossible to check the real-time arrival information. For example, the gates of Phase I and II of the Aoyuan Community face each other. Many cars coming out of Phase I drive directly into Phase II, and cars coming out of Phase II drive directly into Phase I, forming a crossroad that is not a crossroad. People CN (2022) shows that because there are no traffic lights and personnel to direct, many cyclists can only walk through the middle of the traffic lights and the motorway, resulting in confusion and congestion on this section of the road; the school gates are often congested when school is

over in the morning and evening. Therefore, there have been phenomena of bicycles running red lights and riding violating the regulations.

According to Table above, there is no significant difference in the riding behavior of private and dockless bicycles, which shows that the overall riding environment of the Jiuting subway station is poor. There is no apparent difference between private and dockless bicycles because the road conditions are the same for private and dockless bicycles, regardless of whether the bicycle has a sense of responsibility and ownership. The location of Songjiang High-speed Railway South Station is relatively remote, and the road transportation network could be better. It is inconvenient for Songjiang residents to travel to South Station. The location of the traffic lights at the intersection is not obvious, and you need to get closer to the intersection to see clearly. Especially at the intersection between the north gates, the effectiveness of traffic lights and monitoring equipment is not apparent, which brings great safety hazards to cyclists. In addition, Shanghai Daily (2022) argues that the traffic lights frequently change in the morning and evening, and pedestrians need more time to react—the traffic lights at the north gate of Jiuting Subway Station change in 10 seconds. Due to the short reaction time, the probability of dockless bicycles and private bicycles running red lights is relatively high.

6.2.2.2 Parking behavior

6.2.2.2.1 Missing three-dimensional warning signs

Compared with the parking environment of the two subway stations, although there are obvious warning signs near the two subway stations. However, too many dockless bicycles cover all the signs on the ground, and it is not easy to see the apparent white line area. However, the Century Avenue subway station has obvious three-dimensional signs and has established physical barriers for parking spaces. The coverage rate of physical barriers for dockless bicycles and physical barriers for non-motor vehicles in the entire Pudong New Area is 96%. Only the parking spaces on Suzhao Road and Liyue Road need three-dimensional signs. However, in Songjiang District, where the Jiuting subway station is located, only 26% of the physically separated parking areas are covered. In particular, after the first dockless bicycle made an error, the overall speed of picking up the bicycle by mistake increased

significantly. The proportion of wrong parking of private and dockless bicycles passing through Songjiang District is much higher than that of the Pudong New Area.

At 1:40 a.m., outside Exit 2 of Jiuting Station on Metro Line 9, the sidewalk could be more spacious. However, even so, the sidewalk is still covered by dockless bicycles, and pedestrians can only walk on the sidewalk's edge near the non-motorized lane. For the convenience of transportation, many citizens park their cars directly outside the subway station in the morning and come to pick them up after getting off work in the evening. Over time, more and more non-motorized vehicles stop outside subway stations. Near the sidewalk along the street, a sign says "No Parking". However, the sign is almost surrounded by non-motorized vehicles, which could be more useful.

According to the T-test in Table 5.19 and Table 5.21, there is no significant difference in the behavior of dockless and private bicycles. From these two points, it can also be verified that the infrastructure environment of Jiuting Subway Station is poor. Due to the narrow roads and no apparent signs, riding under red lights has led to the dangerous riding of dockless bicycles and private cars.

6.3 Conclusion of Shanghai Observation

The findings from the Shanghai observation provide critical insights into the relationship between urban infrastructure and cycling behavior, emphasizing the need for continuous infrastructure improvement and regulation. The results of this study are beneficial to the formulation of urban infrastructure, for example, the reasonable planning of dockless bicycle parking spaces at subway entrances, the appropriate widening of the width of non-motor vehicle lanes, and the reduction of the number of lazy people to kick. Due to the rapid development of modern society, the facilities of the city also need to match the development. A large number of dockless bicycle trips have led to the fact that the existing infrastructure can no longer meet the existing needs. Therefore, this study can be used as a reference for urban infrastructure construction. At the same time, it is also very urgent to introduce mandatory helmet rules. The equipment of helmets can reduce the degree of danger when danger occurs. This research can also be used as a reference for requiring dockless bicycles to be equipped with helmets.

By comparing the above three subway stations, the degree of perfection of infrastructure impacts dangerous cycling behavior and illegal parking behavior. By comparing the cycling environment of Century Avenue Subway Station and Laoximen Subway Station, it can be seen that in a continuous and relatively intact cycling environment, the behavior of cycling in reverse and non-bicycle lanes will be significantly reduced. Having a single row of continuous parking spaces is conducive to dockless bicycle parking in the parking spaces. However, although private bicycles are more responsible than dockless bicycle riders to a certain extent, the overall comparison of the Jiuting subway station shows that there is no significant difference between the two riding behaviors in harsh riding environments. Therefore, differences among different infrastructures will lead to different dangerous riding behaviors and affect the probability of dangerous riding and wrong parking.

Future studies should consider recording and analyzing the cycling and parking behaviors of the normal cyclist and a different time period of research when there are more riders with diverse riding characteristics. One of the key limitations of the current research is that the difference between seasons is not considered, and the season is also a factor

that affects riding. The time of this research is from September to December, and the number of people riding in autumn in September will be much larger than that in December, so the rates of wrong riding and parking will also be slightly different. Secondly, the time selected in this study is the morning peak and evening peak, and the data collection for the whole day is not selected. The travelers in this period are in a relatively anxious state, which has special characteristics, so wrong riding and parking ratios are high. If the cycling behavior and parking behavior of normal cyclists were recorded, there may be differences between the results and this study.

6.4 Discussion of the Result

The discussion of the results from the Shanghai and Xi'an observations highlights the significant differences in cycling behavior between the two cities, primarily attributed to differences in infrastructure development and management.

6.4.1 Comparing the Riding Behavior of Shanghai and Xi'an

First, it is evident from the data itself that whether it is dockless bicycles or private bicycles, the overall number of illegal cycling behaviors in Xi'an is much larger than that in Shanghai. Among them, the biggest difference in data is riding at red lights, riding in reverse, and riding on non-bike lanes. By comparing the data of Century Avenue Subway Station and North Street simultaneously, it can be known that the data of non-violation riding in North Street is higher than that of Century Avenue Subway Station. Regarding whether illegal riding is related to the degree of imperfection of the infrastructure, the following article will compare the Century Avenue Subway Station and the North Street Subway Station respectively, and analyze it in combination with the local conditions.

The period with the highest percentage of running red lights at the Century Avenue Subway Station is the morning rush hour on weekdays, and the overall number of people who run red lights without docks accounts for 24%. The number of people accounted for 13% during the rest time. In contrast, the highest number of running red lights in Xi'an is also in the morning peak on weekdays, accounting for 33% of the total number of people, and the lowest value is in the evening peak on weekends, accounting for 14% of the total. It can be seen that, on the whole, the morning rush hour on weekdays is indeed a period of

high incidence of illegal cycling. Comparing the highest values of the two, it can be found that the value of illegal cycling in Xi'an is nearly 10% higher than that of Century Avenue subway station. Regarding the above differences, following comparison will be further performed.

6.4.1.1 Road Update Different

The overall length of the Century Avenue Subway is 5.5 kilometers. This road belongs to the Shanghai New District and has been continuously improving the road construction (Century Avenue Subway, 2023). Shanghai Municipal People's Government (2021) mentioned that to 1) Optimize the time of signal lights in the city including both ends of the Changhong Tunnel. At the same time, the green wave setting of the signal lights at both ends of the Changhong Tunnel was adopted, and the opinions of representatives were adopted in the timing of the signal lights. 2) Adjust the overall green light time of Century Avenue to realize small green waves at the two intersections, so that vehicles in the tunnel can pass quickly and reduce intersection congestion caused by the setting of traffic lights. Pengpai News (2023) mentioned that a total of 214 roads will be optimized in Shanghai in 2022, and 50 traffic light congestion points will be solved. The above optimized road and traffic light areas include the entire Pudong New Area and therefore include the Century Avenue subway station. It can be seen that the road facilities near the Century Avenue subway station are in the stage of continuous optimization.

However, although the Xi'an North Street Subway Station will take corresponding measures in the face of the morning peak, in recent years, only in 2022 has the traffic light setting been improved, and there has been no continuous reform like the Century Avenue Subway Station. The optimization method mentioned in Xi'an News (2022) is to split the length of green light and increase the frequency of release by piloting an intelligent control scheme for signal lights at the intersection along Beidajie. The splitting of the green light duration is to shorten the green light lighting time of the upstream and downstream intersection signal lights of the road section and increase the frequency so that when the vehicle passes through the congested road section, it will wait for a while for the red light at each intersection, and by converging the traffic flow and improving the traffic efficiency. Long line congestion. But the actual total duration is the same. Therefore, the

increased frequency leads to less time waiting for the red light, but compared with the Century Avenue subway station, which continues to optimize the road, it is still insufficient. In particular, the video found that at the North Exit of Beidajie Subway Station, when the green light is only five seconds away, more people will ride through the red light, which will lead to a few seconds before the red light changes, and the cyclists without docks will be right in the middle of the road, this delays the normal travel of motor vehicles and causes traffic chaos. In particular, many riders of dockless bicycles lack self-awareness, and more people run red lights in the peak morning.

6.4.1.2 Differences in Bike Lane Settings

In the following, reverse riding and non-bicycle lane riding will be analyzed together. In Xi'an North Street, the highest peak of the above two data rides is also in the morning peak, while the lowest value is in the evening peak on weekdays. Cycling issues have a clear relationship to bike lanes. Shanghai Traffic Management (2022) mentioned that the width of the non-bicycle lanes at Century Avenue Subway Station is 100 meters in overall width, with 8 lanes in general and 10 lanes in a few, and the average width of main roads is 31 meters. Shanghai (2022) reports that non-motorized lanes and motorized lanes are separated by a hard separation belt, generally with a width of 2.5 to 4 meters; nonmotorized lanes are separated from motorized lanes by road markings, the general width is 1.5m to 2.5m. Shanghai (2022) further suggests that the widest riding width of Century Avenue Subway Station is 3.7 meters, and the narrowest width is 3.2 meters. The above width is based on the measurement method of American road riding, and the width of the non-bicycle lane of the above road can accommodate at least three people. All of the Century Avenue Subway Station are equipped with double-sided cycling lanes, so the overall number of reverse riders at the Century Avenue Subway Station is lower than that of the North Avenue Subway Station. However, in contrast to the road facilities of the North Street Subway Station, the bus operation lines in the North Street corridor are too concentrated, with a total of 42 lines, and the one-way passenger flow exceeds 10,000 people/h. The bus operation organization is unreasonable, and the departure interval is unscientific. About 40% of the lines The departure frequency is too dense, the interval is less than 5 minutes, and the average is 7.3 minutes. Some stations are too close to the intersection, which seriously affects the traffic efficiency of the intersection.

Regarding non-motorized lanes, the widest width of the North Avenue subway station is 2.7 meters, and the narrowest width is only 1.3 meters. Most of the bicycle lanes are trumpet-shaped due to the need to give way to motor vehicles. Therefore, there are more dockless bicycles in Xi'an riding on non-motorized lanes.

6.4.2 Compare the Parking Behavior of Shanghai and Xi'an

6.4.2.1 Parking Behavior Comparison

The following compares the parking behavior between Century Avenue subway station and Beidajie subway station. In the comparison of these two subway stations, this article will select the two most obvious illegal parking behaviors, including affecting the sidewalk and the surrounding greening behavior. These four kinds of illegal parking all show that the parking spaces are set unreasonably. In all periods, the peak of the number of illegal parking is located in the evening peak of weekdays. Pudong New Area (2022) mentions that all kinds of advertisements on cone-shaped barrels, stone pits, stone balls, ground locks, bricks, and facilities placed randomly in the back of the area will be cleaned up, and unreasonable and unscientific parking spaces will be set up, made adjustments or banned. At the same time, a single row of continuous bicycle parking spaces is set up, and multiple rows of rectangular parking spaces are reduced as much as possible.

Because there is a lack of constraints in the absence of a separate parking framework, if a car is parked wrongly, all subsequent dockless bicycles will be affected. For example, if one of the cars is parked sideways, it will affect the surrounding row of cars and subsequent dockless bicycles. Therefore, the dockless bicycle parking spaces near the Century Avenue subway station are all single-row and have fixed grans, which is conducive to reducing the possibility of wrong parking. Therefore, it can be seen that the highest amount of false parking at the Shuji Avenue Subway Station, weekday morning peak 30%, which is similar to the lowest parking amount at the North Street subway station, weekend evening peak 30%.

6.4.2.2 Difference Between Parking Space and Walking Distance

China's Pedestrian and Bicycle Traffic Design System Planning Standard (2022) mentions that the bicycle parking space should satisfy the parking of all kinds of bicycles, and guide the reasonable parking and orderly use of urban bicycles. Bicycle parking facilities should be set up close to the destination and easily connected with other modes of transportation. The width of a single bicycle parking space should be 0.6-0.8m and the length should be 2.0m. When the space is insufficient, it can be installed at an angle. The bicycle parking width of Shanghai Century Avenue subway station is 0.73m and the length is 2.2m. The sub-width can not only accommodate the parking of dockless bicycles, but also the fixed iron shelf can prevent the dockless bicycles from falling due to accidents and affecting other bicycles. However, the pile-free bicycle parking area of Xi'an North Street Subway Station is a rectangle without a line. The length of the rectangle is 10.3 meters and the width is 4 meters (Western Network, 2022). Although the rectangle has enough parking space, it lacks obvious drawing lines, which leads to the random parking of all dockless bicycles, which finally leads to a great reduction of effective parking space. Although the North Avenue subway station has a clear parking area, it does not frame every dockless bicycle. Therefore, when people are in a more anxious morning rush hour, they will not have enough patience to park the dockless bicycles in a reasonable direction in the absence of constraints. This is why the wrong parking ratio of dockless bicycles at Beidajie Subway Station is much higher than that at Shanghai Century Avenue Subway Station.

6.5 Conclusion of Shanghai and Xi'an Observation

The comprehensive analysis of cycling behavior in Shanghai and Xi'an underscores the importance of well-designed infrastructure in promoting safe and efficient urban cycling. This study provides an in-depth analysis of cycling and parking behaviors around subway stations in Shanghai and Xi'an, highlighting the differences between dockless bike riders and personal bike users, thus offering new insights into urban cycling dynamics in China. Firstly, in Shanghai, the prevalence of dockless bikes around Century Avenue and Old Ximen Metro Stations was observed, with riders demonstrating distinct behavioral patterns compared to private bike riders. At these locations, dockless bike riders tended to exhibit more non-compliant behaviors, such as running red lights and riding outside designated bike lanes. This underscores the convenience of dockless bikes in urban commuting while raising concerns regarding safety and adherence to traffic regulations.

Similarly, in Xi'an, dockless bikes also dominated, especially around Beidajie Subway Station. However, observations revealed that dockless bike riders in Xi'an exhibited similar non-compliant behaviors to those in Shanghai, including traffic rule violations and indiscriminate parking. This suggests that while the proliferation of dockless bikes improves urban mobility, it also poses challenges in terms of management and regulation.

Furthermore, through the analysis of observation results, the study employed T-tests to further validate the behavioral differences between dockless bike riders and private bike riders across different time periods and locations. The results indicated that dockless bike riders displayed significantly more non-compliant behaviors compared to private bike riders, confirming the observations' reliability and accuracy and laying a solid foundation for future research.

Additionally, it was found that dockless bike parking behaviors presented various issues, such as indiscriminate parking and obstruction of pedestrian pathways, particularly pronounced during peak hours and in densely populated areas. This highlights deficiencies in the current management and regulation of dockless bike systems, necessitating improvements in parking regulations and guidance to enhance the quality and orderliness of urban commuting environments.

In conclusion, this study provides valuable insights into the role and impact of dockless bikes in urban transportation systems, suggesting several recommendations: Firstly, strengthen the management and regulation of dockless bikes by establishing comprehensive rules and regulations and enhancing supervision and guidance on riding and parking behaviors. Secondly, increase investment in urban infrastructure construction to optimize the bicycle lane network, improve parking facilities, and enhance the urban commuting environment. Thirdly, strengthen urban planning and construction, rationalize the planning of dockless bike parking areas, and reduce parking chaos and traffic congestion.

6.6 Final Conclusion

The final conclusion of this study highlights the significant contributions of well-designed urban infrastructure in enhancing cycling behavior and urban mobility, providing valuable insights for future urban planning and policy-making.

6.6.1 Summary of the Study

The objective of this study is to delve into the usage patterns of dockless bike sharing systems in Chinese cities and their integration with urban transportation systems. With the proliferation of DBs in Chinese urban areas, they have exerted significant influence on urban transportation systems. Over the past few years, DBs has gained popularity due to its convenience, flexibility, and low cost, yet it has also brought about some associated issues. This paper aims to provide an in-depth analysis of the relationship between DBs and urban transportation systems through literature review and methodology exposition. Infrastructure, in particular, can improve the relationship with dockless bikes.

The literature review section elucidates past research findings, revealing the impact of DBS on urban transportation systems and associated issues. Specifically, it discusses the advantages and challenges of DBs, as well as its role in urban transportation planning and management. While there has been abundant literature on DBs, focusing on its penetration, user behavior, and technological features, research on its integration with urban transportation systems and its impact on such systems has been relatively scarce. At the same time, the literature review also explains that there are many factors affecting irregular riding, including the built environment, among which infrastructure is the biggest influencing factor.

In Chapter Three, we introduce the methodology of this study. We adopt a combined approach of comprehensive big data analysis and observational methods to gain insights into DBs usage patterns and behavioral characteristics. Specifically, this thesis employ big data analysis to statistically analyze DBs usage data and conduct detailed observations and recordings of DBs users' riding and parking behaviors through observational methods.

In the research process, the paper first analyzed the usage patterns of dockless bike sharing systems near subway stations in Shanghai through big data analysis, uncovering the temporal and spatial distribution characteristics of DBs in urban transportation systems. This analysis revealed the usage patterns of DBs on weekdays and weekends and differences in usage among different subway stations, providing important insights into the role of DBs in urban transportation systems. However, relying solely on big data analysis cannot fully understand DBs users' behavioral characteristics and their impact on urban transportation systems. Therefore, further observational analysis was conducted.

The purpose of observational analysis is to further elucidate DBs users' behavioral characteristics and the impact of urban transportation systems on these behaviors. Through video observation and data analysis of DBs near subway stations in Shanghai and Xi'an, we identified differences in behavior between DBs riders and private bicycle riders. During the observation process, the paper found that DBs riders' behavior tends to be more irregular, and their parking behavior is more casual, which is closely related to their impact on urban transportation systems. Specifically, DBs riders' irregular behavior may increase the risk of traffic accidents, while casually parked DBs may inconvenience pedestrians and other traffic participants and pose safety hazards.

Chapter Four of this study focuses on the usage patterns of dockless bikes (hereinafter referred to as dockless bikes) and their integration with urban transportation systems. Through empirical analysis of riding behaviors around Shanghai subway stations, we delve into the usage characteristics of dockless bikes under different time and space conditions. In this chapter, the paper discovered the significant role and impact of dockless bikes in urban transportation systems, particularly the differences in usage patterns at different times and locations.

One of the key findings of this study is the significant difference in dockless bike usage patterns between weekdays and weekends. On weekdays, dockless bike usage exhibits distinct peak periods that coincide with traditional commuting times, indicating the significant role of dockless bikes in facilitating work-related travel. Conversely, on weekends, dockless bike usage patterns tend to lean towards leisure activities, with a decrease in morning trips and an increase in afternoon trips. This difference in usage patterns not only demonstrates the flexibility of dockless bikes in

meeting different urban transportation needs but also highlights their potential complementary role to traditional commuting solutions.

Additionally, the paper conducted spatial analysis and found that dockless bikes have higher usage in central urban areas, particularly in concentrated areas around subway stations. This spatial distribution characteristic highlights the importance of subway stations as key nodes in the urban transportation network and underscores the central role of dockless bikes in meeting urban travel needs.

However, despite the insights provided by big data analysis into dockless bike usage patterns, the importance of observational research cannot be overlooked. Through observational research, we can gain a more intuitive understanding of dockless bike users' behavioral characteristics and preferences, such as their riding behavior and parking habits. Observational research can also help us identify problems and challenges in the process of dockless bike usage, providing practical guidance for further improving and optimizing urban transportation systems.

The conclusion of Chapter Four provides important background and foundation for the observational research in Chapter Five. Through empirical analysis of dockless bike usage patterns and integration with urban transportation systems, we gain a deeper understanding of the position and role of dockless bikes in urban transportation systems.

Chapter Five focuses on comparing the riding and parking behaviors of DBs near subway stations in Shanghai and Xi'an. Through video observation and data analysis, we reveal differences in behavior between DBs riders and private bicycle riders and explore the impact of urban transportation systems on these behaviors. Specifically, we observed the riding and parking behaviors of DBs near different subway stations and conducted comparative analysis. The results show that DBs riders' behavior tends to be more irregular, and their parking behavior is more casual, necessitating strengthened management and regulation. The study concludes that the level of perfection of Urban Mobility System sand infrastructure considerably alleviates dangerous riding and

illegal parking behaviors, especially during rush hours, and emphasizes the importance of launching proper rules and regulations.

The significance of this study lies in providing new insights into the usage patterns and impact of DBs on urban transportation systems, as well as offering valuable references for urban transportation planning and management. By gaining a deeper understanding of DBs users' behavioral characteristics and their impact on urban transportation systems, this paper can provide more effective strategies and measures to improve the safety, efficiency, and sustainability of urban transportation systems. Additionally, this study provides new research directions and methods for future research on the relationship between DBs and urban transportation systems.

6.6.2 Fulfillment of Research Objectives

This research analyzes the parking behavior as a whole when studying the parking behavior of dockless bicycles. The overall reason for the parking behavior of dockless bicycles is that the parking position setting is not reasonable enough. Therefore, this paper studies the parking area, location, and width to compare different parking behaviors.

In detail, according to the closed comparative analysis, the differences in the behavior of dockless bicycles at Shanghai Century Avenue Subway Station and Xi'an Beidajie Subway Station are mainly due to the differences in bicycle infrastructure. First, there is an obvious difference between the two behaviors for dockless bicycles riding under red lights, and the reasons for this difference in violations are the different speeds of road renewal and the different settings of bicycle lanes. Shanghai's non-motorized lanes and other road facilities are constantly being updated, especially the infrastructure near the Century Avenue subway station is in constant need of improvement. However, the maintenance and upgrading of the infrastructure of Xi'an North Street Subway Station is only in 2022, and the way of updating has not brought about substantial changes. Second, when observing the incidence of reverse cycling and non-motorized lane riding, this research measures the width of the non-motorized lane and finds that the width of the Century Avenue Subway Station can accommodate three bicycles at the same time, and in the entire century, the width on the avenue is more consistent. However, although the width of the non-motorized

lanes in the North Street Subway Station is sufficient for normal riding and overtaking, the temporary increase in the number of motorized lanes often results in a sudden reduction in the width of the non-motorized lanes and presents a horn-like shape. As a result, the overall number of people riding on the motorway on North Avenue has increased due to the sudden narrowing of the lane. In the end, it was found that the overall parking area of the Century Avenue Subway Station is more organized than that of the North Street Subway Station, such as a single-row parking area and fixed markings and iron racks to regulate bicycles. This study can be used as a reference for urban construction and provides theoretical support for the upgrading of urban construction. Secondly, urban construction based on the results of the research can effectively reduce the danger and congestion of dockless bicycles.

6.6.3 Study Contributions

The current research effectively contributes to the understanding of dockless bike usage on mobile apps during the last years in large cities in China and the misbehaviors of dockless bike riders compared with other riders by using both big data, observational method and statistic tests. Furthermore, contributes it to the feasible solutions to the misbehaviors regarding rules and regulations perfection and infrastructure improvement to both reuiqre and help dockless bike riders to reduce misbehaviors, such as unruly riding and random parking, and to improve traffic conditions incidentally. Last but not least, this research will help alleviate any form of public prejudice against dockless bikes and vigorously promote dockless bikes as the main means of transportation for the "last mile" as well as a green lifestyle of urban traffic.

In order to adapt to the improvement of the overall public transportation system in the city, the dockless shared bicycles need to be comprehensively judged from the use of the population and the land and transportation system of urban construction. The use needs of the population affect the time and characteristics of the use of dockless shared bicycles. And urban construction and planning affect people's travel purpose and travel demand. These two points are very necessary for the integration of dockless shared bicycles into the urban public transport system. To a certain extent, it reflects the use time and gathering point of dockless shared bicycles. Based on this information, the government and shared bike operators can reasonably plan the use of dockless shared bikes according to the corresponding characteristics.

From the government's point of view, a large number of gathering places for dockless shared bicycles need to introduce appropriate urban construction policies to regulate the use of dockless shared bicycles, and rationally arrange the connection between parking areas and existing public stations. The operator can carry out reasonable scheduling and dynamic allocation of regional dockless shared bicycles according to the characteristics and time of travel. In addition, the call for standardized behavior of dockless shared bicycles at the social level is also to help it integrate into the overall public transport system of the city from the soft level. This has also played an enlightening role in the future transportation planning. When the new form of public transportation appears, how to adapt and integrate the existing urban transportation system into the new form of transportation? This must also be inseparable from the needs of the population and urban construction. Starting from the use needs of the population, the combination of new forms of public transportation and other existing public transportation is considered, and the use of urban construction is adapted. The emergence of new forms of transportation will gradually affect and renew the urban construction, and feed back to the comprehensive urban renewal and construction.

6.6.4 Limitations of the Current Study

While this study provides valuable insights, several limitations should be acknowledged. Firstly, although employing both quantitative and qualitative methods, the study overlooks certain aspects such as firm-level strategic considerations of dockless bikes, which could provide deeper insights into industry dynamics. Secondly, the data collection methods have inherent drawbacks; reliance on big data from a single source may not capture the full spectrum of dockless bike usage patterns, while observational methods lack standardization across cities, hindering direct comparisons. Thirdly, the study primarily focuses on a few factors related to traffic conditions and urban infrastructure, neglecting potential influences such as seasonality and dynamic traffic conditions. Therefore, future limitations to provide research should address these a more comprehensive understanding of dockless bike usage behavior and its implications for urban mobility. Expanding the study's scope to include more cities, incorporating additional variables, and refining data collection methods would strengthen its validity applicability. Additionally, exploring the long-term effects of dockless bike systems on urban transportation and sustainability could yield valuable insights for policymakers and urban planners.

6.6.5 Suggestions for Further Research

Firstly, a more in-depth comparative analysis of the usage patterns of DBs in different cities, regions, and time periods can be conducted. By expanding the scope of research, a more comprehensive understanding of the usage characteristics and behavioral patterns of DBs in various environments can be achieved. Constructing corresponding time-series dynamic models can provide more targeted recommendations for optimizing urban transportation systems. Secondly, further exploration into the influence of urban transportation infrastructure on DBs usage behavior can be pursued. By analyzing the correlation between the completeness of different city infrastructures and DBs usage behavior, using methods such as correlation analysis and principal component analysis, guidance can be provided to urban planners to optimize urban transportation facilities, thereby enhancing the efficiency and safety of transportation systems. Additionally, deeper research into the preferences and behavioral motivations of DBs users can be conducted to explore the reasons for their choice of DBs and their impact on urban transportation systems. A thorough understanding of the needs and behaviors of DBs users can provide important references for improving the service quality and user experience of DBs. Finally, attention can be paid to the integration of DBs with other modes of transportation, exploring the role and status of DBs in multimodal travel. By studying the interactive relationship between DBs and public transportation, private transportation, and other modes of transportation, the promotion of low-carbon environmental protection and resource allocation efficiency can be facilitated, providing insights and inspiration for the integrated development of transportation systems.

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Appendices

Appendix A: Screenshots of Videos

Old Ximen Subway Station in Shanghai







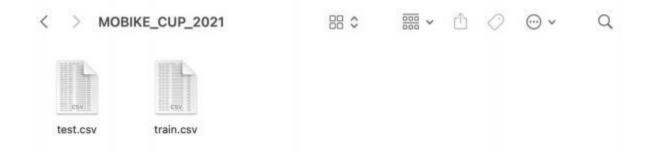
Beidajie Subway Station in Xi'an







Appendix B: Screenshots of Mobike Dataset



Train Dataset:

d	Α	В	С	D	E	F	G	Н	1	100
1	orderid	userid	bikeid	biketype	starttime	geohashed,	geohashed_	end_loc		
2	1893973	451147	210617	2	2021/5/14 22:16	wx4snhx	wx4snhj			
3	4657992	1061133	465394	1	2021/5/14 22:16	wx4dr59	wx4dquz			
4	2965085	549189	310572	1	2021/5/14 22:16	wx4fgur	wx4fu5n			
5	4548579	489720	456688	1	2021/5/14 22:16	wx4d5r5	wx4d5r4			
6	3936364	467449	403224	1	2021/5/14 22:16	wx4g27p	wx4g266			
7	5163705	917620	509044	1	2021/5/14 22:16	wx4gd2e	wx4g6pw			
8	19818	583391	3190	1	2021/5/14 22:16	wx4fhkk	wx4fh7q			
9	495333	185893	67441	1	2021/5/14 22:16	wx4emgw	wx4emgk			
10	2803108	15906	295614	2	2021/5/14 22:16	wx4f8t9	wx4f8tj			
11	271970	183740	38335	1	2021/5/14 22:16	wx4dzjf	wx4dzhn			
12	289754	426024	40489	1	2021/5/14 22:16	wx4dy2p	wx4dwxv			
13	1116773	342055	137447	2	2021/5/14 22:16	wx4f9mt	wx4f9k4			
14	1983324	168457	218956	2	2021/5/14 22:16	wx4dwws	wx4dxnr			
15	714809	559807	95403	1	2021/5/14 22:16	wx4g1zq	wx4g1yj			
16	1090816	195513	135060	2	2021/5/14 22:16	wx4g28s	wx4g23r			
17	630132	655921	85075	1	2021/5/14 22:16	wx4g4bv	wx4g501			
18	2956503	811790	309751	1	2021/5/14 22:16	wx4fcw2	wx4fct6			
19	320760	356302	44503	1	2021/5/14 22:16	wx4dkpw	wx4dknu			
20	1119812	72084	137713	2	2021/5/14 22:16	wx4f6s6	wx4f6s1			
21	3484200	196465	359597	1	2021/5/14 22:17	wx4ejcv	wx4ejb2			
22	187632	25054	26566	1	2021/5/14 22:16	wx4fzre	wx4fzrd			
23	1709501	990289	193073	2	2021/5/14 22:17	wx4f9ms	wx4f9mk			
24	1745122	647684	196465	2	2021/5/14 22:17	wx4g323	wx4g328			
25	3454200	81735	356681	1	2021/5/14 22:17	wx4g15v	wx4g1ej			
26	4664798	990515	466001	1	2021/5/14 22:17	wx4g5z0	wx4g5vg			

Test Dataset:

d	Α	В	С	D	E	F	G
1	orderid	userid	bikeid	biketype	starttime	geohashed_start_loc	
2	86458	467987	13488	1	2021/5/27 19:19	wx4gfbe	
3	1473189	976462	170537	2	2021/5/31 17:45	wx4eqep	
4	1441027	790813	167447	2	2021/5/26 11:31	wx4e5zr	
5	4747983	744823	472963	1	2021/5/31 18:30	wx4dxz4	
6	43984	712391	7158	1	2021/5/25 12:46	wx4ewq5	
7	1871445	549831	208512	2	2021/5/28 21:29	wx4ew9z	
8	4067497	894288	415951	1	2021/5/27 14:02	wx4ekc1	
9	2694849	759740	285692	2	2021/5/28 15:07	wx4f8qk	
10	4592505	618953	460033	1	2021/5/28 18:18	wx4st8w	
11	2287372	100501	247721	2	2021/5/28 17:08	wx4duyk	
12	1181931	994085	143423	2	2021/5/25 21:47	wx4g2nx	
13	4317834	121385	438342	1	2021/5/25 19:27	wx4dzm0	
14	2404919	1058083	258800	2	2021/5/26 8:22	wx4g5gm	
15	2430829	231685	261197	2	2021/5/31 18:10	wx4g5bt	
16	1264092	833976	150955	2	2021/5/27 15:37	wx4ds4d	
17	3249173	676802	337366	1	2021/5/29 13:31	wx4dyvn	
18	338736	112267	47022	1	2021/5/29 10:35	wx4sp8z	
19	531420	465240	72115	1	2021/5/26 15:04	wx4f8mq	
20	3162452	169233	329090	1	2021/5/27 12:25	wx4g1ms	
21	2343693	514036	253046	2	2021/5/257:27	wx4g34y	
22	2676116	737140	284013	2	2021/5/28 8:32	wx4f8q6	
23	2036286	462084	223906	2	2021/5/29 22:59	wx4f8v9	
24	5186692	349544	512116	1	2021/5/28 9:59	wx4g34m	
25	4520183	933055	454439	1	2021/5/26 11:40	wx4uqf1	
26	176841	203577	24844	1	2021/5/27 19:51	wx4ertt	