ISSN: 2710-0588

Bicycle Sharing Travel Characteristics Analysis -- Taking Xiamen as an Example

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Abstract

The emergence of bicycle sharing has greatly impacted the urban transportation structure and residents' travel modes. The massive spatial-temporal data carried by it is of great significance for studying the characteristics of residents' slow travel and guiding the development of green transportation in cities. Through the analysis of Xiamen's bicycle sharing order data, this paper analyzes the riding characteristics of users and explores the urban functional elements that affect the use of bicycle sharing. This paper will use urban bicycle sharing data, Point of Interest (POI) data in internet maps, and population distribution data to carry out mining and analysis on the travel characteristics and spatial distribution features of bicycle sharing.

Keywords

Bicycle Sharing; Spatial-temporal Data; Travel Characteristics.

1. Introduction

As an important component of urban space, the transportation system plays a significant role in achieving the goal of "green city" development through the development of low-carbon transportation. Urban bicycle sharing, as a new form of sharing economy [1], provides convenience for citizens to commute between home and subway or bus stations due to its flexible and lightweight characteristics [2-9]. It has become a reasonable idea and method to solve the "last mile" problem of urban transportation [10,11]. This study is based on the Mobike bicycle lock data in Shanghai, focusing on the spatial-temporal characteristics analysis of bicycle sharing connecting transportation, exploring the correlation between bicycle sharing and important urban elements such as bus stations, and improving the research on bicycle riding characteristics. It is of great significance for enhancing urban bicycle sharing services and standardizing bicycle sharing operation management.

2. Research Methods

2.1. Section Headings

The data used in this paper mainly includes the bicycle sharing order data and parking location (electronic fence) data provided by the Urban Management Big Data topic of the 2021 Digital China Innovation Competition DCIC Big Data Track. Other collected data include Point of Interest (POI) data in Siming District and Huli District of Xiamen City (mainly including catering companies, education, shopping malls, life services, office buildings, medical care, government and residential areas, and transportation-related POI such as bus stations, subway stations, train stations, and airports), traffic road network data, elevation DEM data, and Xiamen's meteorological data in 2021.

ISSN: 2710-0588

2.2. Data Inventory

This paper combines multiple data sources to analyze and explore the potential rules of bicycle sharing during peak hours in the city. The experimental data used mainly include Xiamen's bicycle sharing order data, bicycle sharing trajectory data in Siming District and Huli District, electronic parking location data, POI data, administrative district data, urban road network data, and urban population distribution data.

2.3. Data Cleaning

The survey data mainly comes from the shared data of the Urban Big Data Research Society and other public data analyzed by big data analysis companies. The data has certain confidentiality, and after being processed by the competition organizers, all the competition data used have been de-identified, including bicycle sharing IDs and user information. The scope of data mining is within the main urban area of the two metropolises, with spatial GPS information of shared bicycles (with corresponding vehicle type IDs), recording the GPS location of the starting point before the bicycle is used and the parking location after it is parked. By using data mining techniques and analysis methods, detailed daily travel information of bicycles can be obtained, including vehicle model numbers for daily travel in the area, as well as basic data information such as starting location, start time, arrival location, and arrival date.

(1) Processing of unsuccessful unlock records

The bicycle order data distribution time is from 6:00 to 10:00 in the morning on December 21-25, 2020, and the spatial range is the two island districts of Siming District and Huli District in Xiamen City. The bicycle lock records OD points distributed around the parking spaces, and there are a large number of unsuccessful unlocking records in the distribution of Xiamen Island, that is, Lock_status=0, as shown in Figure 1.

Figure 1. Distribution of shared bicycle order data in Xiamen city

The data is sorted by ID and time, and effective OD is identified based on bicycle sharing order data. After sorting the data by license plate and time, the Status is normally a regular 0-1 change, but there are many unsuccessful unlocking records in the original data that interfere with subsequent operations. Therefore, abnormal riding time is calculated after preprocessing. There are mainly two types of unreasonable riding time: ①riding time<1 minute; ②the abrupt change in riding time distribution from 1-162 minutes to over 1000 minutes, as shown in Table 1.

ISSN: 2710-0588

Table 1. Changes in the number of statistical data before and after data cleaning

Record	Original	Processed	Deleted records with unreasonable riding time
Unlock Records	360325	220752	214365
Lock Records	224967	220752	214365
All Records	585292	441504	428730

(2) Binding of recently parked locations

There is a problem of mobile phone location drift when bicycling sharing locks are opened and closed. For example, when changing bicycles and locking the electronic lock, the user's phone transmits location data. However, due to transmission delay issues, it may usually lead to the user leaving the electronic parking space before the location data is transmitted accurately. Therefore, all bicycle sharing order data is bound by the nearest distance. Since the data transmission delay caused by time delay after the user leaves the bicycle will not be too long, a distance threshold of 50 meters is set, and the nearest distance binding is based on Euclidean distance.

(3) Vectorization of electronic parking spaces

By effectively distinguishing the 5 closed positioning points of the electronic parking space, they are converted to geojson format and visualized in ArcGIS. The visualization result of the electronic parking space shows that most of the parking spaces are rectangular in shape, and their spatial positions extend along both sides of the road, as shown in Figure 2.

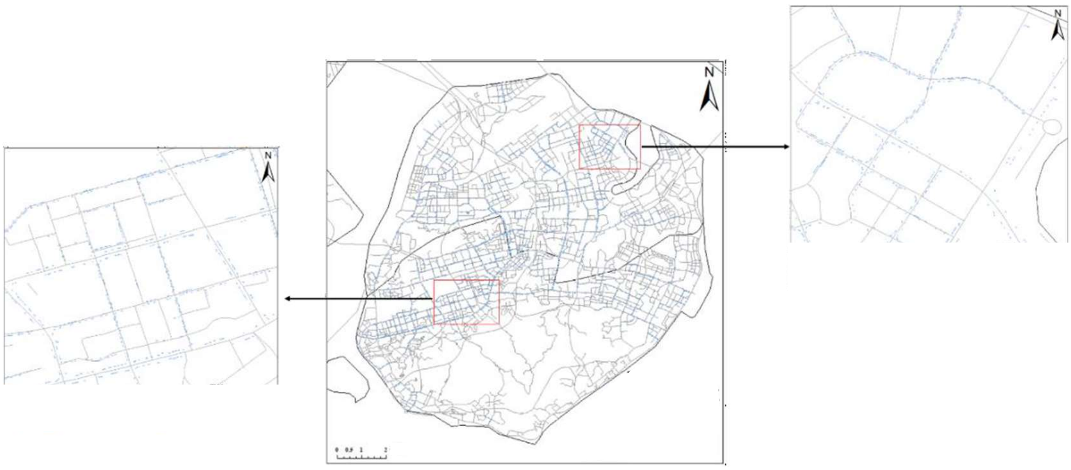

Figure2. Visualization of spatial distribution of electronic parking spaces in Xiamen city

(4) Processing of urban transportation network data

First, appropriate simplification is carried out on the road network in Xiamen City. Then, the elevated bridge section is simplified at the intersection, and the multi-lane road is simplified to a single lane loop. Finally, the original road network data is preprocessed. Considering the actual needs of subsequent experiments, some operations are performed on the original data, including:

① First clean up the road network data by comparing Google image maps and OSM block maps, delete or add roads, load GPS and OD order data, and further simplify and merge the road network according to actual needs.

② Simplify one-way roads as a single line.

ISSN: 2710-0588

③ Modify and improve the attribute table. Delete unnecessary field values in the attribute table according to actual needs.

④ Topological checks are carried out on the road network. Topological relationships are of great significance for data processing and spatial analysis. In the topological check of road network data, six topological check rules are selected: no overlap, no intersection, no self-overlap, no self-intersection, must be a single part, and no dangling nodes.

3. The Spatiotemporal Distribution Characteristics of Shared Bicycle Trips

3.1. Spatial and Temporal Distribution Characteristics of Shared Bicycle Travel

Spatial-temporal analysis of bicycle sharing data has been shown to be effective in solving many research problems related to cities and human travel, including understanding bicycle sharing usage and patterns. Spatial data analysis of bicycle sharing mainly includes two stages: statistical analysis and mining analysis. Statistical analysis is based on cleaned data to calculate and analyze travel times, travel durations, and other indicators. Mining analysis emphasizes flexible search for clues and evidence to discover hidden information in the data. Visualization, tables, and other forms can be used to mine the structure and patterns of the data, which is a method of data analysis.

3.2. Analysis of Experimental Results on Temporal Distribution Characteristics

By dividing time into different scales, based on the time record information of OD points, counting the number of O or D points in each time slice reflects the frequency of bicycle sharing usage in a certain period of time. Daily bicycle travel volume is analyzed and counted based on 5 minutes, 10 minutes, 15 minutes, and 20 minutes, as shown in Figure 3.

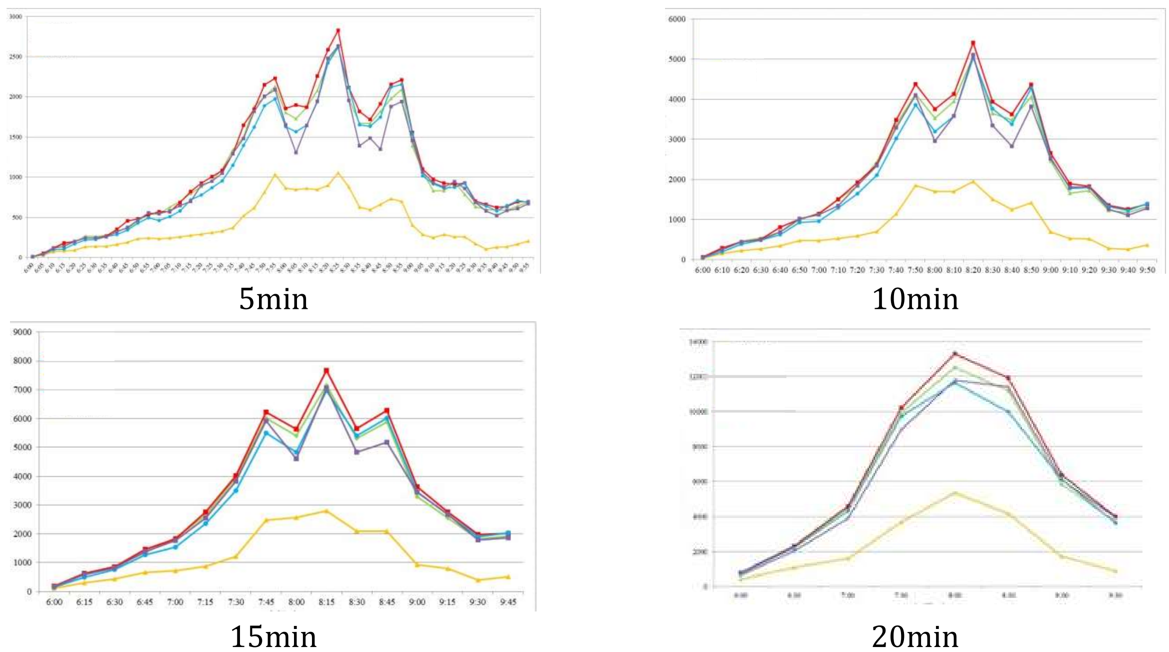

Figure 3. Statistical characteristics of bicycle usage at different time granularities

Overall, there are three small peaks in travel frequency during the morning peak hours of commuting, at 7:50-8:00, 8:20-8:30, and 8:50-9:00. Bicycle usage gradually increases from 6:00 in the morning, and from 7:00, the increase in usage is significantly greater than that from 6:00 to 7:00, reaching the first small peak in the 10 minutes before 8:00. Between 8:00 and 8:10, the trend of bicycle usage volume decreases slightly, but reaches the second small peak between

8:20 and 8:30. Until before 8:50, the number of bicycles being used is decreasing, and the third small peak appears in the 10 minutes before 9:00.

After pairing OD points based on bicycle sharing order data, the bicycle usage time in a trip is calculated by subtracting the O point time from the D point time. The frequency distribution of bicycle riding time is shown in Figure 4.

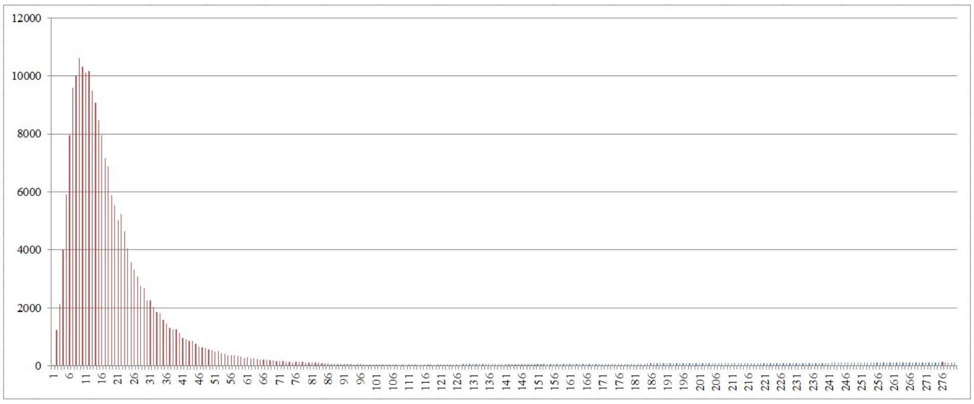

Figure 4. Frequency distribution of riding time

From the division of user bicycle usage time, we can see that the majority of users' riding times are concentrated in the 3-10 minute range, indicating that users generally use bicycles for short trips such as transfer and short-distance travel. In addition, the demand for travel within the 10-20 minute time interval is significantly less than that within the 3-10 minute time interval, and the demand for travel over 30 minutes shows a significant decrease. This also indicates that the acceptance of long bicycle usage times by users is generally within 10 minutes, and the proportion of long-distance recreational travel is relatively small. From the comparison of the distribution of riding time, most users choose to ride a distance of 0.5-1.5 km and spend 3-10 minutes, with a relatively low riding speed. This is closely related to the distance between residential areas and transfer transportation stations, and the distance between work locations and transfer bus stations. Due to the short distance and the relatively small proportion of waiting time at traffic lights during the ride.

There is a negative correlation between rainfall and the number of trips. The greater the rainfall, the significantly lower the number of bicycle sharing trips made by residents because rainfall increases the risk of riding, and residents are less likely to choose bicycles for travel. The daily usage volume breakdown and local conditions in Xiamen show that moderate rainfall has a significant impact on bicycle sharing usage, with a noticeable decrease in usage, while light rain does not have a significant impact on residents' bicycle travel.

3.3. The Analysis of Experimental Results on Spatial Distribution Characteristics

In addition to time characteristics, there is also significant spatial differentiation in bicycle sharing travel. The spatial distribution of residents' travel demand and the spatial distribution pattern of the city's road network give rise to different types of resident travel patterns in different regions. Different residential areas have different travel mode choices for residents; there are also differences in travel time and travel spatial range. Due to commuting reasons, residents' travel will appear spatial agglomeration in the urban area, with flexible travel time, while the travel space-time characteristics of residents in the outskirts of the city are relatively dispersed and their travel time is more fixed.

The high-density areas where bicycle sharing is used coincide with subway lines. This pattern is most evident between 7:00 and 9:00 on weekdays, representing the pick-up and drop-off of

ISSN: 2710-0588

bicycle sharing during the morning rush hour. This phenomenon indicates that people are more inclined to use bicycle sharing from home to major transportation hubs such as subways during the weekday morning rush hour and then drop off the bicycles. After leaving the public transit system, people may pick up another bicycle and ride to their workplace. Therefore, during these times, usage near bus stops shows a peak.

4. Conclusion

The slogan proposed by shared bicycles is to bring back bicycles to the city and solve the "last mile" transportation problem. In this study, order data was used as the data source, and visualization tools were used to explore the spatial and temporal characteristics of shared bicycles in Xiamen, revealing the activity patterns between bicycles and public transportation. The study found that the use of shared bicycles has indeed brought convenience to citizens' commuting, and the density and mix of functions of public transport stations, residences, workplaces, and leisure activities all promote the use of shared bicycles. A bike-friendly environment can be created from the perspective of optimizing the space around urban functional elements. By mining cycling data to explore residents' travel patterns, it is expected to provide effective guidance for bicycle deployment and optimization, thereby improving the efficiency of shared bicycle usage and achieving seamless integration with public transportation. Of course, due to data limitations, this study still has certain limitations and requires further exploration and application.

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