Bicycle-Metro Integration for The 'Last Mile' in Shanghai*

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Abstract: Cycling is always considered to be one of the most popular daily traffic tools in cities due to its flexibility, convenience and low cost. Moreover, Bicycle-metro integration is theoretically considered to be an effective solution for improving public transportation efficiency of "last mile" between home and metro station in big cities. However, this proposition has not been fully proved in practice. In recent years, the emerging dockless bike-sharing system makes it possible to examine the spatial integration between flexible bicycle traffic and rail transit. Compared with traditional public bicycle systems with fixed docks, such as New York Citibike, this new bike-sharing system demonstrates the mobility and flexibility of cycling. We randomly sampled the GPS coordinates of 80,000 dockless bikes in Shanghai, which represent the origin and destination points of cycling. We mapped the bicycle traffic on an equal population cartogram of Shanghai to distinguish overall patterns within the center of Shanghai. Results show that most of the high-frequency cycling streets still centre around metro stations. The streets basically present a gradual decline from the metro stations to outlying areas in terms of cycling frequency, which indicates that bicycle-metro integration has already become the basic model for daily transport in Shanghai.

Keywords: Bicycle-metro integration, the 'last mile', dockless bike-sharing system, Shanghai

Introduction

Traffic-oriented development (TOD) is a way to ensure the sustainable development of transportation and urbanization. As a fast, efficient and large-capacity transportation mode, the subway system is the focus of the TOD strategy. However, in the suburbs of the city, the subway stations are sparsely distributed, and their service radius often needs to be extended to more than one mile or even three miles, which seriously reduces the public accessibility of the subway system. In such cases, passengers in the subway system usually enter the station by other means, such as walking, cycling, and taking a bus. This transfer process is described as the last mile issue. Improving accessibility and strengthening the integration of other modes of transportation with subway stations will definitely increase the passenger capacity of the subway system.(Zhao and Li, 2017).

Meanwhile, cycling is always considered to be one of the most popular daily traffic tools in cities due to its flexibility, convenience and low cost (Akar and Clifton, 2009; Parkes et al., 2013). The traditional bicycle sharing system began in the late 1990s and has been extensively researched to date. For bicycle sharing systems in different cities, Pfrommer et al.(2014) determined that the peak usage of working days is between 7 am and 9 am, 4 pm to 6 pm, and the weekend peak is at noon. Ahmed et al.(2010) argue that the shared bicycle system is busier in warmer months, which usually confirms the relationship between weather and private cycling tendencies. A study of bicycle-sharing travel time based on data from Melbourne, Brisbane, and Washington,

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DC Researchers at the University of Minnesota and the University of London determined that this duration was within a narrow band between 16 and 22 minutes(Fishman, Elliot, Simon Washington, and Narelle Haworth., 2014). Another study shows that average users of a particular bicycle sharing service typically travel longer than annual membership (Buck, Darren, et al., 2013). Tao et al.(2013) analyzed the global and space-time modes of traditional public bicycle sharing systems in Nanning, China, and studied the impact of urban patterns on these models. Froehlich et al.(2009) conducted a spatio-temporal analysis of the use of bicycle stations in the shared bicycle system in Barcelona for 13 weeks, applied clustering techniques to identify sharing behaviors between stations, and compared experiments with four prediction models used in nearby stations. result. Some studies have focused on the sustainability of bicycle sharing systems.

Bicycle–metro integration is an effective solution for improving the accessibility of metro systems and facilitating green transportation (Zhao and Li, 2017). In recent years, dockless bike-sharing programmes have been launched in China at an impressive speed. These new common-usage bikes cover almost every street in Chinese big cities, and can be accessed via smartphone (Chinta and Sussan, 2018). Compared with traditional public bicycle systems with fixed docks, such as New York Citibike (Faghih-Imani and Eluru, 2016), this new bike-sharing system demonstrates the mobility and flexibility of cycling. People do not have to depart from or arrive at fixed docking stations; they may enjoy cycling from/to anywhere in the city. This design is effective in solving the 'last mile' problem, which is spreading across hundreds of cities around the world, including San Francisco, Seattle and London, by providing people with the transportation tools between public transport hubs and home.

Data and methods

With a surging number of active users, bicycle sharing is growing rapidly. Shared bicycles are used by more than 32 million users every month on average, reaching a coverage of 8.04% in first-tier cities in China. Currently, GPRS-based smart locks are widely used in the bicycle sharing industry. OFO, as the first and one of the biggest dockless bike-sharing firms in China, provides the bicycle-sharing system with more than 700,000 bikes in Shanghai. This study randomly sampled the GPS coordinates of 80,000 OFO bikes in Shanghai, which represent the origin and destination points of cycling.

Figure 1. Working mechanism of dockless bike-sharing system

Source: https://www.zdnet.com/article/chinese-bike-sharing-company-ofo-arrives-in-seattle/

Navigation in the Google Maps App provide a feasible approach to generate the cycling route from the origin and destination points. Furthermore, in order to eliminate the interference caused by the passing behavior of the research, The 80,000 cycling origin–destination (OD) lines were intercepted into 141,317 cycling directional lines, each with a length of no longer than 500 metres, which is generally considered as the basic service radius of metro stations.

Results and discussion

In order to explore the spatial relationship between rail transit stations and shared bicycle riding behavior, as shown in Figure 2, the shared bicycle riding behavior is divided into five categories: starting, riding, inner, outer and transit. Cycling data. This study mainly focuses on the starting and riding, arrival and riding behaviors around the various rail transit stations, and records the starting, reaching, and internal riding of the 500-meter radius around the rail transit station i as Di. , Ai and Ci.

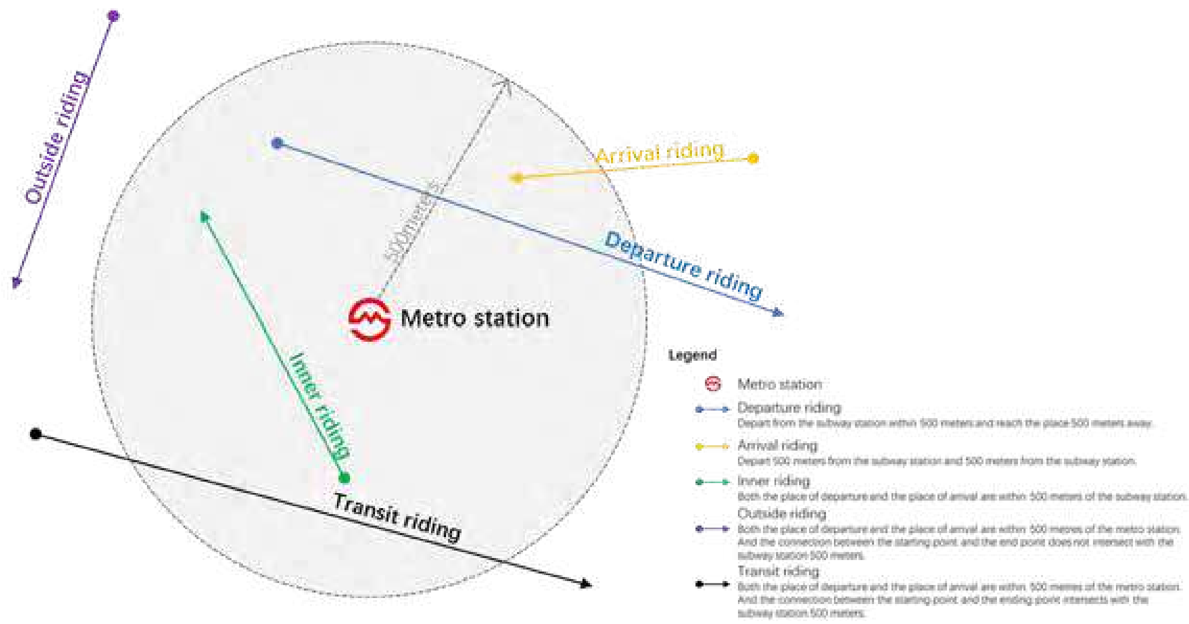

Figure 2. Division of riding behavior based on metro stations

According to the test, the number of riding, arrival, and internal riding around the Shanghai Rail Transit Station were 35,492, 31,646 and 1,245 respectively, and the number of rides related to the 500-meter range of the rail transit station reached 68,383. The ratio is as high as 85.48%, which indicates that there is a great spatial matching relationship between the shared bicycle riding data and the rail transit as a whole.

Shanghai Rail Transit Line 1 was selected as the research object, and Shanghai Rail Transit Line 1 was the first subway in Shanghai. There are 28 stations on Line 1, including 8 interchange stations, running through the Shanghai city from north to south, connecting the city center (People's Square), the city's sub-center (Xujiahui area), the suburban area, and the transportation hub (Shanghai South Railway Station, Shanghai Railway Station) can reflect the spatial connection characteristics of subway and bicycle travel in different locations. After testing, there were a total of 9455 cycling data around the rail transit line 1 site, accounting for 11.82% of the city's data.

Comparing the number of rides within 500 meters of each orbital station, it is found that: 1) the urban center system is clearly reflected: the city center, the sub-center and the commercial center of the district have high riding capacity; 2) the starting distance and the number of arrivals There is a clear positive correlation (the correlation coefficient between the two reaches 0.960), but the starting distance of each station is generally higher than the arrival of the ride (the ratio of the two is 1.26:1); 3) the number of terminal rides is obvious

"Zoom in" phenomenon: the number of rides around Xinzhuang Station and Fujin Road Station is significantly higher than that of Outer Ring Road Station and Youyi West Road Station; 4) There are some gradients in the process of attenuation of the center-suburb ride: such as Hengshan Road - Xujiahui, Tonghe New Village - Hulan Road.

Compared with the starting and the riding, the distribution characteristics of the two are relatively the same, except that the total number of starting and the line density is obviously stronger than that of the riding. Compared with the bicycle to the railing station, people are more It tends to ride from the perimeter of the rail transit site.

Compared with working days and rest days (Table 1), the average daily riding time on working days is 895 times, which is slightly higher than the rest day (858 times), but the riding distance is 1896 meters, which is obviously less than the riding distance of the rest day (2601 meter). At the same time, comparing the total travel time of each time period, it is found that there is a clear "early peak + late peak" double travel peak feature on the working day, while the rest day more reflects the single travel peak feature of "noon peak".

Table 1. Working days and rest days in 500 meters of each station on the rail transit line 1

	Weekdays		weekends	
	Cycling frequency(per day)	Average cycling length(meters)	Cycling frequency(per day)	Average cycling length(meters)
Departure cycling	524	1874	495	2785
Arrival cycling	371	1928	363	2352

We mapped the cycling directional lines of Shanghai (Figure 3) to distinguish overall patterns within the centre of Shanghai. The cycling directional lines are represented clearly as groups of radial lines from/to metro stations. Furthermore, with the help of the bicycle route navigation of Google Maps (www.maps.googleapis.com), each cycling trip was simulated by inputting coordinates of its start point and end point. Each street is assigned the number of starting and ending trips (no longer than 500 metres), which represents the cycling frequency. As is shown in Figure 3, most of the high-frequency cycling streets still centre around metro stations. The streets basically present a gradual decline from the metro stations to outlying areas in terms of cycling frequency, which indicates that bicycle–metro integration has already become the basic model for daily transport in Shanghai.

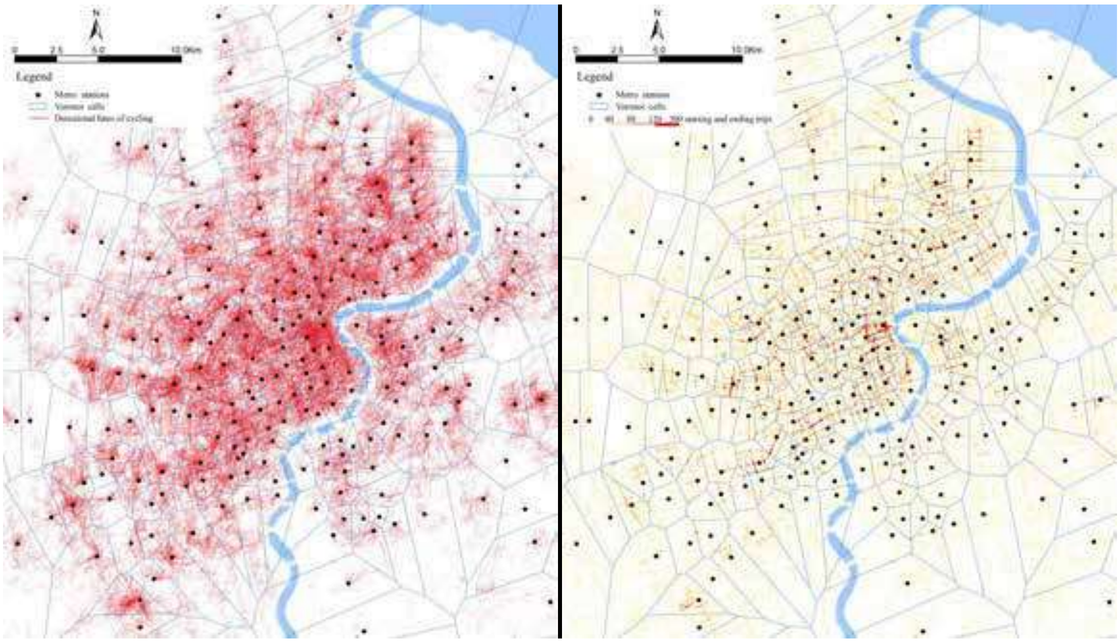

Figure 2. The cycling directional lines and cycling frequency of Shanghai's metro station voronoi diagram

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