WHETHER THE BIKE-SHARING INDUSTRY IN SHANGHAI IS SUSTAINABLE OR NOT

A THESIS

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Mathematical Economics

Abstract

Aiming at the problem of "last mile" of urban public transport, the shared bicycle — a personal transportation tool has been put into operation in Shanghai since 2016. This paper analyzes the current situation of bike sharing industry to determine whether it optimizes existing travel pattern including other major means of transportation in Shanghai. Data was collected from shared bike stands in Shanghai during January of 2019 to prove the dependence between the number of bikes and time period during a weekday. Through discussing the "last mile" problem, current earnings performance and allocation vs. usage pattern, this paper believes that this industry is of sustainable development if improvements can be made on profit and allocation.

KEYWORDS: (Bike-sharing, Sustainability)
JEL CODES: (R4,C8, D2, D4)

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Introduction

With the advancement of science and technology, the transportation tool has changed from “two wheels” to “four wheels” since the 1990s in China. Cars took the place of bikes. The rapid development of transportation has greatly promoted the growth of the social economy, and increased the productivity of the society while facilitating people's travel. However, the environment is deteriorating, primary energy such as fossil fuels is overly harvested, and urban traffic problems are becoming serious. The original efficient and convenient way of travel then became a prominent problem that restricted the harmonious development of society and hindered the healthy life of the people within just 20 years. Some cities in China suffered from traffic congestion, so they curbed the purchase of vehicles for private use and implemented traffic restrictions based on the last digit of license plate numbers. At the same time, local governments actively encouraged the use of public transportation and urban slow-moving systems containing walking, riding and public transportation. However, there still exists some problems in the current transport system, such as the “last mile” problem.

The “last mile” is not an absolute one-mile journey. It refers to the intermediate distance between the public transportation exit and the actual destination. Normally it refers to the distance between the exit of metro or bus station and the place of residence or workplace. As such, people usually choose walk, taxis, private cars, and even illegally operated vehicles to solve this problem. This neither long nor short distance has caused inconvenience to a considerable part of the citizens' travel, restricting the citizens from green commuting (Travel mode which is environmental friendly and minimize energy consumption). Increasing use of private cars has caused traffic congestion and illegally

operating vehicles have disrupted the normal public transportation order. Therefore, solving the “last mile” travel problem of urban traffic is not only an urgent need to solve the difficulties of citizens' travel, but also a construction of the city's "green travel" transport system.

The urgent need gave rise to the bike-sharing industry which is the topic of this thesis paper. This new mode has features of high degree of freedom, low-carbon environmental protection, and low-cost. This paper aims at figuring out whether bike-sharing industry is sustainable by examining different transport system in Shanghai including metro, bus, private cars, ride-hailing service and finally bike-sharing. The unsolved “Last mile” problem, restriction in private cars and safety problem in car-hailing are all possible factors which work together to promote the development of the bike-sharing industry. Aside from analyzing other transport system, the paper would also try to find out the answer based on actual data collected from bike stands in Shanghai.

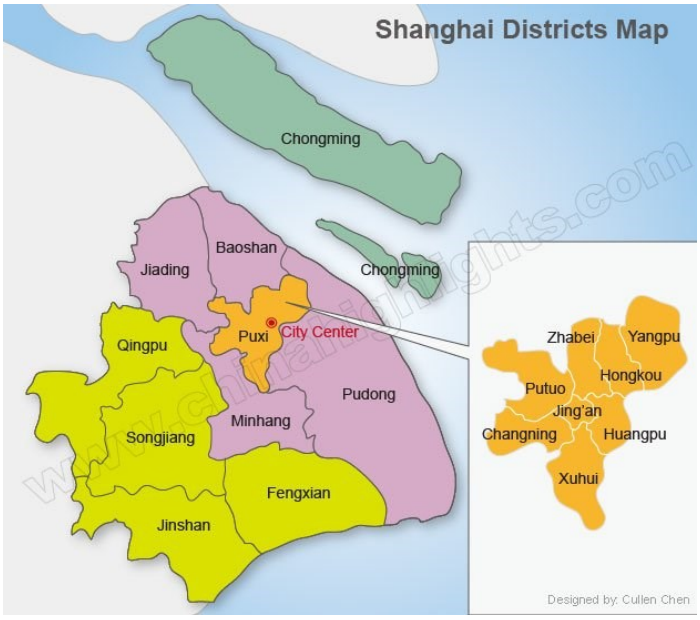
Shanghai's Transportation Picture

Introduction to Shanghai

Shanghai, Hu for short, is a renowned international metropolis drawing more and more attention from all over the world. Situated on the estuary of Yangtze River, it serves as the most influential economic, financial, international trade, and cultural center in East China. Also it is a popular travel destination for visitors to sense the pulsating development of the country. In downtown Shanghai, the average population density is 25,600 people per square kilometer, or 9,884 people per square mile (Chen, 2018).

The total area of Shanghai is 6340.5 square km, consisting of 16 districts which can be divided in to 4 groups — 7 central areas (Huangpu, Jing'an, Xuhui, Changning, Yangpu, Hongkou, Putuo), 1 semi urban and semi suburb (Pudong New Area), 3 suburban areas (Minghang, Baoshan, Jiading), and 5 remote suburbs(Songjiang, Jinshan, Qingpu, Fengxian, Chongming). According to the report, the total number of permanent residents in Shanghai dropped to 24.18 million at the end of 2017, down 14,000 from 2016, (Development Report of Shanghai Transportation Industry, 2018).

Figure 1 Shanghai Districts Map



Source: China Highlights.com (2018)

Transportation System of Shanghai

Following the rapid process of urbanization, the increasing rate of city expansion, and the growing number of residents and private cars, the importance of a successful transportation system becomes obvious to urban planning engineers. The urban infrastructure investment in transportation reached a peak at 2009 and has increased again since 2015 (Shanghai Statistic Yearbook 2017). Investment in Shanghai transportation infrastructure was 72.76 billion yuan($10.39 billion) in 2017, growing 4.2 percent from 2016. As for public transportation subsidies, buses ranks first with 80.5 percent, which was followed by the metro, which accounted for 17.2 percent (Development Report of Shanghai Transportation Industry, 2018).

Metro System. The metro system in Shanghai is the world's largest rapid transit system by route length totaling 675 kilometers (420 mi). By the end of 2017, there are 16 lines(including the Maglev) in operation with 393 stations. In 2017, it

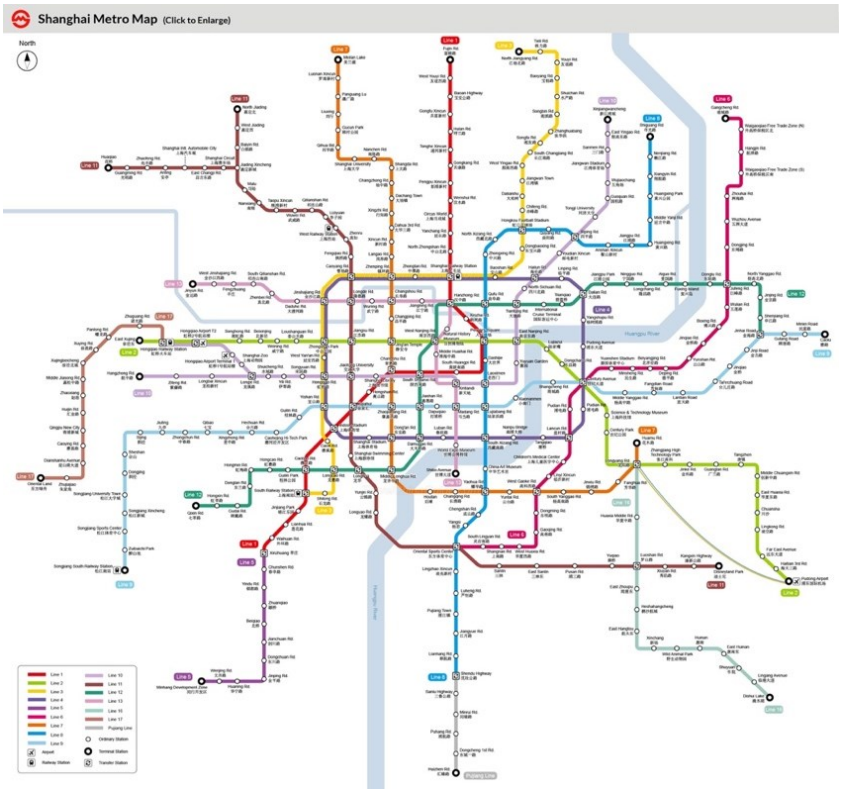
ranks second in the world by annual ridership with 3.53 billion rides (Development Report of Shanghai Transportation Industry, 2017). The historical daily ridership peaks at 12.5 million on September 21, 2018(Shanghai Metro Official WeChat, 2018).

Figure 2 Basic Information of Urban Metro Communication

Indicators	2013	2014	2015	2016
Urban Metro				
Operating Vehicles (car)	3 490	3 677	3 797	4 025
Number of Operation Lines (line)	15	15	15	15
Length of Operation Lines (km)	567.42	577.55	617.53	617.53
Operation Mileage (10 000 vehicle-km)	5 872	7 007	7 574	8 430
Volume of Passenger Traffic (10 000 person-times)	250 628	282 727	306 798	340 106
Year-end Number of Staff and Workers (person)	28 783	28 987	29 315	28 733

Source: Shanghai Statistic Yearbook 2017

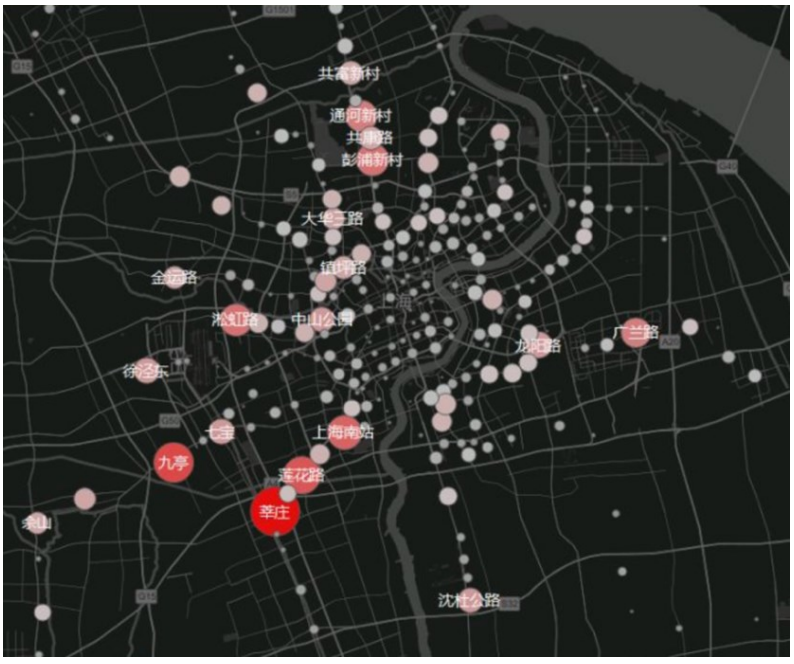
Figure 3 Shanghai Metro Map



Source: Travel China Guide (2019)

Shanghai Metro uses a distance-based fare system just like many other metro systems in the world. The system uses a "one-ticket network", which means the user will be charged by the nearest interchanging fee between the entrance and exit stations no matter how many lines he/she actually take by using one ticket. Instead of buying a ticket, people can also use the Shanghai Public Transport Card, like the MetroCard in New York City, or the official App on the phone to pay for the fare. The Shanghai Public Transport Card is a stored value smart card allowing access to almost all kinds of public transportation in Shanghai and some nearby cities. The price for metro is 3 yuan (0.44 dollars) for journeys under 6 km and then 1 yuan (0.15 dollars) for each additional 10 km. The operating hour varies from different lines but mostly ranges from 5:30am to 23:00pm.

Figure 4 Shanghai Metro Enter Station Distribution During Morning Peak



Source: Zhihu.com

Figure 5 Shanghai Metro Exit Station Distribution During Morning Peak

Source: Zhihu.com

According to Yuxiao Shen's big data analysis, most residents in Shanghai live next to line 1, line 3, line 7 and line 8 while line 2 is the one with biggest number of exit during morning rush hour (Shanghai Metro Fun Facts Using Big Data, 2016). Most of these pink and red bubble in figure 5 are stations on line 2 , indicating that this line connects main work places in Shanghai and mostly around downtown.

Bus system. The other major public transport system in Shanghai is the bus system. A great expansion on the scale of bus system can be noticed since 2010 (Shanghai Statistic Yearbook, 2017). At the end of 2017, the total number of public bus lines is 1657 with the total travel length of 26, 500km (China Main Cities Public Transportation Big Data Analysis, 2017). The price of a bus ticket ranges from 1 to 2 yuan, that is fixed for each ticket no matter how far the destination is.

Figure 6 Basic Information of Bus in Main Years

Indicators	2000	2010	2015	2016
Buses and Trolley Buses				
Length of Public Bus Lines (km)	23 260	23 131	24 027	24 169
Number of Public Bus Lines (line)	978	1 165	1 429	1 457
Operating Public Transportation Vehicles (vehicle)	17 939	17 455	16 531	16 693
# Buses	17 358	17 038	15 056	13 911
assenger Volume of Pubilc Bus (100million person-times)	26.49	28.08	25.49	23.91

Source: Shanghai Statistic Yearbook (2017)

Most Shanghai's bus stations have digital signs at the bus stop displaying arrival times, and others have QR codes for time information. Shanghai Airport Bus CO., LTD., combining internet into transportation system, developed an App for users to get the latest bus information from their phone which increases commute efficiency. The average operating speed of bus during rush hour is less than 12 mile per hour, making it less attractive for white collar workers. In that case, Shanghai transportation department is deciding to create specific lanes for buses to avoid time waste on bearing off other cars. By 2020, Shanghai aims at achieving covered bus specific lanes at the length of 500km (Chinese Public Transportation Information website, 2016).

Automobiles. Private cars, taxis, and online car-hailing services compose the total population of automobile in Shanghai. Private vehicle ownership levels are well below other cities of similar income. Among 100 urban households, only 30 families have a private car in the year of 2016 (Shanghai Statistic Yearbook, 2017).

Figure 7 Durable Consumer Goods Owned by Each Hundred Urban Household at Year-End (2015~2016)

Indicators	2015	2016
Family Cars(vehicle)	26	30
Electric Booster Vehicles(vehicle)	51	56

Source: Shanghai Statistic Yearbook (2017)

Figure 8 Gas Prices in selected countries worldwide

	Gasoline price in U.S. dollars per gallon
China	4.4
Mexico	4.17
U.S.	2.99

Source: Statista (April 6, 2018)

It is no longer easy to drive a car on the street even though you have one because of the car registration quota system. Certain big cities such as Shanghai and Beijing use this system for allocating license plates through the monthly online auction. This system aims at handling the city's problems of traffic congestion and asphyxiating pollution by reducing the number of private cars. An auction is used to award new plates or reassign previously used plates and single man/women are required to apply via their family. In a monthly sale this year, around 217,000 bidders battled for 9,855 license plates ending with the average winning bids for each plate at 88,176 yuan ($14,022) which is higher than the price of many domestically made cars. Last year Shanghai raised 12 billion yuan in license-plate sales which is about 2% of its total revenue (The Economist, 2018). Since

the ownership ratio of private car in China is not high, the limited number of driving licenses makes a concerted effort to the huge demand for ride service.

Figure 9 Beijing and Shanghai Price of Car Plate

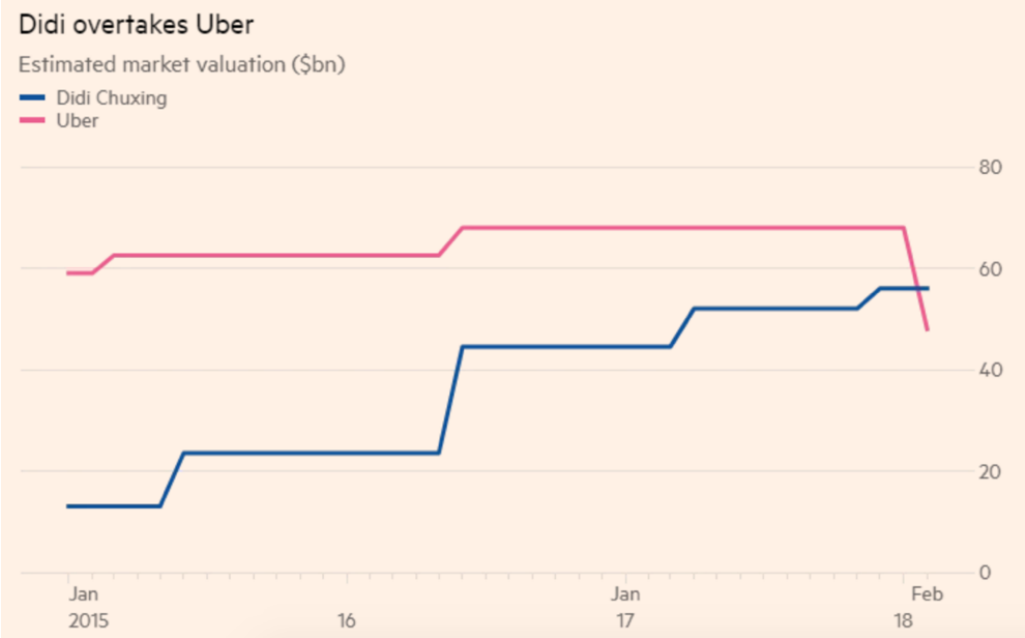
Source: Economist.com (April 19, 2018)

Taxi works as an important part in the transportation system in Shanghai. The price of taxi is 14 yuan or 16 yuan (2 dollars or 2.28 dollars) for first 3 km and accumulates up depending on distance travelled. In recent years, with the steady improvement of public transportation and the rise of online car-hailing service, the number of passengers taking taxi continuously shrinks. Take one of the oldest taxi operators Qiangsheng as an example, the company with the biggest market share in Shanghai taxi market has a hard time when ride-hailing break into the market. In 2015, when online car-hailing service started to enter the market with attractive in-app subsidies (such as coupons and free rides), the profit of Qiangsheng suddenly decreased by 1.28% compared to 2014 with a

total profit of 11.37 billion yuan (Qiangsheng Holding Group Annual Financial Report, 2015).

The car-hailing company — Didi, said it had 450 million registered users and 21 million drivers serving 25 million rides per day while there are roughly 2.6million licensed taxi drivers in the whole country (Financial Times, 2018). American e-hailing giant Uber also entered the Chinese market in 2013. But during its first years in China, Uber was not doing too well as it lost over $1 billion a year. Uber China suffered greatly from the competition with Didi and in August 2016, Uber China signed a deal to sell its Chinese operations to Didi. The deal is worth about 35 billion dollars.

Figure 10 Estimated Market Valuation for Didi and Uber



Source: Financial Times (March 9, 2018)

Because of the great prospect of this car-hailing market, Meituan, a lifestyle services platform for food delivery, restaurants reservation and other daily life entertainment app has decided to enter the market dominated by Didi. The company first obtained a license

to provide car-hailing service including taxi and ride sharing in Shanghai in June 2017. It completed 7.43 billion rides for 450 million users in over 400 cities in 2017 (Xinhua, 2018).

According to city regulations in Shanghai, drivers of riding-services need to register their information for supervision, which means that drivers have to equip a local permanent household registration which only local residents have. Also, Didi announced a requirement for the price of car to be at least 12,000 yuan as a prerequisite for entering the car-hailing service. These regulations make it hard for many drivers to remain in this industry.

The Status Quo of Bike-Sharing in Shanghai

The transport system is becoming mature and shaping the travel pattern for Shanghainese. With all these choices available, Shanghai was still chosen as the first city for bike-sharing trail operation and surprisingly within a year it becomes the biggest smart bike-sharing city in the world (Xinhua Daily Telegraph, 2016).

The History of Bicycle Usage in Shanghai

The popularity of bicycles in China began in the Republic of China and was completed in the 1970s. When the Republic of China was founded in 1949, the total annual production of bicycles in China was only 15,000 (Jiemian.com, 2017). This means that the bike at that time was a scarce item, meanwhile with a high demand due to its convenience. By the end of the 1980s, the mass production by state-owned enterprises has promoted the popularization of bicycle. China was then known as the bicycle kingdom in the world with 500 million bikes countrywide (Xinhua Daily Telegraph, 2016). At that time, the most famous bicycle companies throughout the country were Yonghe and Phoenix which were all from Shanghai.

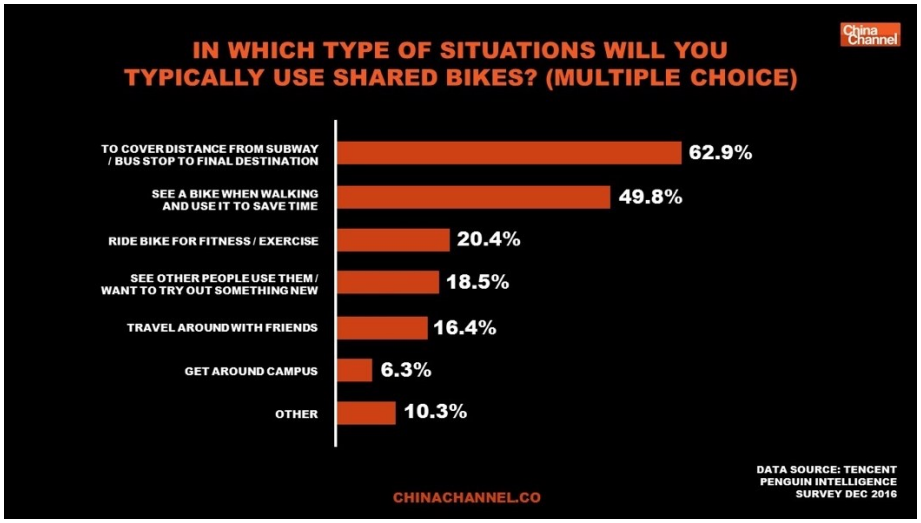
The industry of bike experienced a great change after 1995. Land development and housing marketization rapidly changed the scale of cities in China. Most residents' commute distance increased with the expansion of the city, while the traditional pattern of living close to the working place was broken. The daily travel distance between home and workplace of large cities in China was no longer inside the advantage travel distance of bicycles. Bikes started to fade out of people's life.

After entering the 21st century, in addition to urban expansion, there are also the boom of household private vehicles brought by economic development, making the role

of bicycles gradually weak. The usage rate of bicycles in large cities has fallen by half, and the bicycle usage rate in Shanghai has dropped by 80% (Xinhua Daily Telegraph, 2016).

According to 2017 China Main Cities Public Transportation Big Data Analysis Report, Shanghai's average travel time of 1km is about 3 minutes, which is the shortest time in the country. However, the average travel time by public transportation in Shanghai is the longest throughout China (China Main Cities Public Transportation Big Data Analysis, 2017). This can be explained by the highest average number of transfer times (between the same means or different means of public transportation) and the longest average walking distance. Shanghai has a large scale with 16 districts, so there is high demand for cross-district travel which would lead to large potential for transfer. In addition, one-way street and narrow road section account for a relatively high proportion, and the road conditions are complicated. Usually, the bus station cannot be located at where the subway station or residential area are so it is difficult to meet the short-distance walking conditions. The lack of speedy transportation from the starting location to the metro or bus station and from the station to the workplace motivates people to use motor vehicles. In other words, if Shanghai had better public transportation solutions to the "last mile" problem, then Shanghai's public transport travel efficiency would increase a lot as well as relieve the pressure of traffic congestion.

Figure 11 “In Which Type of Situations Will You Typically Use Shared Bikes”

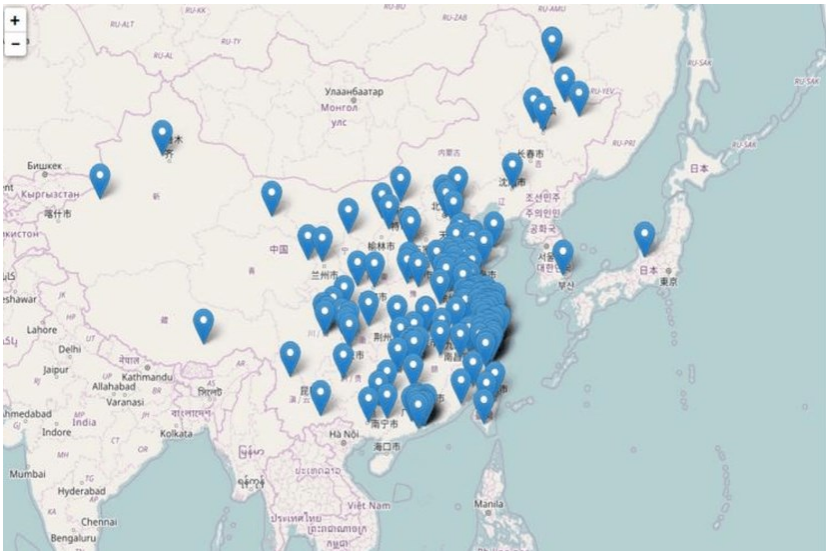


Source: Chinachannel.co (March, 2017)

3 Stages of Development of Bike-sharing in Shanghai

With the acceleration of urbanization in China, traffic congestion and environmental damage have caused headaches to the Chinese government. In order to alleviate or even solve these problems, the government has tried many ways, one of which is the introduction of public bicycles. In August 2007, the government bicycle-sharing mode came into being and started in Beijing, China. As figure 12 shows, most cities at the south east part of China were covered by public bikes.

Figure 12 Government Bicycle Distribution Map 2016



Source: Sohu.com

The second stage is the intervention of private enterprise. In 2010, Yongan Bank, a private enterprise, was established and began to undertake public bicycle system projects in Jiangsu and Zhejiang provinces in the same year and successfully operated. By the end of 2016, the Yongan bank has opened more than 100 public bicycles stands in China (Sohu, 2016).

Then it comes to today's dockless bike modes since 2016. China had around 70 bike-sharing companies in 2017, which put more than 16 million bicycles on streets nationwide and attracted over 130 million users, according to the Ministry of Transport (Xinhua, 2017). The so-called dockless bicycle is tracked by GPS and has no limitation for parking, meaning there are no docking stations. Bike-sharing Apps are built on a simple and ingenious combination of IOT + GPS + Mobile Payments (Vikram Chachra, 2017). Once the user downloads the App of any platform of bike-sharing, he/she has to pay a deposit ranging from 99RMB to 299RMB via WeChat or Alipay to complete the registration. The

deposit is refundable, although it will take up to 1-5 working days for it to be processed after you request for a refund. After that, users would have access to all nearby bikes with bike icons popping up all over the screen on a GPS map. Once the bike is found, riders can either scan the QR code on the bike or enter the bike number into the App to unlock the bike. The rental price is around 1RMB per hour. When the trip is completed, riders are encouraged to park at any public bike rack or public location that does not interfere with pedestrians or traffic.

Figure 13 Map of Available Shared Bikes On the Smartphone

Source: Screenshot on my phone in 2018

Bike-sharing has then rapidly become a popular industry attracting a large number of companies. However, most of them did not realize what the business principle of bike-sharing was and how to make profit. During 2017, several shared bicycle companies in the

second and third echelons went bankrupt. From the earliest collapsed Wukong bicycles to Xiaolan and Cool Cycling, there have been at least six shared bicycle companies declared closure and ceased operation in just over five months. Till last year, China's bike-sharing scene had intensified to a game of three main players: Ofo, HelloBike and Mobike. While the former two are backed by Alibaba Group and Ant Financial respectively, Tencent-backed Mobike was acquired by Meituan for US$2.7 billion in April (China Technology, 2018). Ofo was started by a Peking University student who aimed at providing bikes for college students, while Mobike was founded in January 2015 by Beijing Mobike Technology co. ltd. Both of them have invested in tens of millions of bikes for 200 cities in China to compete for the "last mile" market.

Ofo, the bike-sharing startup in China, admitted considering bankruptcy in December 2018 (Li & Horwitz,2018). Price and coupon battles for market shares lasting for a long time are costly and make it hard for companies to make profit. When facing the debts to suppliers and users' demands for refunds, Ofo has to resolve its liquidity problem.

At the same time, urban management encountered challenges with the increasing number of bikes. More and more bikes are strewn onto the streets, and many end up piling as trash heaps. Officials say that Shanghai have reached saturation point with no more available space for new bikes to get in circulation (Time, 2018). The operation of shared bicycles needs to rely on public traffic resources. As the public goods provided by the government to the society, the traffic road resources have the characteristics of no competition and no exclusion. Therefore, the shared bicycle operators can overuse the public resources without paying. The social cost on large-scale investment in vehicles is not equal to the cost of the enterprise itself, which causes negative externality. The national and

provincial governments meant to make follow-up regulation based on the development of this new industry; however, they are not prepared for the colorful seas of unorganized parked bicycles. Rather than serve as a sustainable complement for current transport systems, bike-sharing operators fought for market shares which led to an oversupply of bicycles resulting in being dumped on landfills.

Facing these problems, the Chinese government issued guidelines in August 2017. The guidelines affirmed the positive role of share bikes in facilitating short-distance travel and building a green and low-carbon transport system. The guiding opinions proposed relevant measures from three aspects: implementing development policies, standardizing operation services, ensuring user deposits and the security of network information.

For the second aspect, guiding opinions proposed that the local government should take the main responsibility for bike-sharing management. It is necessary to promote the setting and construction of bicycle parking points. Develop technical guidelines for the setting of bicycle parking areas that are adapted to local characteristics. In response to bikes allocation issues, the national government encouraged every province and city to establish a bike allocation mechanism based on factors such as urban characteristics and developmental conditions, and to guide enterprises to place vehicles in a rational and orderly manner.

The phenomenon that user deposit was hard to get back if the company bankrupted aggravates the distrust situation of bike-sharing industry. Facing this problem, the guideline encouraged a deposit-free way to provide rental services. Otherwise, the company is required to set up special deposit accounts for supervision (New guidelines to keep China's bike sharing on track, 2017).

Method

Procedures

In order to find out whether the bike-sharing industry is sustainable in Shanghai, I chose three bike stands as my sample locations to examine the usage pattern at different types of areas.

I went to each stand on a random weekday from 7 am to 7 pm and counted the number of available dockless bikes (unbroken) at the stand every 2 hours. 7 data points would be collected in one day and 2 visits were spent on each location. Since there are 3 stands, 42 data points in total are collected for analysis. Weekdays can reflect more general using pattern for the working class while weekends contain more randomness depending on weather condition and personal interest in going out.

The time period I choose is from 7 am to 7 pm due to working hours in Shanghai. The average working hours are from 8 in the morning to 6 in the afternoon, with a lunch break from 12 pm to 2 pm ("Business Hours In China", 2018). We assume that everyone would spend at most 1 hour on commuting. Since bike-sharing aims at solving the "last-mile" problem, people are more likely to use shared bikes for short distance travel. So, for bike stands at residential area, people might start riding shard bikes from home to the nearby subway/bus stations around 7 am depending on the commuting distance. If the assumption is true, a difference in bike numbers can be noticed from 7 am to 9 am. For the same reason, ending the data collection at 7 pm can reflect the number of shared bikes used for getting back home from nearby bus or subway stations.

The time interval is designed as 2 hours which means every data is collected 2 hours after the previous one. There is no exact pattern for how people would use the shared

bike during the day between the chosen time period. However, the lunch break is 2 hours on average as known so I pick it as my interval assuming that the number of shared bikes would not change a lot during the lunch break time. The last thing about method is the way I collect the data. I chose a nearby café or library for a day-long stay and went to the stand every 2 hours to record the number of bikes. Instead of sitting next to the location of stand, I think it would better for people to choose whether they want to ride or walk without noticing someone looking at them.

Location of Bike Stands

There are 3 shared bike stands for my data collection. Each of them belongs to different categories of neighborhoods — commercial zone, financial zone and residential zone. I would name them as A,B and C.

Description of location A. Location A lies in a commercial zone at Jing' an district which is in the area of city center.

Figure 14 Location A in The Map of Shanghai

Source: Google Map (Pin is the location A and yellow star is the nearest subway station)

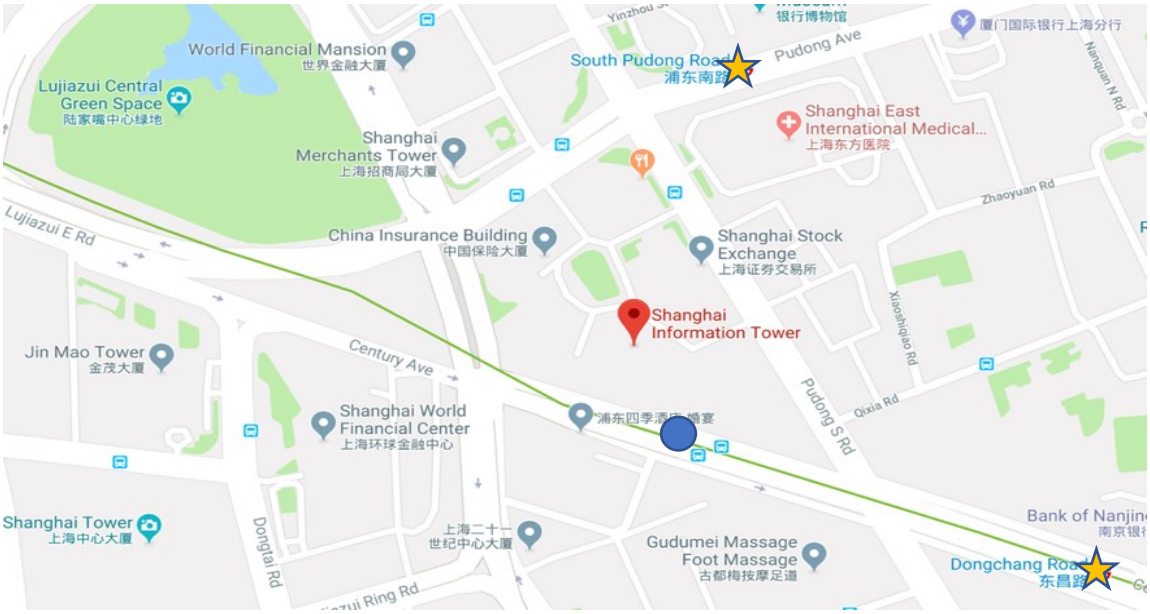
This stand is outside a mobile phone maintenance center with only 1 minute walking distance from the Nanjing West Road subway station (the yellow star). As figure 14 shows, it is surrounded by shopping malls, restaurants and other kinds of commercial activities. The most famous and flourishing commercial area is 15-30 minutes of walking from this stand. The reason why I choose this location is its relatively long walking distance toward entertaining places people are heading to after getting off the subway. The capacity of this stand is about 45. Some of the bikes here are private and docked which is consistent with other two bike stands. All kinds of bikes are required to parked inside the white line area as shown in figure 15 below.

Figure 15 The Shared-bikes at Location A (Personal Photo Taken at 9 am)

Description of location B. The second stand is located in front of the Shanghai Information Tower where big companies such as China Telecom and Ford China are settled inside. More importantly, this area is part of the largest financial zone in China — Lujiazui. There are more than 400 financial institutions and about 5000 companies here,

meanwhile, most of the tallest landmarks of the city are constructed here as one of the most famous tourist attraction.

Figure 16 Location B in the Map of Shanghai



Source: Google Map (Pin is the location B, yellow stars are the nearest two subway stations and blue circle is the nearest bus station)

There are three subway stations around this stand, however, the nearest one is about 10 minutes walking distance. For white-collar workers who work at Shanghai Information Tower and commute by subway, they are likely to use the shared bike especially if they are in a hurry. It is worth mentioning that there is one bus station between Dongchang Road station and the tower (the blue circle). The bus station is just next to the working place and connect with surrounding residential area which means people can choose between bus and shared-bikes for commuting. Since it is winter when I collected the data, I assume that bus would be a better choice. In that case, those who parked shared-bikes between 7 am to 9 am at this location are mainly white-collar

workers who rode from subway station to the tower. The capacity of this stand is approximately 90 and bikes can placed by two rows inside the bolded white line area.

Figure 17 The shared bikes at Location B (Personal Photo Taken at 7 am)

Description of location C. The third location is at the residential zone where I have been lived in for 10 years. It is outside the Jinda Garden and next to Jinqiao Road subway station of Metro line 6. I picked two bike stands for location C because they are respectively next to two exits of the same subway station. As figure 18 shows, there are several residential courts at both side of two exits. Jinda Garden and Huangshan Mountain Xinyuan are close to exit 3 (which is not shown on the map but on the same side of exit 4) while people living in Jindong Famous Garden and Jintai Unit are more likely to use exit 1 and 2. By adding the data from two stands, I can have a more clear understanding of the usage pattern of shared-bikes in this residential community. Residents are likely to ride shared bikes from their living area to these two stands and commute with bus or subway.

Figure 18 Location C in the Map of Shanghai

Source: Google Map (Pins are two bike stands I picked as the location C, yellow star is the nearest subway station and blue circle is the nearest bus station)

What's more, instead of being a typical residential zone, this community includes a plaza which is called Jinqiao International Business Plaza. The plaza covers an area of nearly 60,000 square meters with a total construction capacity of 180,000 square meters and is one of the largest commercial centers along Line 6. Since the plaza is a lot bigger than the map shown, the longest distance can be 0.4 miles from one side to the other side of the plaza. Besides for commuting, shared-bikes are here in place for using as a means of short distance transport.

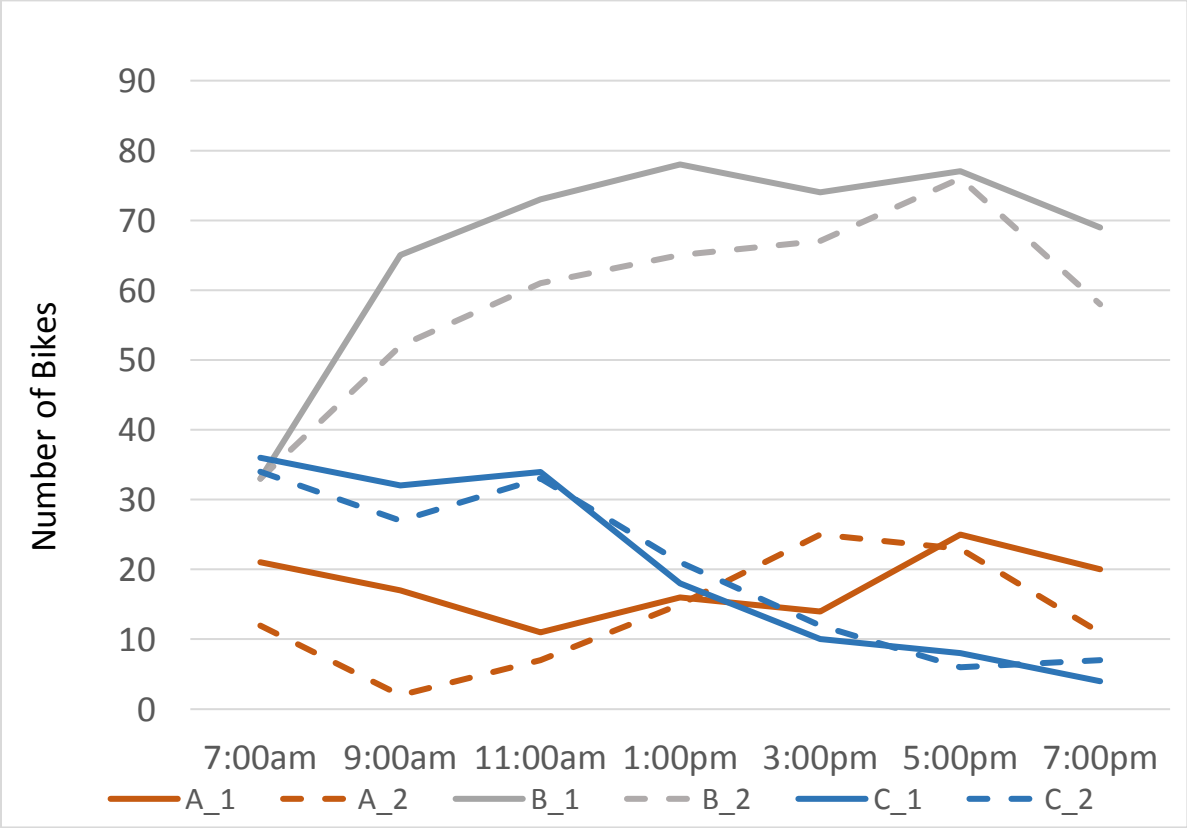
Results

Two questions of interest in this data collection are: "How many shared-bikes are there in the stand?" and "What time period is it of the day?". The raw data collected from 3 stands on 2 days and every 2 hours from 7:00 am to 7:00 pm is shown in table 1.

Table 1 Raw Data

Type of Location	7:00am	9:00am	11:00am	1:00pm	3:00pm	5:00pm	7:00pm
A_1	21	17	11	16	14	25	20
A_2	12	2	7	15	25	23	11
B_1	33	65	73	78	74	77	69
B_2	33	52	61	65	67	76	58
C_1	36	32	34	18	10	8	4
C_2	34	27	33	21	12	6	7

Figure 19 Graphic Comparison Between 2 days for Each Stand



A_2, B_2 and C_2 present the data collected on Monday while A_1, B_1 and C_1 are from other weekdays in Figure 19. Each stand has its pattern of usage for shared bikes while there exist difference between two days for the same location. Noticeable difference can be seen for location B where the number of bikes is lower for almost every time period on Monday compared with the other day. A possible explanation would be that, most white collar workers have to go to office on Monday since it is the beginning of the week even if the job is telecommuting. The other possible reason is that people would go to financial organizations such as banks on Monday because some of them are closed during weekends and some urgent service is needed to be done as soon as the week begin.

In order to make the two variables qualitative, I average the data collected from two days for each shared-bikes stand as well as categorize three time period group. "Morning" stands for the total number of bikes at 7 am and 9 am which mainly represents the shared bikes for commuting during morning rush hours. "Mid-day" includes 11 am, 1 pm and 3 pm which indicates the usage of shared-bikes around lunch break. "Evening" combines data from 5 pm and 7 pm providing the information of evening commuting.

The data collected from each time period are then classified according to two qualitative variables: the time period of the day when data is collected, and the number of available shared bikes in the stand. The raw data fall in the two-way table shown in table 2, with rows corresponding to the number of shared bikes at the stand at each time, and columns corresponding to the time period.

Table 2 Contingency Table

		Time Period			
		Morning	Mid-day	Evening	Totals
Location	A	26	44	39.5	109.5
	B	91.5	209	140	440.5
	C	64.5	64	12.5	141
	Totals	182	317	192	691

		Time Period			
		Morning	Mid-day	Evening	Totals
Location	A	26 28.84	44 50.23	39.5 30.43	109.5
	B	91.5 116.02	209 202.08	140 122.40	440.5
	C	64.5 37.14	64 64.68	12.5 39.18	141
	Totals	182	317	192	691

I chose chi-square test to figure out whether the number of bikes are dependent on the time period of the day. It is a test of hypothesis about category probabilities in a two-way table. The null hypothesis is that the two directions of classification in the contingency table are independent. The alternative hypothesis is that they are dependent.

Test statistic: $\chi^2 = \sum_{i=1}^{r}\sum_{j=1}^{c}\frac{(o_{ij}-e_{ij})^2}{e_{ij}}$ where r = number of rows in the table, c = number of columns in the table and O_{ij} is observed number of responses in the cell in row i and column j. e_{ij} is the estimated expected number of responses in cell (ij). Rejection region for this test is where $\chi^2 > {\chi_\alpha}^2$. χ_α is the tabulated value of the chi-square distribution based on $(\mathrm{r}-1)\times(\mathrm{c}-1)$ degrees of freedom such that $\mathrm{P}(\chi^2 >$

$\chi_\alpha{}^2) = \propto$. (significance level is 0.01)According to the above test steps, chi-square equals to 50.0361 with degrees of freedom 4, P-value for this specific distribution is less than 0.00001which is got by consulting a chi-square table. The P-value suggests that we can reject the null hypothesis so the number of bikes in the stand and the time period are dependent with each other.

In order to find out the difference of two days on each location based on data, data are put into online chi-square calculator for examining. Results show that data from weekdays other than Monday has higher chi-square statistic, which means the dependence between two variables is more statistically significant.

Table 3 Chi-square Result for data collected on Monday

Results						
	Morning	Mid-day	Evening			***Row Totals***
A_2	14 (23.49) [3.84]	47 (44.93) [0.10]	34 (26.58) [2.07]			95
B_2	85 (101.89) [2.80]	193 (194.86) [0.02]	134 (115.26) [3.05]			412
C_2	61 (34.62) [20.10]	66 (66.21) [0.00]	13 (39.17) [17.48]			140
Column Totals	160	306	181			**647 (Grand Total)**

The chi-square statistic is 49.4481. The *p*-value is < 0.00001. The result is significant at *p* < .01.

Source: Social Science Statistics

Table 4 Chi-square Result for data collected on Weekdays other than Monday

Results						
	Morning	Mid-day	Evening			***Row Totals***
A_1	38 (34.42) [0.37]	41 (55.34) [3.71]	45 (34.25) [3.38]			124
B_1	98 (130.17) [7.95]	225 (209.30) [1.18]	146 (129.53) [2.09]			469
C_1	68 (39.41) [20.74]	62 (63.37) [0.03]	12 (39.22) [18.89]			142
Column Totals	204	328	203			**735 (Grand Total)**

The chi-square statistic is 58.3423. The *p*-value is < 0.00001. The result is significant at *p* < .01.

Source: Social Science Statistics

Discussion

The topic discussed in this paper is whether bike-sharing industry is sustainable in Shanghai. It will be answered in this section from three aspects: whether allocation fits the usage pattern, whether the "last-mile" problem is solved and whether this industry is making profit. The data collected in Shanghai suggests that the number of shared-bikes at different bike stands has statistically significant association with the time period of the day. In other words, people are actually using shared-bikes according to different patterns based on the type of neighborhood of the chosen location. The dependence between two variables directly reflects how bikes are allocated according to usage patterns; bike-sharing industry turns out to be a solution to the "last mile" problem, which can be indirectly determined according to the neighbouthood of three locations; the last aspect cannot be directly conclude from the data but the observation on bike-sharing usage brings a lot thought to this question.

A previous study on bike-sharing in Shanghai was done by Jiaqi Dong, who was graduated from NYU Shanghai. She discussed the interaction of Mobike usage and Shanghai Metro system, and how to improve the company's operating efficiency through bike relocation. Based on her study, this paper includes all bike-sharing companies and all major choices of transportation in Shanghai to determine the sustainability of this whole bike-sharing industry.

Allocation Fits Usage Pattern or Not

According to Jiaqi Dong's study, there are strong patterns of "tide effect" during rush hours at specific metro stations which requires the reallocation of shared-bikes (2018). The tide effect can be reflected from the data of location C.

From the traffic level analysis, the phenomenon of "tide effect" mainly refers to the use of shared bikes to reach the subway station, bus station and other traffic interchange stations during morning peak; the demand for shared bicycles at subway stations, bus stations and other transportation interchange stations to complete the "last mile" toward residential areas during evening peak. Most of the "tide effects" are concentrated at transportation hubs, passenger flow collector-distributor points and office buildings (corresponding with location C, location A and location B).

This kind of tide traffic phenomenon has obvious characteristics. During morning rush hours, popular transportation hubs will attract large-scale of shared bicycles to park, which adds great pressure to traffic around the stand. At the evening peak, on the contrary, bikes move back to surrounding residential areas making bikes hard to come by. Oversupply and overdemand happen in the same day but different time period. However, during non-peak time, those popular shared-bikes stand idle with low-usage outside the transportation hubs or office buildings.

As data in table 1 and 2 shows, location B has 209 bikes on average during mid-day and the change in number of bikes is smaller than 10. What's more, at 7 pm there are still 69 and 58 bikes left in the stand. Shared-bikes here are oversupplied during the whole day which needs reallocation considering whether any place nearby is lacking of bikes. I assume that there are bike-sharing company staff to relocate shared-bikes. It is possible that they move 20-30 bikes from location B to the nearest subway station after 7 pm so that white-collar workers have enough bikes to ride during the morning peak. As for location C, the number of bikes at 7 am is around 35 but it decreases greatly to less than 10. It is very likely that a worker is able to ride a shared bike to the subway station in the

morning but cannot find one to ride back home. The difference in the number of bikes between 7 am and 5 pm should not be too large so that statistically everyone heading back to home is able to get a bike from the same bike stand.

Balancing supply and demand of bike allocation is vital to ensuring sustainability of the industry. It is important for shared bicycle companies to use the data already generated for analysis, make scientific predictions on bicycle supply, user demand, vehicle usage frequency, parking status, etc., and provide effective guidance for accurate operation and maintenance. Technically speaking, companies should adjust the accuracy of GPS positioning by cooperating with major map companies. Then, effort should be put on strengthening divisional management through assigning stand managers for every bike stand or several stands in the same community. Managers are responsible for requesting maintenance, allocating bikes in the community and avoiding intentional damage or steal action to lower the depreciation of bikes.

“Last Mile” Problem

The “last mile” problem is mainly found in densely populated cities in countries with very high population density such as Japan, Philippines, China and Germany. Among them, Japan mainly focuses on the development of ultra-small electric vehicles with a low speed. In Philippines, due to the backwardness in the construction of transportation infrastructure, the "tuk tuk" taxi which is an electric tricycle, has become the first choice for “last mile” because of its small size and flexibility (Hideyoshi Kume, 2015). The policies on transportation that these two high-density areas implemented are not hard to find the common ground, which is to encourage the development of relatively smaller vehicles other than cars. The shared-bike fits in this standard and is a possible

solution to the “last mile” problem in Shanghai which is supported by the data. The chi-square test proves that the number of shared-bikes in each stand is associated with the time period. So people are making use of bike-sharing at all three locations , and location A, B and C are places where the “last mile” problem does exist.

For location A, to arrive surrounding commercial areas, people would choose between walking, shared-bikes and car-hailing service. Most shopping malls and restaurants open around 10 am and lunch break usually ends around 1:30pm. We can assume that 1 hour before or after these two time points are the time periods when people are most likely to use shared-bike to replace the walking distance. As shown in the data , the number of shared bikes overall decreased during 9 am and 11 am, and increased up after 1 pm which corresponds with the assumption. As for location B, the “last mile” covers the distance between Shanghai Information Tower and the subway station during morning peak hours. The data describes the trend that a sudden increase happened between 7 am and 9 am, and then the number of shared-bikes gradually went up till 7 pm. People prefer to use shared-bikes at the morning peak instead of at the evening one. It is the same distance between the metro station and the workplace but at different time periods there exists different user choices. The “last mile” problem is more likely to become a trouble when time is precious. Location C has the most clear trend which experienced an outflow of shared-bikes from 7 am to 7 pm. The “last mile” problem appears in the morning when surrounding residents ride and park bikes at the stand for subway or buses. The demand for shared-bikes can be reflected by the fact that the number of bikes reached the peak at 7 am for both days at location C. Also, the gradual outflow of shared-bikes during the day can be explained if people use them to get to

further parts of the Plaza which is also included in the “last mile” problem. However, as discussed before, location C facing the problem of the low stock of shared-bike during evening peak when people try to go back home.

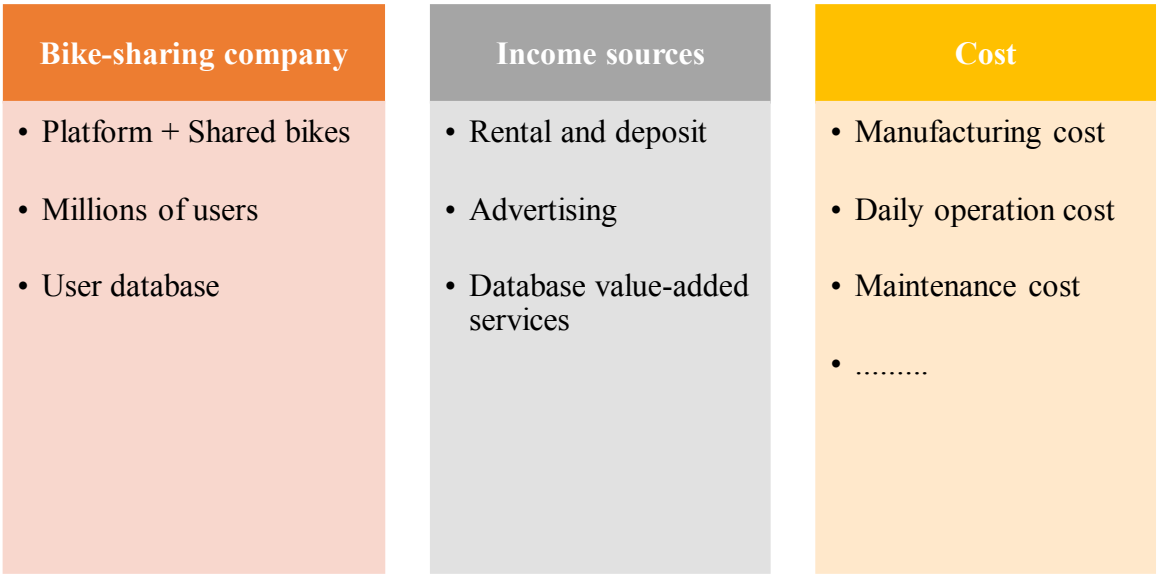
In general, the “last mile” problem exists at each location which motivates the usage of shared-bikes, and in return the data shows us how shared-bikes serve as a choice for “last mile” problem.

Making Profit or Not

Whether bike-sharing companies are making profit or not is an important metric for determining sustainability. For now, this industry is experiencing a hard time to make profit merely with rent so that companies should make use of platform and data to increase income.

The business principle of this industry is that the company raises funds to do research and drive large-scale standardized production of bicycles by upstream manufacturers in the bicycle industry. After that, the company would select key cities for trial operation. In the process, it is important to solve the problem of appropriate allocation and organize periodic maintenance for broken bikes. Compared with typical sharing economy model, the bike-sharing industry occupies both the supply side and the platform side. Therefore, its profit model adopts both the traditional rental industry profit model and the platform profit model.

Figure 20 Bike-sharing Industry Profit Model



Source: Huxiu.com (Mobike vs Ofo)

The shared bicycle profit model first reflects the characteristics of the traditional rental industry which are deposit and rent. The deposit for Mobike is 299 yuan (42 dollars) and for Ofo is 99 yuan (14 dollars). However, the deposit income is not expected be the main source of income. The guideline mentioned before states that deposit-free mode is encouraged and all deposit would be standardized for supervision. The other one is rent which is the main source of profit for the current shared bicycle industry. The current kind of rental fees is divided into two categories: 0.5 yuan (0.07 dollars)/ half an hour (classic) and 1 yuan (0.14 dollars)/ half an hour (lite), depending on the type of bikes ("Mobike pricing standard", 2017). According to the analysis done by Zhixing Zhang, he assumed that the pricing is 0.83 yuan (0.12 dollars) per ride and total monthly depreciation is fixed at 41 million dollars (the depreciation in December 2017). In order to reach a balance on revenue and cost in a month, the number of ride has to be 1.1

billion which doubles the actual number of ride in December 2017 (2018). In other words, it is hard for bike-sharing companies to make profit merely through rental fees.

The industry should make full use of the platform to integrate with lifestyle services and establishe its own ecosystem. Through the open platform with a great number of users, industry partners can integrate short-distance riding services into their own APP applications, providing users with a convenient riding experience and increasing their user stickiness. For example, Meituan, as a lifestyle app, could recommend surrounding restaurants to users and locate the nearest Mobike stand with calculated shortest path. Also, the shared bicycle set-up system can collect a large number of short-distance travel data which has great potential value. These data is of great commercial value to retailers, restaurants and even automobile companies, as well as local governments seeking more detailed information on urban planning.

Difference Between Monday and Other Weekdays

In the result section, chi-square tests on Monday (A_2, B_2 and C_2) and other weekdays (A_1, B_1 and C_1) are conducted separately. The chi-square statistic for Mondays is 49.4 while 58.3 for other weekdays which means the number of bikes and time period are more statistically associated on weekdays other than Monday. We can say that on Monday there exists more randomness on shared bikes usage pattern. The possible reason can be that many people rent temporary house near their workplaces and go back to their permanent houses or parents' houses for weekends. Those who choose not to live in their permanent houses may find it too far to get to their workplaces. In that case, when they commute on Monday, public transportation may not be ideal which takes too long time but private vehicles or car-hailing services can be a top choice.

Limitation and Suggestion

Firstly, the data was collected for this paper in winter when Shanghai is really cold. Those who use bikes as a rigid demand would still use them but people who take riding a shared bike as an exercise or hobby may change to other types of transport means. I would suggest further study to cover the usage pattern throughout different seasons and different type of weather to find out how much does weather weigh in influencing the use of shared bikes.

The second limitation is the small amount of data. Because of time limitation, this paper only have 42 data points for analysis. Although data shows the association between two variables, the result can be more strong with the support of a bigger database. Further study should pick more stands of different types of zones in Shanghai or other big cities in China, and go to every stand for more days. In that case, it is possible to figure out the model of the type of zone and usage pattern.

As for the "tide effect" problem, I suggest further study to calculate the max difference between the number of bikes after morning peak and before evening peak. By figuring out this, companies can allocate bikes by station managers to make sure enough shared bikes are waited at the bike stands for residents back home. More data is needed for this statistic problem.

The last suggestion for future research is about the randomness on Monday. It is meaningful to find out whether there exists consistent difference between bike usage on Monday and other weekdays. The result can not only shows how bikes should allocate on Monday but also indicates the rationality of public transportation and housing price around business zones.

Conclusion

The sustainability for current bike-sharing industry can be reflected by its appropriate allocation matching with usage patterns and its success in alleviating the “last mile” problem. At the same time, there is still room for improvement to maintain sustainable development. Bike-sharing companies should make use of the platform and rich users’ data to make long-term profit. In the future, researches should collect more data and try to solve the “tide effect” and allocation problem by specific models.

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