Investigating the Usage Characteristics of Bicycle-sharing System under Multi-scaled Built Environment of Hangzhou

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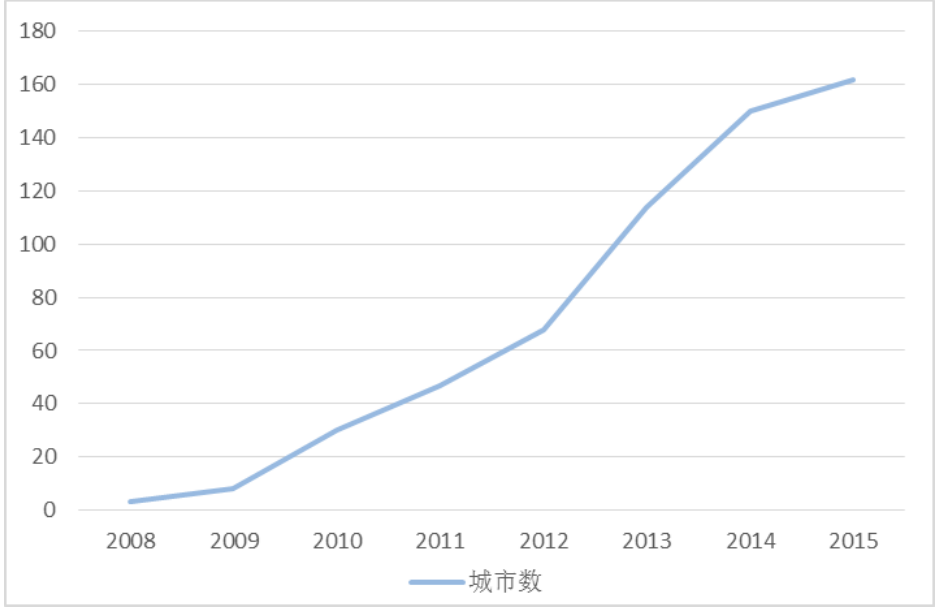
1.Overview

There are 162 cities in China which operate a bicycle sharing system in 2014.

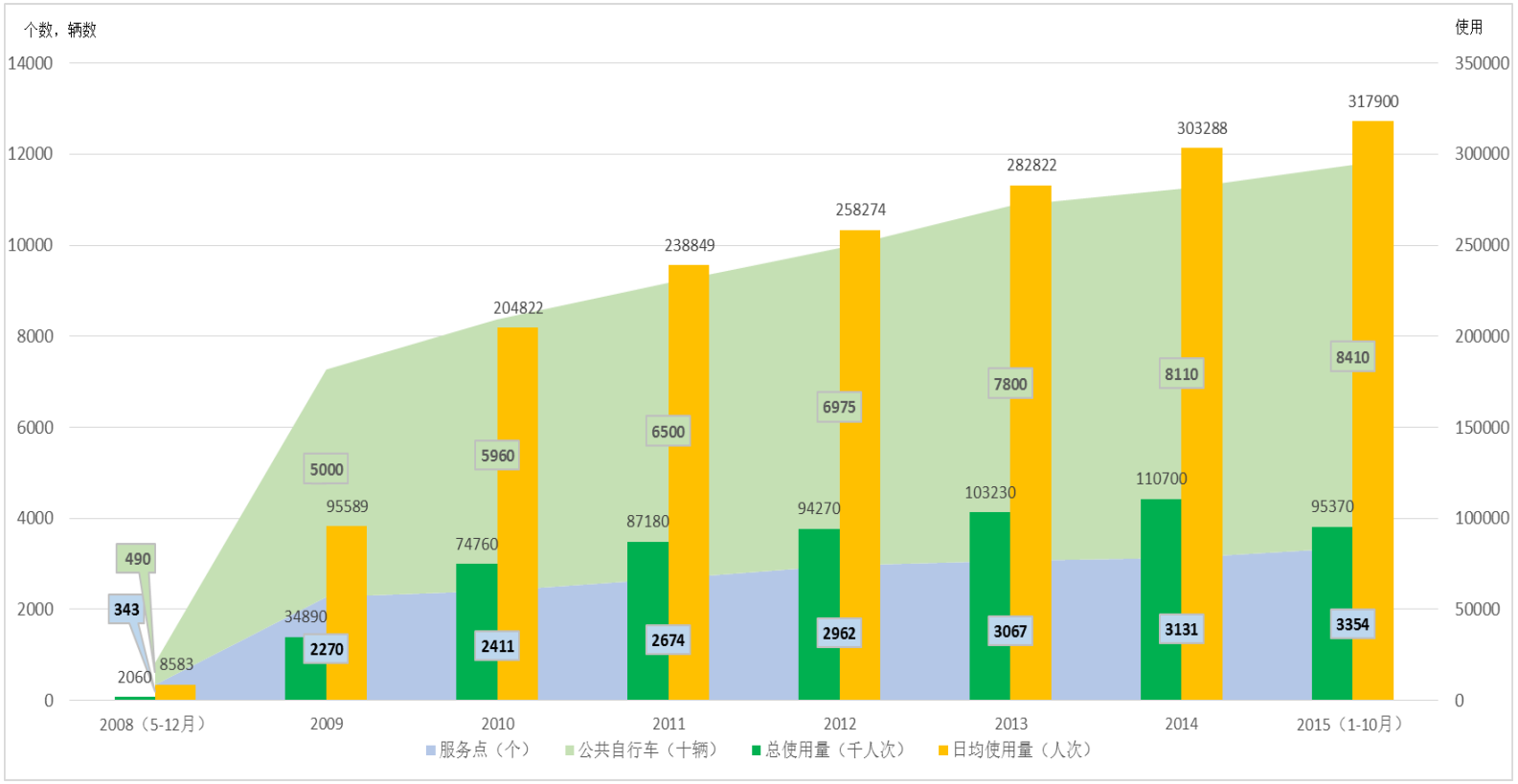
In 2014, the number of public bicycles in Chinese cities exceeded the sum of other countries, with more than four hundred thousand in total.



1.Overview

Bicycle-sharing system of Hangzhou is one of the largest in the world.

Bicycle: 84100+; Station:3300+; Total rental amount/day: 310,000+



How about the usage characteristics and performance of the system?

What is the relationship between the usage and BE factors.

1.Overview

Spatial structure of Hangzhou :

Central city

Periphery towns

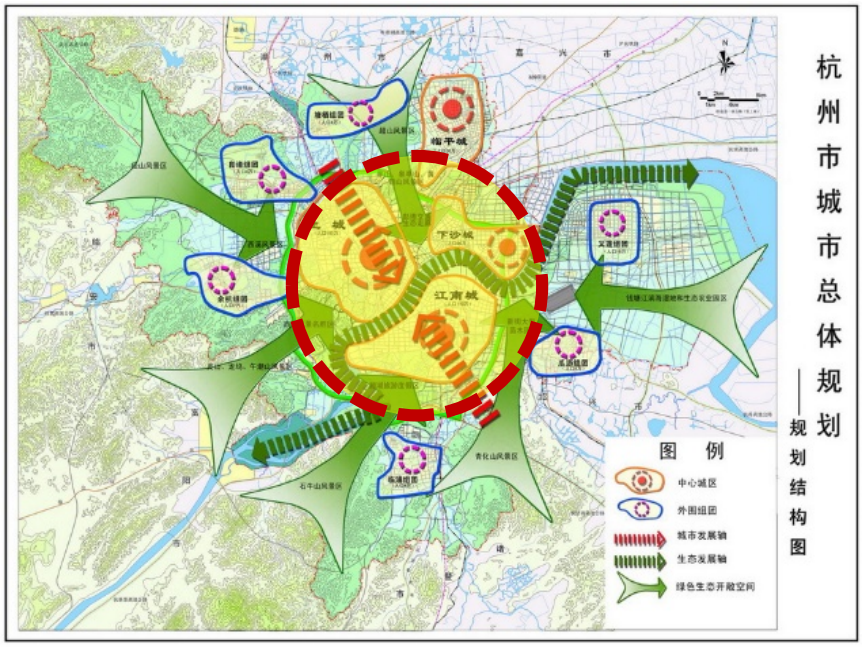
Area of the study (6 districts):

- Center part
- Eastern part (Xiasha area)
- Southern part (Binjiang area)
- Western part (Xihu)

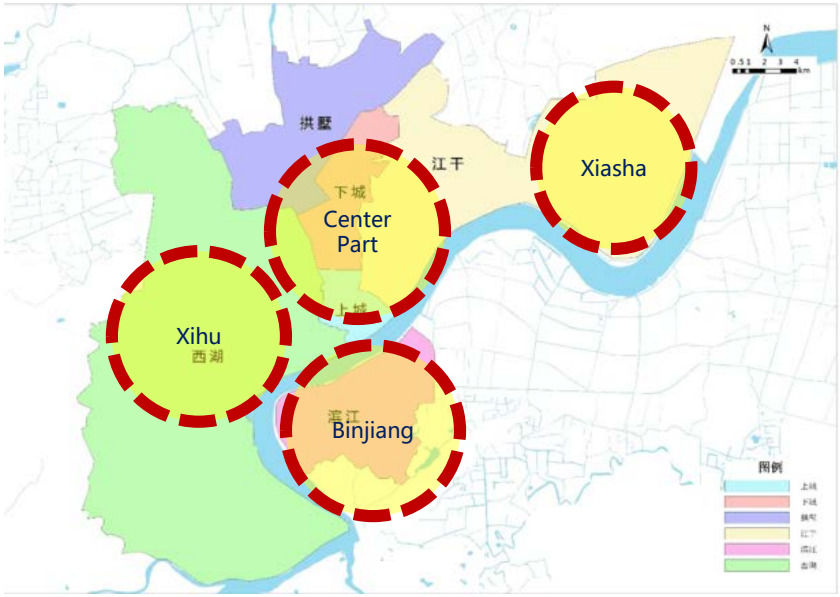
Total area is 682.6km² with 333.86km² urban built-up area , and 2176 stations.

Multi-scale

- TAZ-based: coarse-grained
- Station-based: fine-grained



Spatial structure plan of Hangzhou administrative region

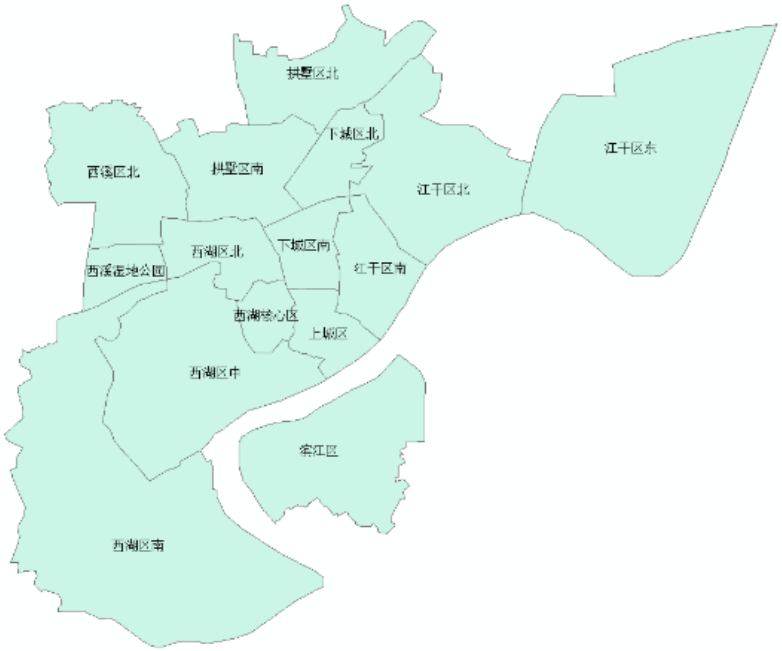


Area of the study

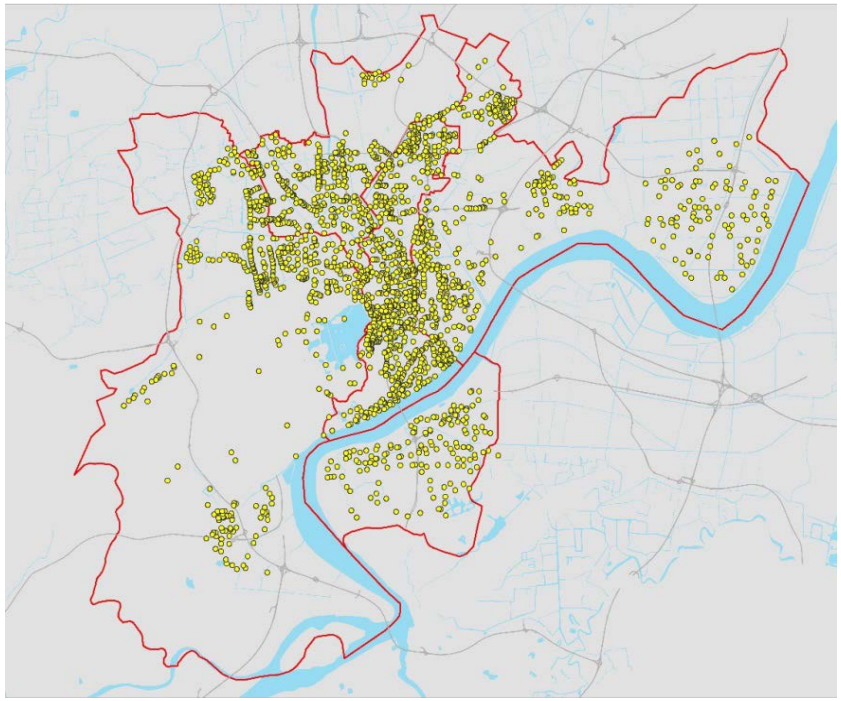
1.Overview

Methodology

- GIS: bicycle-sharing system, land use, bus, road, metro, etc
- Big Data: IC records of one weekday in Aug, 2012
- Quantitative analysis: Correlation analysis, Cluster analysis



TAZ

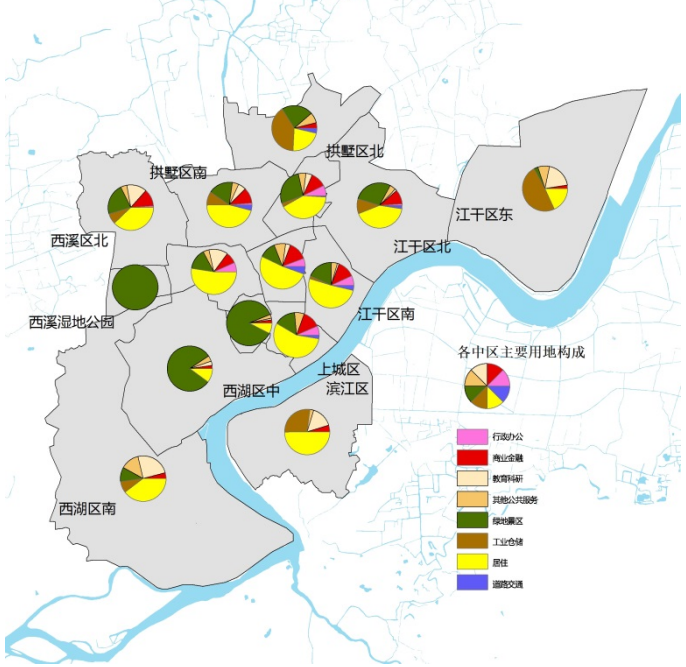


Distribution of stations

1.Overview

Land use constitution of each TAZ:

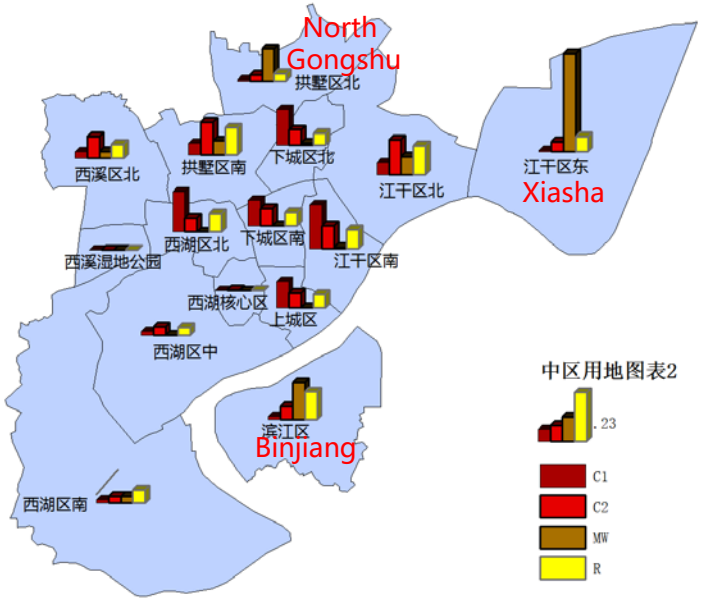
- The proportion of commercial and business use is higher in the TAZs in the core area than other areas.
- The proportion of industrial land is the highest in outskirts like Xiasha and Gongshu.
- West Lake and Xixi Wetland rank the highest proportion of green space.



Land use constitution of each TAZ (%)

Share of land of each category among TAZs :

- office and commercial lands are mainly in the core areas.
- Industrial lands concentrate in Xiasha, Binjiang and Northth Gongshu.



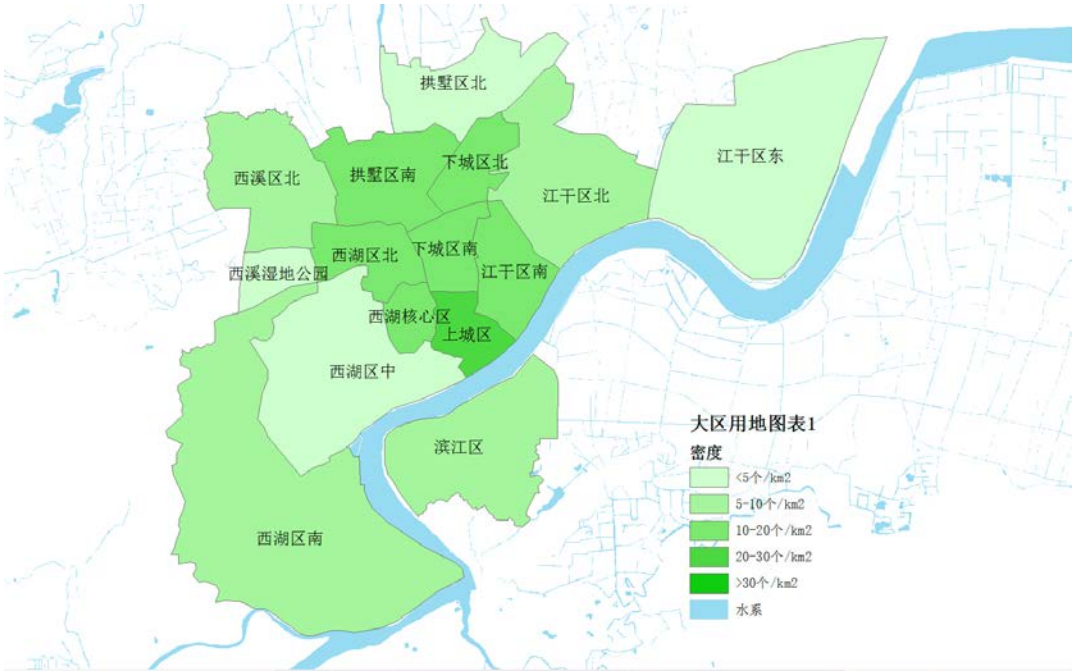
Proportion of TAZ area accounted for the total amount of each category of land (%)

2.Usage Characteristics Analysis

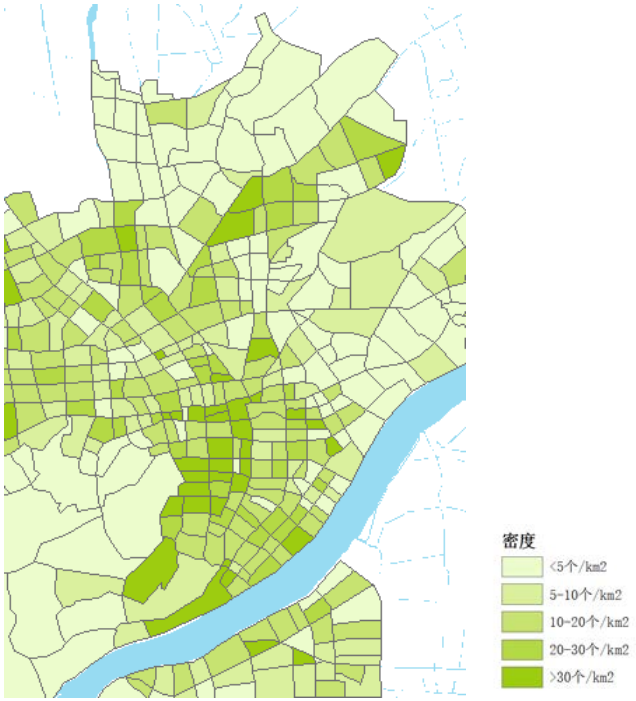
2.1 Station density

Average density is 7.87 stations/km^2, up to 24.15 station/km^2 in TAZ of Shangcheng；and the minimum is 1.83个/km^2 .

For sub-TAZs, the highest ones are in the core area, east of West Lake.

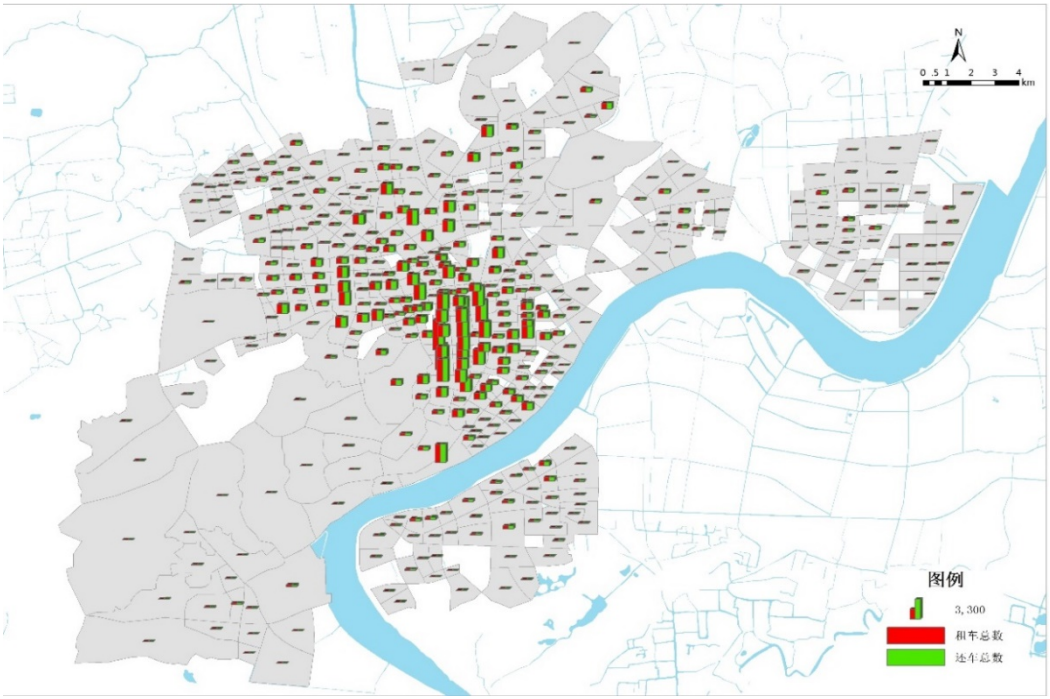


Station density of TAZ

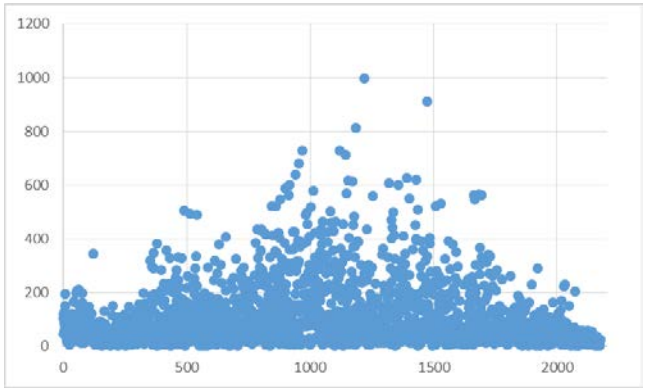


Station density in urban core area

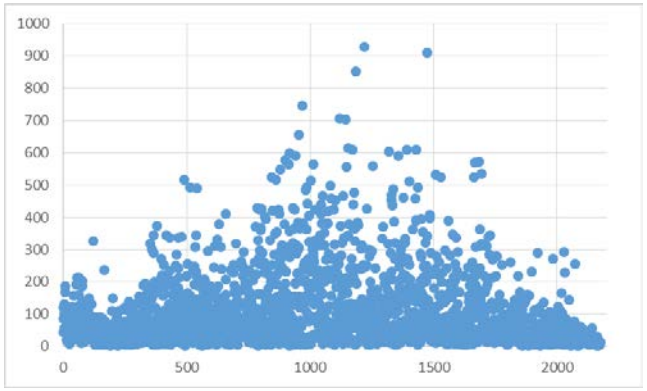
2.Usage Characteristics Analysis



Rental and return amount of each station for all day



Rental amount of each station(times/day)



Return amount of each station (times/day)

2.2 Rental-Return Amount

The total rental and return amount is 233,157 and 232163 times/day. The average amount for each station is 107.15 and 106.69 respectively.

The amount for each station varies greatly, the largest ones concentrate in the urban core.

2.Usage Characteristics Analysis

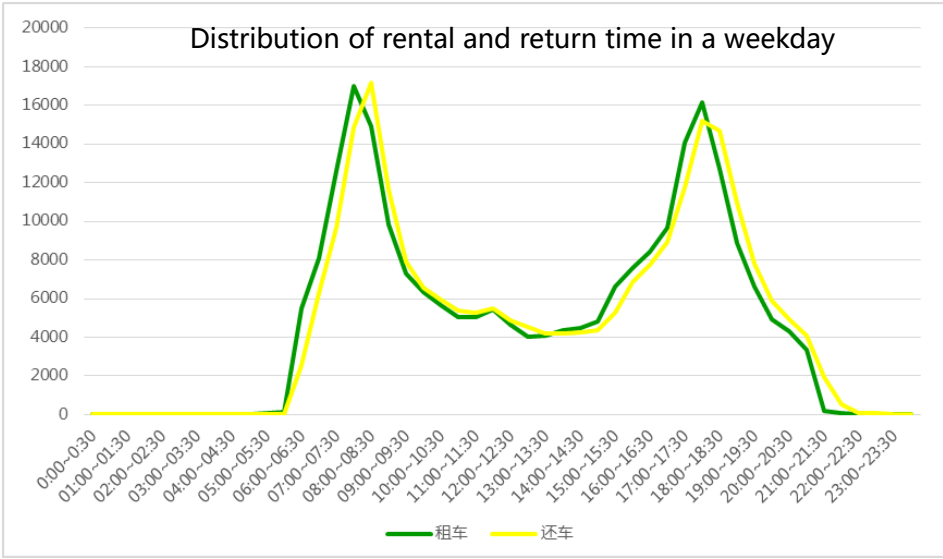
2.3 Hour distribution

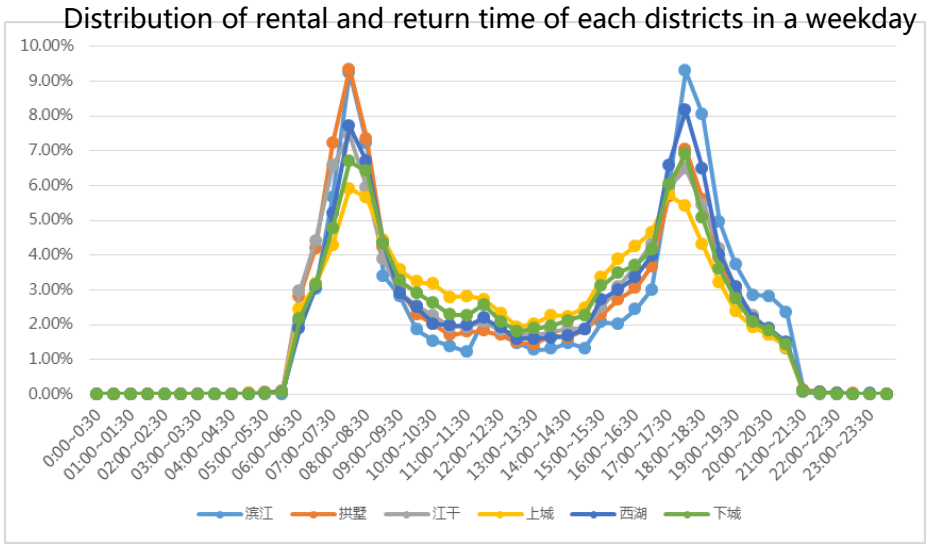
Distribution of rental and return hour shows a clear "Twin Peaks" feature.

Morning peak: 7:00 - 9:00;

Evening peak: 17:00 - 19:00.

Rental and return amount during morning peak accounts for 23.3% and 23.0% of its total , and the proportion in the evening peak is 22.2% and 22.7%.





The peak coefficient is different for 6 districts, that Shangcheng and Xiacheng is the lowest ; while Binjiang and Gongshu is the highest. It can be seen the hour distribution is more evenly in the core area.

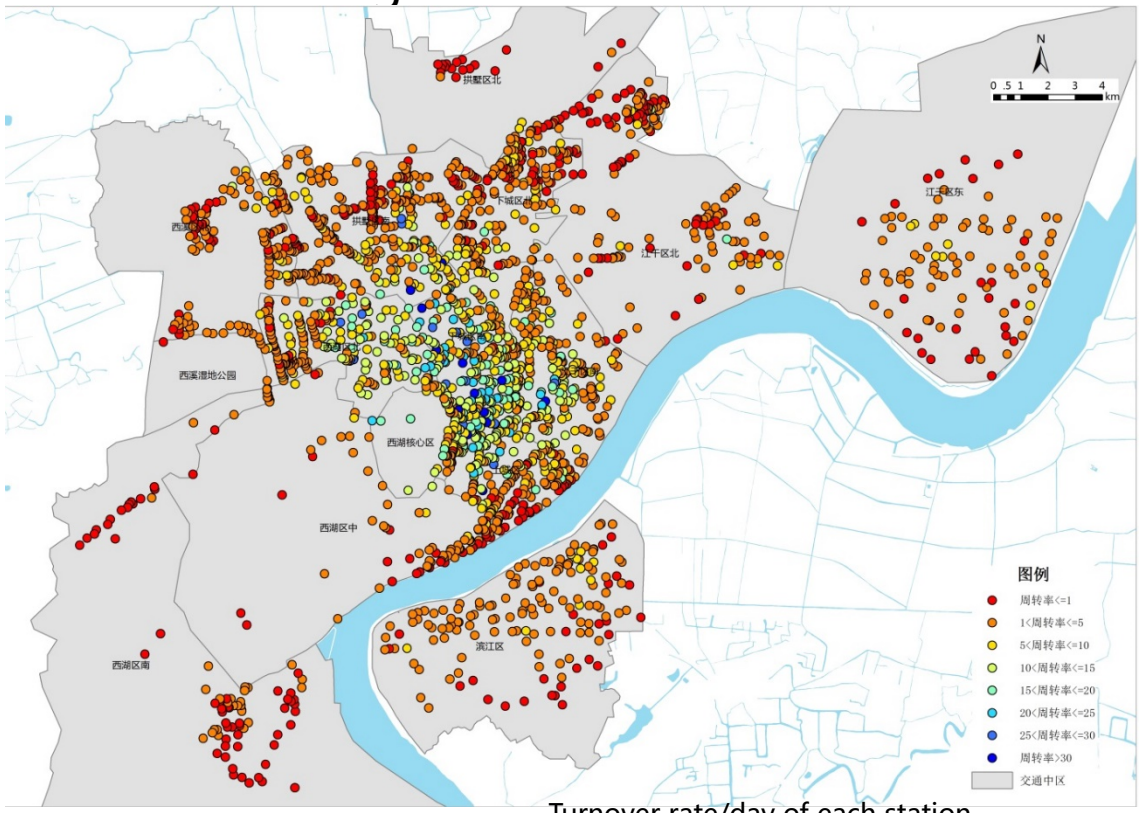
2.Usage Characteristics Analysisc

2.4 Turnover rate

Average daily turnover rate=daily return amount/the number of locks

Average daily turnover rate of all stations is 4.73.

The spatial distribution of turnover rate shows a circling structure, with the values of stations decreasing from the center outward.



Turnover rate/day of each station

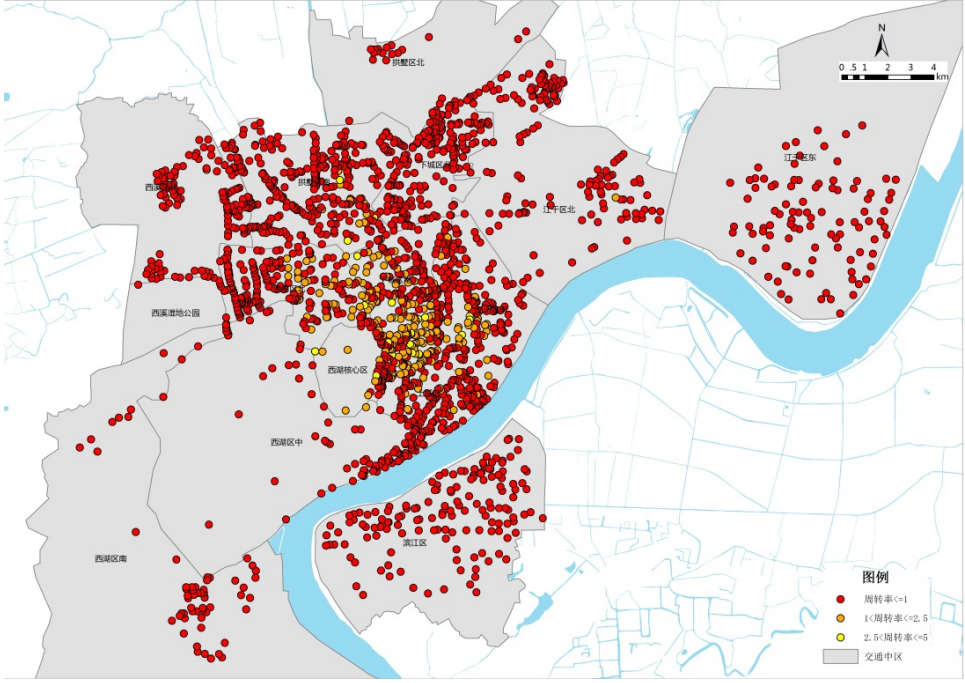
2.Usage Characteristics Analysis

2.4 Turnover rate

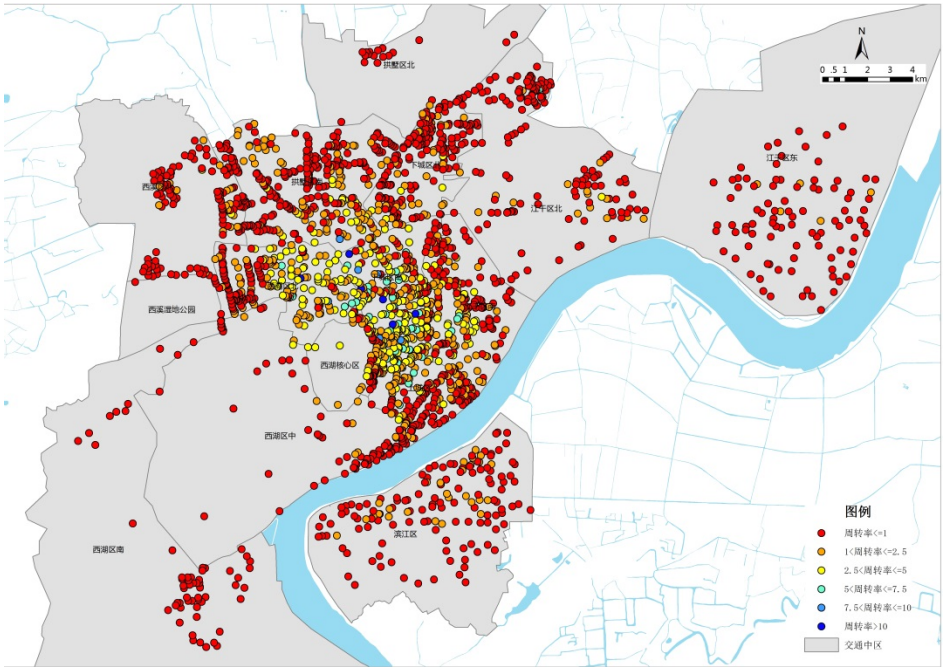
Average turnover rate in the morning and evening peak periods of all stations is 1.09 and 1.07 respectively.

Average turnover rate in the off-peak period of all stations is 0.36, much lower than the two peak periods.

From the distribution pattern, the turnover rate is relatively high in the core area, even in the off-peak periods.



Turnover rate of each station in the off-peak period



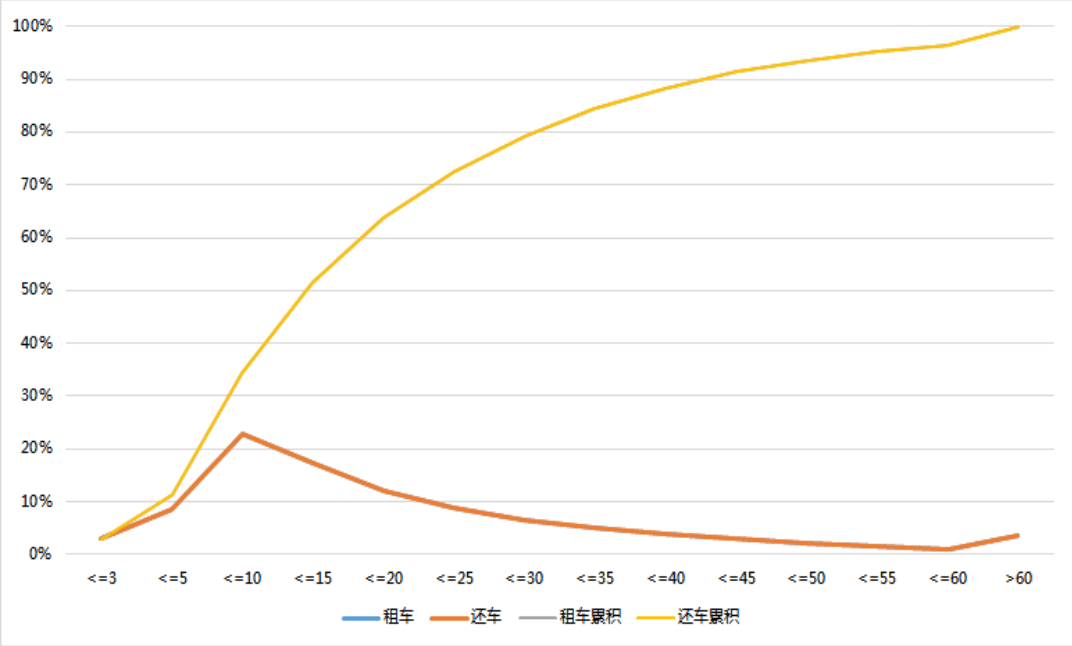
Turnover rate of each station in the morning peak period

2.Usage Characteristics Analysis

2.5 Time-length distribution

Average time length of rentals for all bicycles is 20.39min, equivalent to 4km of riding distance.

More than 50% of rental is less than 15min (3km), while 80% of that is less than 30min(6km) , which make up the bulk of the total.



Distribution of time-length of all bicycles in a weekday (%)

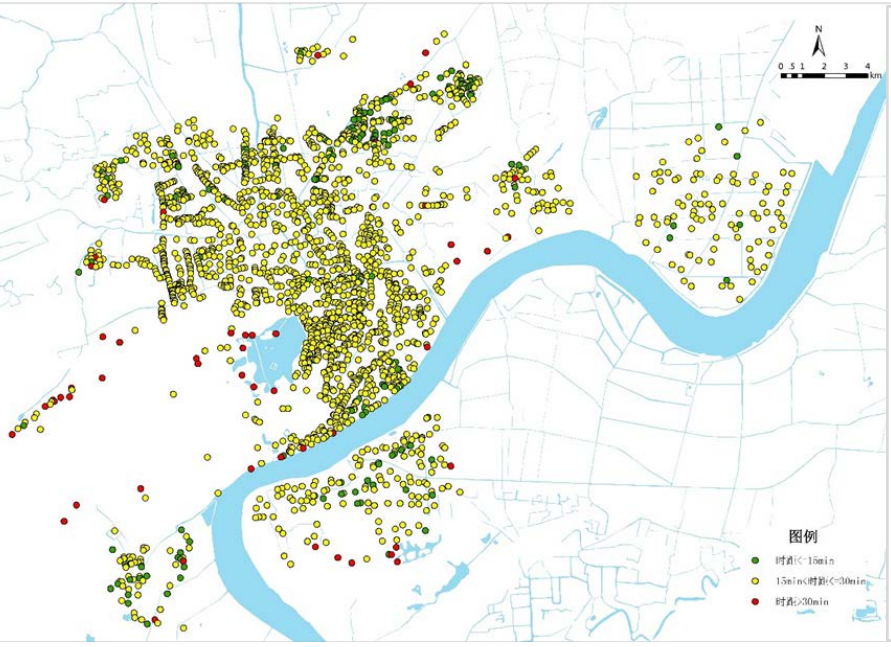
2.Usage Characteristics Analysis

2.5 Time-length distribution

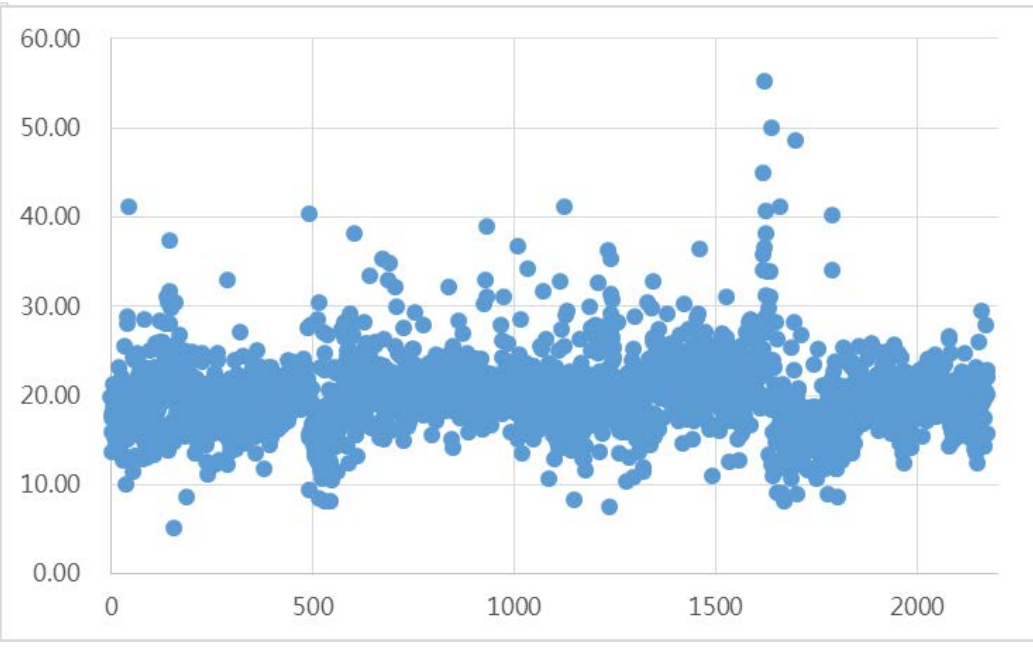
For most stations, the average time-length of rental is between 15 and 30min (excluding 15min).

Stations of more-than-30min distributes in the West Lake and other scenic areas, the least in number. Stations less- than-15min mainly spread in the peripheral functional zones.

Although the land use is more mixed in core area, but due to greater attractiveness of public facilities, time-length and riding distance there is not shorter than other areas.



Spatial distribution of average time-length of all rental and returning bicycles for each station



Scatterplot of average time-length of all rental and returning bicycles for each station (min)

2.Usage Characteristics Analysis

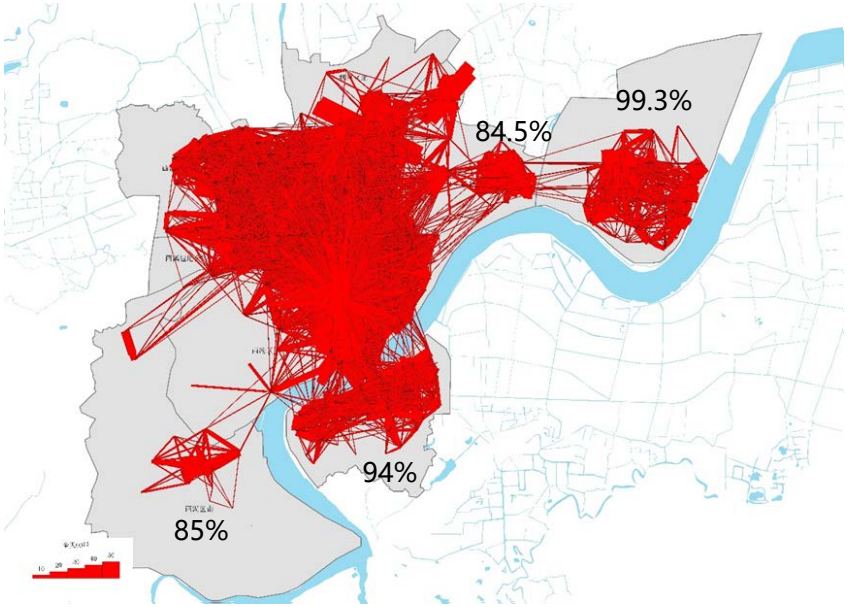
2.6 OD distribution of rental trips

For districts separated far from the center part, internal rentals are dominant.

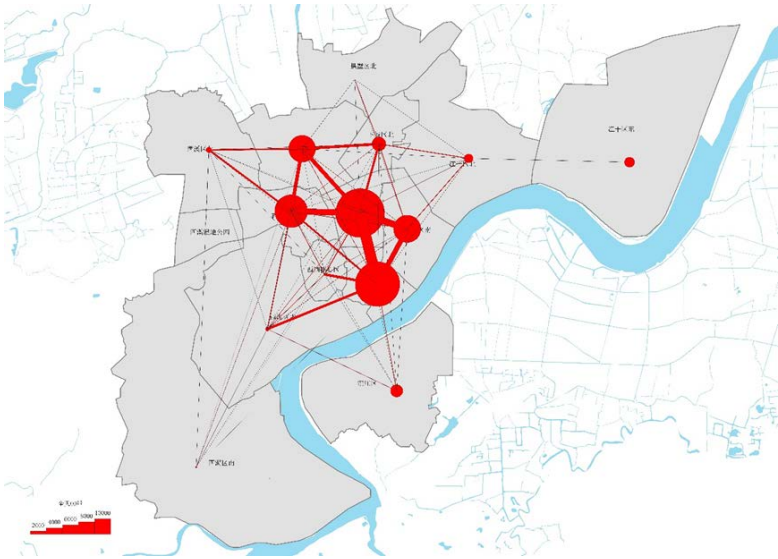
This is close related to the suitable distance of bicycle mode, only 4% of them exceeding 12km. So there is less demands linking Xiasha with other districts.

While for districts in the central part, the links are densely overlapped, forming a continuous range as a whole, although the core area attracts most of the rentals.

The proportion of internal rentals accounts for 60-70% for TAZs in the core area and its neighboring area.



OD distribution of subdivided TAZs in a weekday



OD distribution of TAZs in a weekday

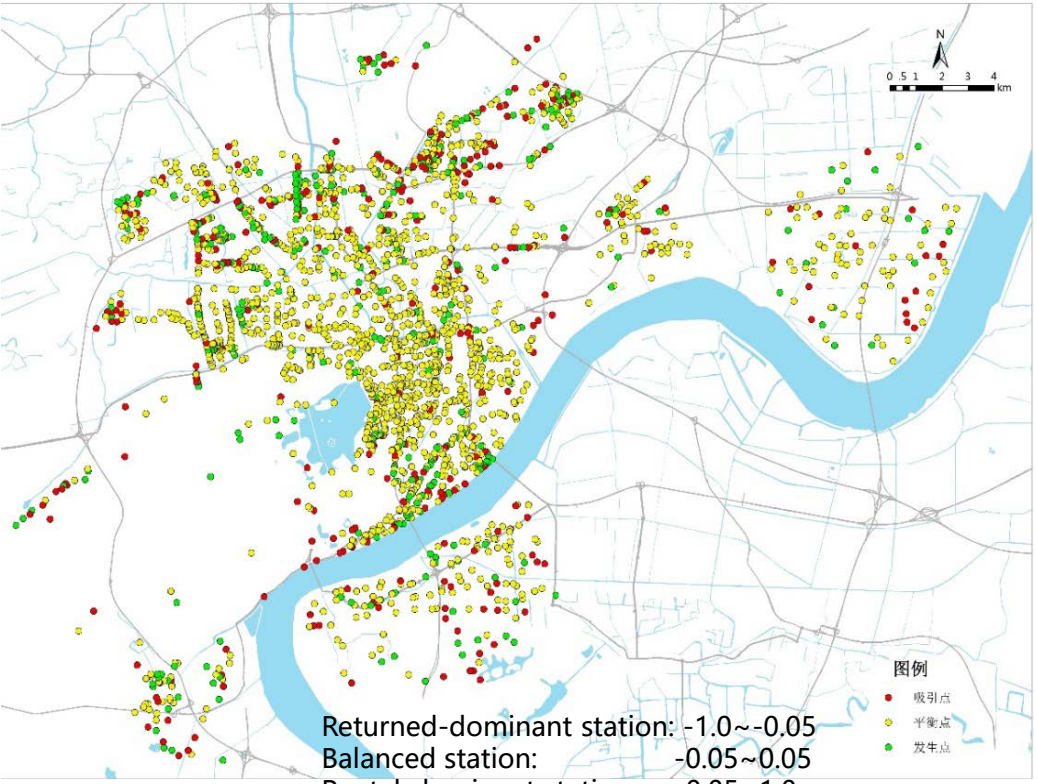
2.Usage Characteristics Analysis

2.7 Rental-return ratio

Rental-return ratio/station=(amount of rental-amount of return)/ (amount of rental+amount of return)

For a certain period of time, it can be regarded as rental-return balance if the ratio of a station falls in the threshold of +/-0.05.

Rental-return ratio of each station in a whole workday



Returned-dominant station: -1.0~-0.05
Balanced station: -0.05~0.05
Rental-dominant station: 0.05~1.0

Most stations is balanced for a whole day in general, especially in the core area.

The rental-dominant and return-dominant stations are mainly in the surrounding areas, showing a pattern with mixed distribution.

2.Usage Characteristics Analysis

2.7 Rental-return ratio

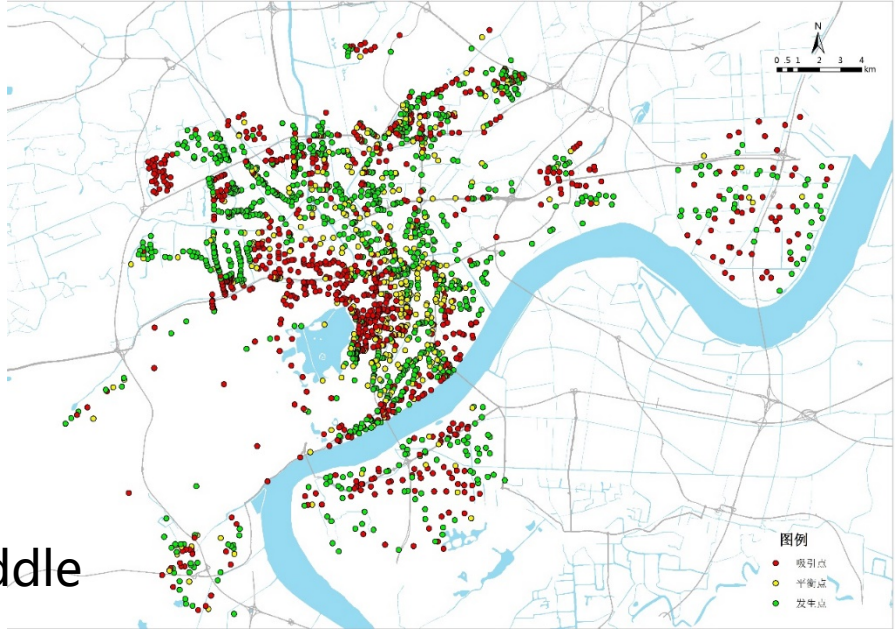
Rental-return ratio of stations in two peak periods presents a circle structure.

Morning peak period

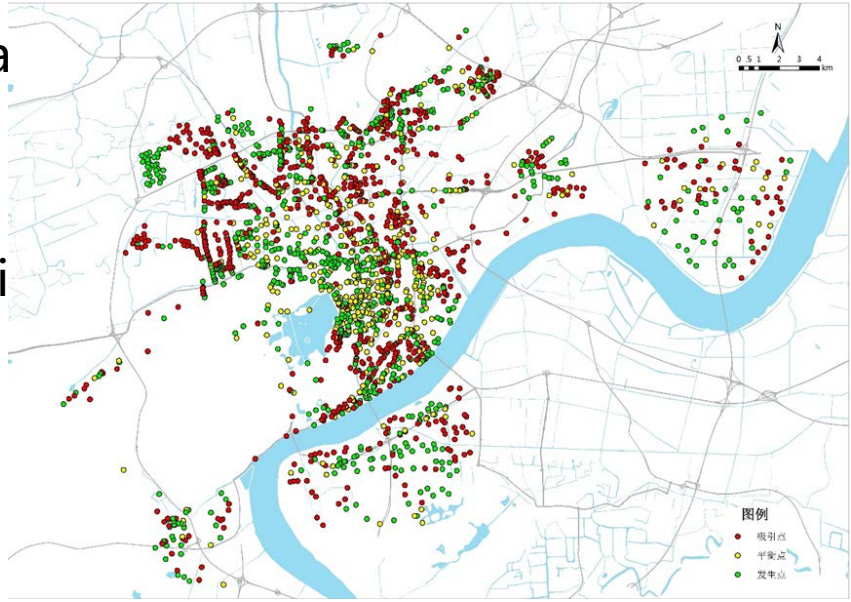
- Balanced stations are mostly in the middle layer of core area;
- Return-dominant ones are in the inner layer of core area and periphery industria lands;
- Rental-dominant ones are in the outer layer of core area and periphery residenti areas.

Evening peak period

The spatial distribution of return-/rental-stations is contrary to that in morning .



Rental-return ratio in the morning peak period(2h) of each station

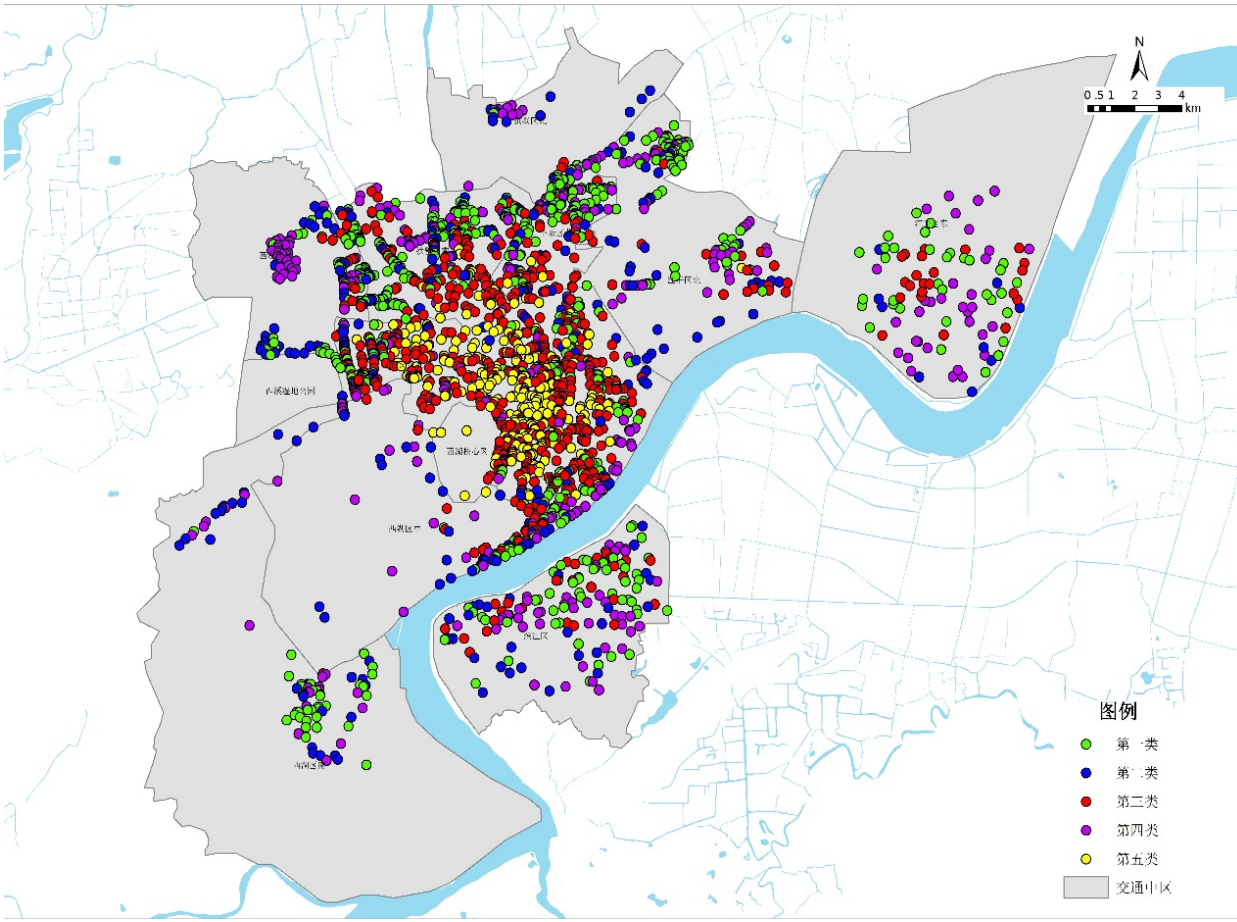


Rental-return ratio in the evening peak period(2h) of each station

3.Relationship between usage and built environment

3.1Cluster analysis

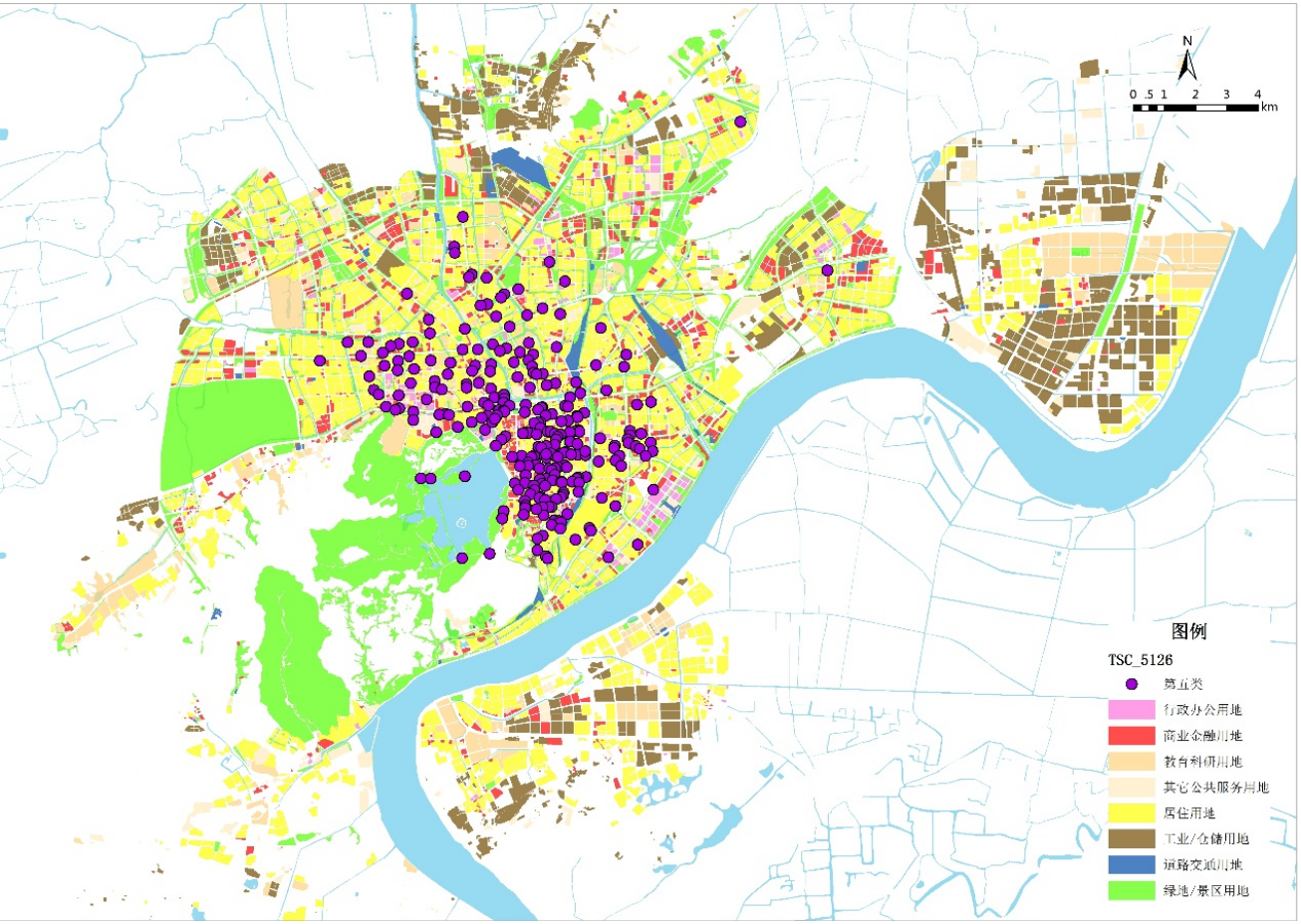
Usage characteristics of different aspects: daily amount of rental, daily average turnover rate, turnover rate of morning peak, peak coefficient, 15min and 30min-length proportion, rental-return ration of morning peak, etc.



5 categories of stations based on the usage characteristics

All stations can be divided into five categories by cluster analysis.

3.Relationship between usage and built environment



Station distribution of Category 5

Category 5:

Best

Highest amount of rental and turnover rate, lower rental-return ratio and peak coefficient.

The proportion within 15min and 30min length of time is relatively low, with greater range of attractiveness.

The stations mainly locate in the core area of Hangzhou.

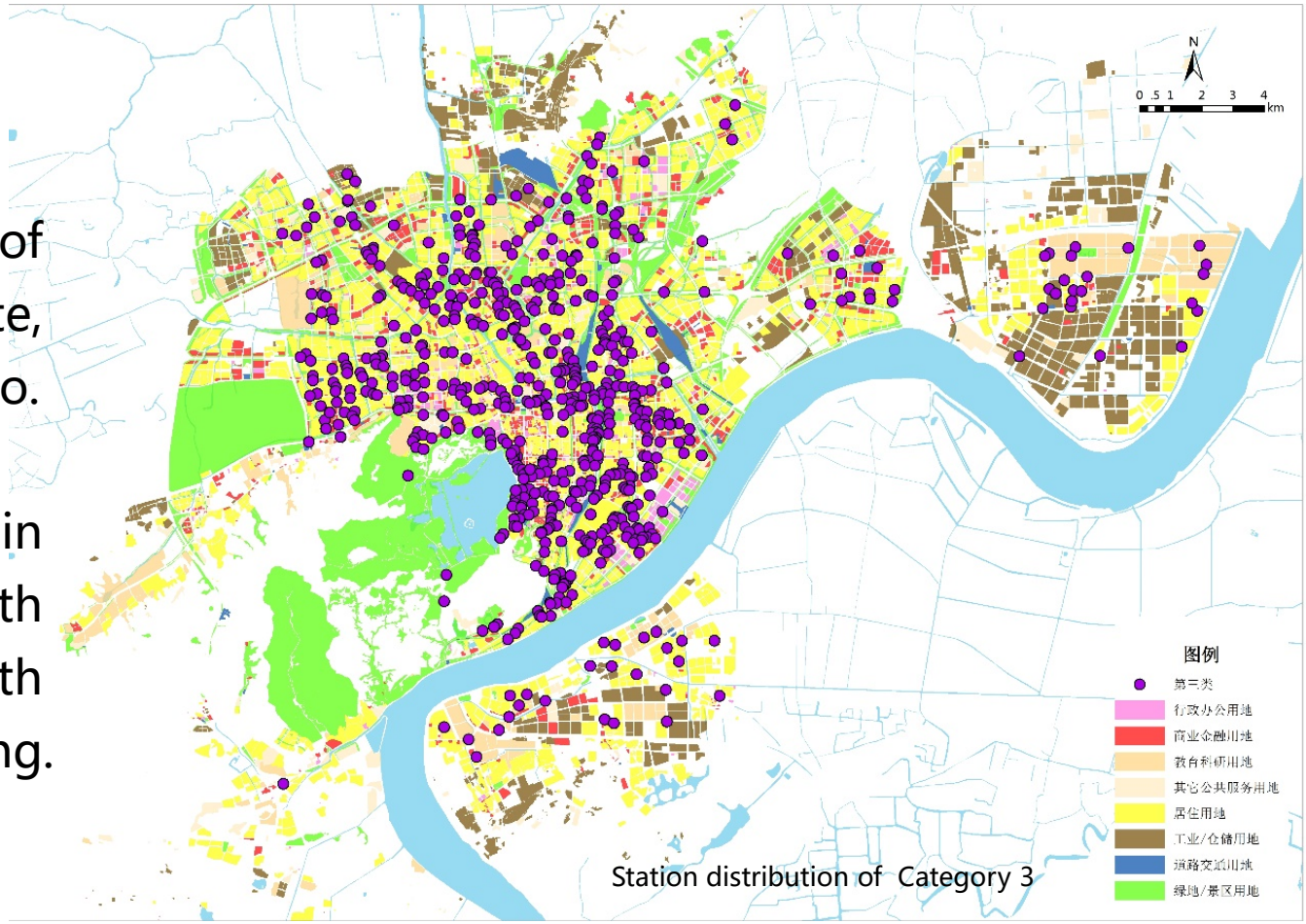
3.Relationship between usage and built environment

Category 3:

Better

Higher amount of rental and turnover rate, lowest rental-return ratio.

The proportion within 15min and 30min length of time is high, with shorter distance of riding.



Station distribution of Category 3

The stations mainly locate in the inner and outer layer of core area, as well as the centers of periphery districts.

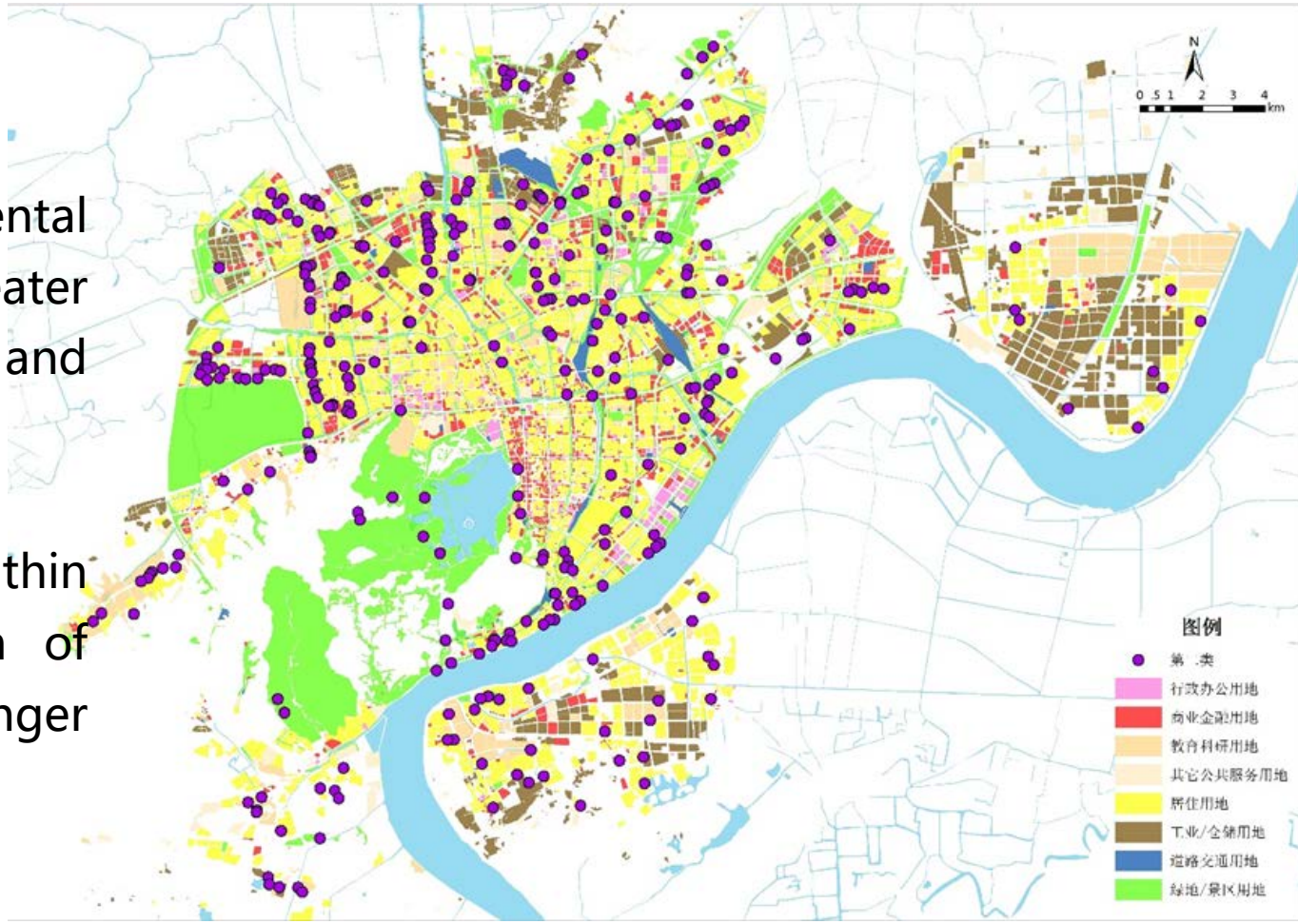
3.Relationship between usage and built environment

Category 2:

Worst

Lower amount of rental and turnover rate, greater rental-return ratio and peak coefficient.

The proportion within 15min /30min length of time is low, with longer distance of riding.



Station distribution of Category 2

The stations mainly locate at the edge of built-up area, and some remote scenic areas.

3.Relationship between usage and built environment

		复合度
7_9Rental-return ratio	Pearson 相关	-.177**
	显著性（双侧）	.000
	N	2168
Proportion within 15min	Pearson 相关	-.063**
	显著性（双侧）	.003
	N	2168
7-9 turnover rate	Pearson 相关	.317**
	显著性（双侧）	.000
	N	2168
Turnover rate/day	Pearson 相关	.279**
	显著性（双侧）	.000
	N	2168

3.2 Correlation analysis

Based on the categories of stations, the relationship between usage characteristics and built environment is investigated with correlation analysis approach.

In the 500m radius around stations:

- Rental-return ratio in peak period is negatively correlated to land use mixture index. **More mixed, more balance.**
- Turnover ratio is positive relevant to the land use mixture index, especially for that in morning peak period. **More mixed, higher efficiency.**

4.Conclusions and suggestions

- Public bicycle is suitable for short-to-medium distance of travel, with more than 50% of rentals within 15min, indicating it is not only a feeder to but also a competitor against PT. – *more efforts should be made to feed rapid transit and provide complementary service.*

- Usage characteristics is compared from district, TAZ and station level, which varies according to multi-scaled built environment factors, such as location, home-work distribution, urban center layout and urban form, etc.

- Land use mixture of neighborhood scale is very helpful to improve the performance of the system, with more balanced and efficient utilization of the system –*optimize land use in order to improve the service level and operating performance of a bicycle-sharing system.*

Thank you for your attention!