Bicycle Parking Demand Model for the Trips Combined of Urban Rail Transit-Bicycle Chain

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ABSTRACT

With China’s large-scale construction of urban rail transit, using bicycle to transfer to rail transit has become a common and efficient travel pattern. It can not only make full use of bicycle’s advantage in short-distance travel, but also make up for the shortcomings of rail transit. In Shanghai, China, the rail-bicycle combined trips are increasing year by year. This will inevitably make corresponding demands on the bicycle parking facilities planning and construction. Therefore, a reasonable model to estimate the bicycle parking demand around the railway station is necessary. In this paper, based on the bicycle parking on-site survey and questionnaire survey around the rail transit stations, the researchers analyzed and summarized the transfer characteristics of the metro-bicycle combined mode, and extracted the major influencing factors, such as passengers entering the station in the morning rush hour, scale of residential area within the bicycle attractive region, the number of bus routes in the visible range of the station. After that, the researchers built the relationship between each factor and the amount of parking, and developed a model by multiple regressions. In support of the trips characterized by subway-bicycle chain, the model could be used to estimate the bicycle parking demand for the urban transit system.

Keywords: Rail transit station, bicycle parking demand, influencing factor, multiple regressions
1. INTRODUCTION

Urban rail transit system is the most important infrastructure in Chinese large cities, which has provided some new trip chains and changed the structure of the travel modes. A large amount of money has been invested on this system and the related service facilities. Beijing, Shanghai, Guangzhou, Nanjing, Tianjin and other cities have already had a rail transit network in operation. However, the network only covers main passenger corridors and has to depend on the feeding of other transport systems. It’s important for the rail system service to find an efficient and economic connection to integrate with it. The data from The Fourth Comprehensive Transport Survey of Shanghai (2009) showed that more than 5% of the metro passengers arrived at the stations by bicycles with an average riding distance of 2.4 kilometers, which was just the reasonable travel distance for bicycle. As a feeding mode should be encouraged, a convenient and adequate bicycle parking space is necessary for improving the accessibility of the rail-bicycle trip mode.

Using bicycle to transfer to rail transit is a common, efficient and green travel pattern. With the expansion of rail network, metro-bicycle combined trips are growing rapidly. In Shanghai, for example, the trips in 2004 were 80 thousand passengers per day, which increased to 150 thousand passengers per day in 2009 (1). In Beijing, the passengers riding to or from the metro stations are about 4 to 9% of the total volume (2). Compared with other countries such as Japan (30%) and the Netherlands (35%) (3), there is still a large space for growth. It means that the bicycle parking facilities are necessary around the railway station. How many parking spaces should be reserved and how many parking lots should be built are important considerations when the rail transit system is planned.

Most of the Chinese cities are lack of the data accumulation and facilities planning experience on the metro-bicycle combined trip mode, although using bicycle as an independent transport tool has had a long history in China. This situation contributes to the low efficiency in the trips combined of urban rail-bicycle chain. For example, the average transfer rate in Shanghai is only 5% (1). Bicycle parking demand around the station is influenced by many complex factors. If some policies are made and the relevant measures are taken in the cities when the influencing factors are well understood, it will be helpful to estimate the bicycle parking demand and to improve parking facilities’ planning and construction. This will also be the core issue to encourage and support the development of the bicycle-rail combined trip mode.

This paper takes Shanghai as a case, which chooses Shiguang Road Station, Yangsi Station, Qu yang Road Station, Zhenping Road Station in the central urban area for the study of the parking demand for the trips combined with metro and bicycle. Shanghai has the largest operating rail transit network in China. There are 11 routes in total, with a length of 420km as of 2010 since the first urban subway operated in 1996. The bicycles still play an important role, sharing 28.6% of trip mode. Based on the parked bicycles volume survey considering time distribution, the riders questionnaire survey in the stations, the passengers volume data survey of the rail system, the surrounding land use survey, and the bus network survey, the researchers use statistical analysis and correlation analysis to find how these factors influence the bicycle parking demand, and then build a bicycle parking demand model. The model could be applied to
estimate the space demand of the bicycle parking and support the plan and design of metro stations.

2. LITERATURE REVIEW

The rail transit-bicycle intermodal study is focused on the following two aspects: One introduced the typical cases and successful experience in the world; the other mainly addressed the metro-bicycle transfer demand analysis, and established the models for demand forecasting.

Successful experience is mainly found in the Netherlands, Japan and Denmark. Rietveld (3) introduced the Dutch experience. It was noted that in the Netherlands bicycle as the access mode played a significant role with a share of 35%, while at the activity end the share was only 10% (1994). Meanwhile, in the access end, bicycle was the main mode within the range 1.2 ~ 3.7km from the station and the range was much larger than the activity end.

Martens (4) discussed the use of bike and ride in three countries with widely different bicycle cultures and infrastructures: the Netherlands, Germany and the UK. The share of the bicycle in access trips had a comparable level in these three countries, but only for train services and other fast public transport. In addition, it was found that the majority of bike-and-ride users’ travel distance and the travel purpose were greatly similar. They often traveled between 2 and 5 km to a railway station. Working and education were the main purpose for trips. In 2007, Martens (5) further introduced the use of bicycles and the measures taken to encourage riding bicycles to transfer train in the past decade in the Netherlands. It indicated that promoting the use of rental bicycles not only led to a reduction in car use, but also growth in train trips and in bicycle use for non-recurrent trips.

Pepogle (6) made investigations in the Netherlands, Denmark and United States. Based on the observation result, the study discussed and compared the benefits and costs between P&R and B&R. The results showed that regardless of cost, space, environmental protection and passengers’ transfer will, bike and ride was more effective. The study also found that land use and the distance from the city center would affect the amount of bicycle parking around the station. In addition, the national bike and ride overview were described, and the reasons for growth were also discussed at last.

In 2010, Pan (7) examined the challenges and opportunities for improving the bicycle-rail connection, using Shanghai as a case study. Based on two questionnaire surveys of rail transit riders, it was noted that bicycle had comparative advantage for a distance of 800-2500 meters. In addition, people residing in areas not adjacent to bus stops preferred to use bicycle. And the development of a bicycle rental system would likely be an effective way to increase bicycle use among rail transit riders.

Some researchers are dedicated to bicycle demand forecasting. For example, Wardman, Tight, and Page (8) identified factors influencing the cycling to work in UK. They developed a mode choice model for the journey to work using both revealed preference data and stated preference data obtained from travel surveys. They then used the model to forecast future trends in urban commuting mode shares and to predict the impacts of different measures to encourage cycling. Improving bicycle facilities and providing financial incentives to bicycle users were among the policies analyzed.
Christopher (9) reviewed past researches on bicycle travel demand forecasting methods. One of the methods was to develop a regression model to estimate the proportion of bicycle users for commuting. Demographics, facilities, and regional characteristics were considered. It was also found that terrain and climate was one of the important factors which had a significance impact on the bicycle travel. At last the researcher suggested that bicycle and pedestrian considerations should be integrated into mainstream transportation models.

Taylor and Mahmassani (10) did some analysis of stated preferences for intermodal bicycle-transit interfaces. A stated-preference survey was conducted using hypothetical scenarios. The researchers then developed a nested logit choice model to find out travelers’ preference. From this model, it was found that three potential factors might have great influence on this choice, which were bicycle lockers, bike lanes and wide curb lanes, 1.6~2.4km bicycle access distance to transit. This survey result could provide a reference for bicycle parking planning.

In China, most cities are lack of the practical experience on rail-bicycle combined trip mode. The researchers devoted themselves to the bike and ride demand forecasting study. There are mainly three methods: (a) Demand forecasting method based on bicycle parking features. Kuang (11) divided bicycle parking lot into three types: only for the railway services, close to public transport hubs, and next to large supermarkets. Through investigation, the researcher figured out the bicycle parking hourly-variation characteristics, obtained some indicators such as transfer rate, daily parking turnover rate, etc. In combination with passenger flow volume, the researcher built bicycle parking demand model. (b) Discrete choice model. Mi (12) described the factors influencing individuals’ choice of bicycle for rail station access and egress. In order to forecast the parking demand, a suitable zone of the railway station was delineated firstly. Then, the researcher chose discrete choice model to obtain the bicycle transfer selective probability, multiplied by bicycle trips in the morning peak, thus the bicycle parking demand could be predicted. (c) Parking demand forecasting model based on attraction. Chen (13) used gravity model to forecast parking demand. He thought that the amount of bicycle parking within the residential area was related with demographic characteristics, rail transit service and bike lane connecting residential area and the railway station.

From the above literature review, it can be learned that great achievements have been made on rail-bicycle intermodal transit in some European countries and in Japan. The policies and measures of these countries are worthy to be learned to encourage the combination of urban metro and bicycle. In China, using bicycle to transfer to rail transit is common and economic. However, although there have already been some methods to estimate bicycle parking demand around the station, the theory is still not mature yet. Further theoretical and empirical studies are needed.

3. SURVEY METHODOLOGY AND DATA COLLECTION

As of June 30, 2010, rail transit network in Shanghai included 11 routes, reached 420 kilometers, plus a high-speed Maglev route serving the Pudong International Airport. The network structure has been basically formed. In particular, the extension of Lines 1, 2, 3 and the completion of Lines 5, 7, 8, 9, 11 make the metro stretch outside the city, and create a link between central city and suburban areas. In this paper, the researchers select Line 4 and Line8 as the study object,
which are crossing a wide range of residential areas. Line 4 is a ring line, located within the inner ring in Shanghai; Line 8 is overall in north-south direction. In the North it starts from Shiguang Road Station, after crossing the city center, it extends to the Minhang Development Area in the South. The stations selected from Line 4 and Line 8 and the land use along these two lines are showed in Figure 1.

![FIGURE 1 Stations and land use along Line 4 and Line 8 in Shanghai](image)

In this study, the researchers did some surveys as follows: the parked bicycles volume survey considering time distribution, riders’ questionnaire survey in the stations, the passengers volume data survey of the rail system, the land use survey around the station, and the bus network survey. Through these surveys, the researchers extracted the main factors influencing the amount of bicycle parking, and further described the quantitative relationship between these factors and bicycle parking demand.

Bicycle parking status around the stations can be summarized as follows: (a) A serious shortage of Bicycle parking space with parking racks in short supply. The total parking area of Line 8 is approximately 7,500 m², which meets only half of the Standards for Design of Traffic and Setting Parking Lots (Garages) in Architectural Engineering in Shanghai. Parking supply and demand ratio of Line 8 is 1:1.3. (b) Parking mismanagement. Parking area around the station is more dispersed and difficult to manage; nearly 70% unattended parking area leads to security risk (14). Bicycle parking volume, parking forms, parking charges of Line 8 are showed in Table 1.
TABLE 1 Bicycle Parking Status around Line 8 Stations

<table>
<thead>
<tr>
<th>Station</th>
<th>Maximum parking volume</th>
<th>Supply and demand ratio</th>
<th>Parking forms</th>
<th>Parking charges</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Line mark</td>
<td>Parking racks</td>
</tr>
<tr>
<td>Aerospace Museum</td>
<td>487</td>
<td>1.3</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Lianhang Road</td>
<td>198</td>
<td>1.5</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Jiangyue Road</td>
<td>174</td>
<td>1.7</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Pujiang Town</td>
<td>185</td>
<td>1.4</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Luheng Road</td>
<td>94</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Lingzhao Xincun</td>
<td>33</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Yangsi</td>
<td>297</td>
<td>1.5</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Chengshan Road</td>
<td>207</td>
<td>1.6</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Yaohua Road</td>
<td>104</td>
<td>1.1</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>South Xizang Road</td>
<td>175</td>
<td>1.2</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Lujibang Road</td>
<td>107</td>
<td>0.9</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Laoximeng</td>
<td>160</td>
<td>1.2</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Dashijie</td>
<td>27</td>
<td>1.4</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>People's Square</td>
<td>64</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Qufu Road</td>
<td>28</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Zhongxing Road</td>
<td>57</td>
<td>0.4</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>North Xizang Road</td>
<td>262</td>
<td>2.8</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Hongkou Football Stadium</td>
<td>137</td>
<td>2.0</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Quyang Road</td>
<td>199</td>
<td>1.7</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Siping Road</td>
<td>179</td>
<td>0.6</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Anshan Xincun</td>
<td>77</td>
<td>2.2</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Jiangpu Road</td>
<td>308</td>
<td>1.1</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Huangxing Road</td>
<td>351</td>
<td>1.1</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Middle Yanji Road</td>
<td>226</td>
<td>1.7</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Huangxing Park</td>
<td>147</td>
<td>0.6</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Xiangyi Road</td>
<td>132</td>
<td>1.2</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Nenjiang Road</td>
<td>236</td>
<td>1.0</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Shiguang Road</td>
<td>639</td>
<td>1.5</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Bicycle parking volume survey and hourly variation characteristics

In order to get the maximum parking volume at the railway station, the researchers selected 4 typical stations to take a continuous observation from 7:00 a.m. to 7:00 p.m. They are Shiguang Road Station, Quyang Road Station, Yangsi Station and Zhenping Road Station. There are large residential communities near these stations. Quyang Road Station and Zhenping Road Station are located within the inner ring. Shiguang Road Station and Yangsi Station are respectively the first and the last stop. The researchers took 1 hour as the survey interval and continuously observed bicycle arrival and departure within 50m from the entrance and exit around the stations, and recorded the bicycle parking number each hour. The results are showed in Figure 2.
FIGURE 2 Bicycle parking volume curves at four different stations

From the bicycle parking observations, the researchers found that parked bicycles were concentrated in the morning rush hour of 7:00 ~ 9:00, while the maximum parking volume appeared in different periods, Shiguang Road Station and Quyang Road Station was in 9:00 ~ 10:00, Yangsi Station and Zhenping Road Station was in 13:00 to 14:00. The researchers tried to establish the relationship between morning peak-hour parking number and the maximum parking number, which fit with a linear function, $R^2 = 0.9708$, and the result is showed in Figure 3. Since a good linear relationship exists between these two variables, so in the future survey, the researchers only need to investigate the amount of parking in the morning rush hour of 7:00~9:00, and then use them to calculate the maximum number.

FIGURE 3 Relationship between peak-hour parking number and maximum number
Riders’ questionnaire survey

Riders’ questionnaire survey was based on the parked bicycles volume survey. The researchers chose the rail transit stations which have more rail-bicycle transfer amount, used the revealed preference survey and the stated preference survey to obtain transfer travelers’ individual characteristics, trip characteristics and transfer will. Questionnaire consisted of three parts: The first part was individuals’ information, including gender, age, monthly incomes, etc., and these questions were asked in order to figure out which kind of people use bicycle to transfer to rail transit. In the second part, the researchers tried to obtain some trip characteristics such as travelers’ trip purpose, riding time and parking duration. Transfer wills were asked in the third part. Through inquiry, how riders’ features and convenience of service influence the parking demand would be found out.

Surrounding land use survey and bus network survey.

The data from The Fourth Comprehensive Transport Survey of Shanghai (2009) showed that the average riding distance at both ends of the station was 2.4 kilometers. Using the railway station as the center and extending 2.4km along the road into the polygon, the space enclosed by such boundary is called bicycle attractive region of the railway station. The researchers counted the scale of different land areas within the attractive region and the number of bus routes in the passengers’ visible range (50–80m). The passenger volume data were collected by Automatic Fare Collection System at different stations and counted in hours.

4. PARKING DEMAND MODEL

4.1 Analysis of influencing factors

In order to build the bicycle parking demand model, the relationship between parking demand and each influencing factor should be found out. These factor(s) which have a significant influence on the model and can be quantified should be selected. In this study, the researchers find that different factors have different influences on the parking demand, such as the volume of passengers passing in and out, the nature of surrounding land, the number of bus routes, bicycle parking facilities and services. Therefore, these factors need to be emphasized for a further analysis, and the appropriate ones should be selected as model variables to the developed bicycle parking demand model.

Passenger volume of rail transit station

Analysis of the passenger factor comes from two aspects: First is the transfer characteristic of the travelers. The researchers used RP survey with a total of 400 questionnaires, and 351 copies were collected as valid. In terms of individual characteristics, some results are drawn: the proportion of men (64%) is higher than that of women (36%), the travelers aged from 18 to 40 years old are the main transfer group accounting for 67.7%, whose monthly incomes concentrate in a range from 3,000 to 5,000 Yuan. Transfer characteristics show that commuting is the main trip purpose of the travelers who use bicycle to transfer to rail transit. The proportion of working and education is 91.1%, and entertainment, visiting friends and business travel accounts for 2.1%,
2.3% and 4.5% respectively.

Second, the study points out the relationship between the passengers’ volume and the parked bicycles’ volume. The researchers took a 12 hours continuous observation at 4 typical stations to obtain hourly variation of these two factors. Results are showed in Figure 4. The researchers find that the bicycle parking characteristics and the passengers’ volume characteristics show similar trends, and these two both have a significant tidal nature. The further study also finds that the amount of bicycle parked has a linear correlation with the volume of passengers passing in, $R^2 = 0.8791$. Considering that there is also a linear relationship between the morning-peak parking number and the maximum parking number, the researchers choose the passengers getting into the station in the morning rush hour of 7:00~9:00 as an independent variable in this study in order to build the relationship with the parking demand.

![Hourly variation at Yangsi Station](image1)

![Hourly variation at Shiguang Rd. Station](image2)

![Hourly variation at Quyang Rd. Station](image3)

![Hourly variation at Zhenping Rd. Satation](image4)

**FIGURE 4 Hourly variations at four different stations**

**Land use around the station**

Demarcating the attractive range of railway station can be used to study how different land uses may impact on bicycle parking demand. Within different range, the proportion of bicycle-rail trip mode will vary greatly. In Shanghai, the proportion is only 3% within 0.5km; while it is up to 11% in 1.5~2.5km range (14), which is the largest proportion. In this paper, the researchers also found similar results. Based on the survey of travels’ transfer characteristics, the average riding
time from home to railway station is 11 minutes, when the bicycle travel speed is 150m/min and
the distance is about 1600m. 85% of travelers’ riding time is 16 minutes, and the distance is up to
2400m. In this study, the researchers use 2400m as a feeder distance.

There are several different kinds of land within bicycle attractive region. The researchers
first divided the surrounding land into 7 categories: residential land, industrial land, commercial
land, farm land, institutional land, transportation land and green land, and then counted the area
of different land. After that, the researchers discussed the relationship between each kind of land
area and the amount of bicycle parking, using Spearman Analysis to study the correlation. The
results are showed in Table 2. It indicates that bicycle parking demand has a significant
correlation with the scale of residential area with a correlation coefficient of 0.860. With
residential land as a trip generation source, a large number of travelers will choose rail transit for
trip, and the purpose of travelers who use bicycle to transfer rail transit is mainly for commuting.
So in the morning and evening peak, bicycle is one of the main modes for access and egress.
This trip mode well makes a link between home and the railway station. And it also explains the
reason why the amount of bicycle parking has a strong correlation with residential area.

| TABLE 2 Correlations between Parking Demand and Different Land Uses |
|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| Parking Demand   | Residential      | Industrial       | Commercial      | Farmland         | Institutional    | Transportation   | Greenland        |
| Correlation Coefficient | .860**          | .352**          | .120            | .034             | .011            | .166            | .432**          |
| Sig. (2-tailed) | .000             | .009            | .388            | .810             | .935            | .230            | .001            |
| N            | 54               | 54              | 54              | 54               | 54              | 54              | 54              |

**. Correlation is significant at the 0.01 level (2-tailed).

Convenience of Bus service

The bus network and the number of bus routes will also affect the bicycle parking demand.
According to the relationship between the bus route and the rail transit route, the buses will be
divided into two kinds: the cooperative one and the competitive one. The route of cooperative
buses shows a larger angle or is vertical to the rail transit, it can transfer some passengers to the
rail system, but weaken the metro-bicycle transfer amount. The competitive buses and the rail
transit move towards the same direction, it can be another option for passengers to travel. When
the surface bus provides better service and higher reliability, it may attract parts of rail-bicycle
passengers to use buses. In short, both cooperative and competitive buses have the negative
impact on the amount of transfer. In other words, more bus routes around the station, less the
amount of cycling transfer feeder.

In this study, the results from travelers’ transfer will survey show that 85.2% of the people
believe that if there are convenient and reliable bus routes around the railway station, they will
consider selecting bus to transfer to the rail transit. In this group, 56.5% of them want to walk in
only 1 min or less than 1 min from the bus station to the rail transit station. This distance is just
the visible range (50–80m), which means that one can easily find a bus stop when getting out of
the station. The researchers tried to build a relationship between the amount of bicycle parking
and the number of bus routes in the visible range. It is found that they are showing a strong
negative correlation, and the correlation coefficient is -0.694.
Bicycle parking facilities and services
Walking distance is an important indicator to measure parking services. However, as this investigation is confined to a parking area within 50m of the station entrances and exits, walking distance has little effect on the amount of bicycle parking. So this factor would not be considered in this study. Different parking forms and parking charges may have different impacts on the amount of bicycle parking. Based on the parking survey along the Line 4 and Line 8, there are three kinds of parking forms: line mark, bicycle racks, and open space. The parking lot is divided into the paid and free ones. The researchers took these two factors as control variables, and tried to find out whether they have a significant impact on the amount of bicycle parking. Using multivariate analysis of variance, the results are showed in Table 3.

TABLE 3 Tests of Between-Subjects Effects

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
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<td>154743.915</td>
<td>1</td>
<td>154743.915</td>
<td>6.696</td>
<td>.013</td>
</tr>
<tr>
<td>Parking forms</td>
<td>5302.623</td>
<td>2</td>
<td>2651.312</td>
<td>.115</td>
<td>.892</td>
</tr>
<tr>
<td>Charge forms * Parking forms</td>
<td>51450.134</td>
<td>2</td>
<td>25725.067</td>
<td>1.113</td>
<td>.337</td>
</tr>
<tr>
<td>Error</td>
<td>1109261.675</td>
<td>48</td>
<td>23109.618</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3729120.000</td>
<td>54</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From the table above, some results can be drawn: the concomitant probability of charge forms as independent role is 0.013<0.05, It indicates that different parking charges have a significant different impact on the bicycle parking demand. From the mean point of view, the number of bicycles parked in the paid parking lot (269 bicycles) is more than that in the free parking lot (148 bicycles), which shows that people pay more attention to the safety and want to park bicycles in the paid parking lot. However, the concomitant probability of parking forms as independent role is 0.892>0.05, it means that different parking forms have no significant differences. At the same time, the concomitant probability of these two factors’ joint action is 0.337. The impact on the amount of bicycle parking is not significant, either.

4.2 Bicycle parking demand modeling
In this study, the researchers use regression analysis to build a multiple linear regression model to estimate the bicycle parking demand around the railway station. The purpose of using regression analysis is to identify independent variables which are relevant with the dependent variable, so the factors must have an important impact on the dependent variable and be quantifiable. Some factors, such as road and traffic conditions, bicycle theft, parking facilities and service, terrain and climate, do not have obvious influence or are difficult to be quantified. Therefore, based on the analysis mentioned above, this study selected the passengers volume in the morning rush hour, the scale of residential area within the bicycle attractive region of the station, the number of bus routes in the passengers’ visible range, as independent variables, and the amount of bicycle parking as the dependent variable. Using Line 4 and Line 8, 53 railway
stations data as the sample to build the multiple regression model, the equation is as follows:

\[ Y = 40.290x_1 + 1.618x_2 - 1.931x_3 - 4.914 \]  \hspace{1cm} (I)

Where \( x_1 \) is passengers volume getting into the station in the morning rush hour of 7:00–9:00 (million person-trips); \( x_2 \) is the scale of residential area within the bicycle attractive region of the station (ha.); \( x_3 \) is the number of bus routes in the passengers’ visible range.

The researchers did some analysis to test the regression model. First, the regression coefficients of the model were tested. The results are showed in Table 4. It indicates that these three independent variables coefficient signs have the same positive and negative effects as the results discussed at chapter 4.1, so the regression coefficient of this mode is reasonable.

Standardized coefficient of each independent variable is used to check the impact on the dependent variable. The higher the value, the greater the impacts on parking demand. In this study, the coefficient of the residential land area is 0.823. It indicates that the predictive value of this variable has the greatest influence. In collinearity test, the variance inflation factors (VIF) are less than 10. It means that the collinearity problems are in the acceptable range. In other words, there are almost no collinearity problems in this model.

<table>
<thead>
<tr>
<th>TABLE 4 Coefficients and Collinearity Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
</tr>
<tr>
<td>-----------------------------------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>(Constant)</td>
</tr>
<tr>
<td>Passenger flow volume in peak-hour</td>
</tr>
<tr>
<td>Area of residential land</td>
</tr>
<tr>
<td>Number of bus lines</td>
</tr>
</tbody>
</table>

Second, the researchers did some analysis of variance. The results are showed in Table 5. The statistics \( F = 51.518 \), greater than the critical value 2.41 (the level of significance is 0.05), means that it rejects the assumption that the regression coefficient is zero. At the same time, accompanied by the probability of less than 0.001\((p<0.001)\), it shows that multiple independent variables and the dependent variable have the linear regression relationship, and the three independent variables combined have a significant contribution to the bicycle parking demand forecasting. Model R-squared is 0.756, adjusted R-squared is 0.741, and it indicates that the sample fits well.

<table>
<thead>
<tr>
<th>TABLE 5 ANOVA(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
</tr>
<tr>
<td>Regression</td>
</tr>
<tr>
<td>Residual</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

\(^a\) Predictors: (Constant) , \( x_1 \), \( x_2 \), \( x_3 \)  
\(^b\) Dependent Variable: \( Y \)
5. CONCLUSIONS

The study is based on the bicycle parking on-site survey and the questionnaire surveys around the rail transit stations in Shanghai urban areas. The researchers sum up the bicycle travelers’ transfer characteristics, extract the major factors influencing the trips combined of urban rail-bicycle chain and analyze the relationships between each factor and the parking demand. Finally, the bicycle parking demand model is developed. The main conclusions are as follows:

First, metro-bicycle combined mode is common in China. It is and will be an importation trip pattern, especially in the residence area of the mage-cities. The trip purpose with the transfer between the rail and the bicycle is mainly for commuting, when travelers’ riding time by the bicycles is less than 20 minutes, and the transfer rate in the morning peak is about 5% at the survey stations.

Second, among the bicycle parking demand influencing factors, the passengers volume of the rail transit system in the morning rush hour, the scale of the residential area within the bicycle attractive range of the station, the number of bus routes in the passengers’ visible range, have a significant impact on the bicycle parking demand. These three factors all present a linear correlation with the amount of bicycle parking, and they are all selected as the independent variables in the model. The researchers build the multiple linear regression model. The model has a good explanatory ability. It could be used to estimate the bicycle parking demand and support the bicycle parking facilities planning and construction of the urban rail transit system.

Finally, some non-quantifiable factors are not addressed in the regression model, such as parking forms, parking charges and so on. They will certainly have an impact on the bicycle parking demand, but they are difficult to be quantified based on the data collected in the paper. In this study, they are only described qualitatively. For example, the results from the multi-factor analysis of variance show that different forms of parking charges lead to different parking demand. The amount in the paid parking lot is more than the amount in the free parking lot. Therefore, these factors should be given adequate attention in parking lot planning and management.

REFERENCE


[10] Taylor, D. and Mahmassani, H. *Analysis of stated preferences for intermodal bicycle-transit interfaces,* Transportation Research Record 1556, 86-95


