Research on Cycling Distance Based on Cyclist Perception

Ruiyan Li¹, Shujuan Ji¹* and Yuanqing Wang¹
¹ Highway College, Chang’an University, Xi’an, Shaanxi, 710064, China
*Corresponding author’s e-mail: xiaojichd@163.com

Abstract. Traffic congestion and environmental pollution have become more serious problems in the urban development process, and the choice of bicycle travel can effectively improve these problems. Firstly, this paper adopts stated preference (SP) survey, taking the bicycle survey in Xi’an as a data sample to analyse the influencing factors of cyclists’ path choice based on understanding the cyclist’s perception. It is found that mixed traffic is the main factor affecting the proportion of bicycle trips. Then, using revealed preference (RP) survey obtains the OD and path of cyclists and records bicycle facilities settings along the way. Based on the above conclusions, a multivariate linear regression model is established for the logarithmic value of the actual cycling distance and the cycling distance of various bicycle facilities. It is found that adding 1 km of cycling lanes separated with obstacles, cycling lanes separated with dashes adjacent to bus lanes and cycling lanes without bicycle facilities, cyclists are willing to increase the cycling distance by 1.968 km, 1.433 km and 1.405 km.

1. Introduction
In recent years, the problems of traffic congestion and environmental pollution have become more serious. In 2018, 61% of 361 cities in China were in a state of easing at the peak of commuting, and 13% of the cities were in congestion. (Amap, etc., 2019) The transportation sector contributes 27% of energy-related CO2 emissions, which is considered to be a key issue affecting global climate change. (U.S. Energy Information Administration, 2012) with the concept of “public transit priority” and “low-carbon travel” being widely recognized by the public, bicycles provide more convenient, economical and healthy traffic service for travelers, which plays an important role in reducing these problems [1]. However, problems such as unclear signs of cycling lanes and serious mixed traffic affect the safety of cyclists. Therefore, by studying the influence of cycling environment factors on the individual perception of the rider, it is reasonable to arrange bicycle facilities, thereby increasing the proportion of trip by bicycle.

2. Literature review

2.1. Concept of perception
Perception is the process of organizing, identifying, and understanding sensory information in order to present and understand our environment [2]. Traditional perceptions consider that the perception process accepts sensory information passively. With the deepening of research, perception is defined as a process of active learning, remembering and acquiring experience [3].
2.2. Concept and travel behavior
Through perception, people will change their behavior. The understanding of perception in ecology originated from James J. Gibson's early research on the relationship between perception and action, which considered perception as an essential characteristic of action. Without perception, action has no direction, and perception will be meaningless [4]. Human movement is based on continuous perception. The most popular theory of the relationship between perception and motion is that the perceptual and motor regions of the human brain have certain connections [5].

2.3. Perceived personal attributes
Different personal attributes have different effects on perception.

Gender has no significant influence on whether to choose bicycle travel or not [6-7]. Middle-income people prefer to choose green transportation such as bicycles, walking and public transportation [6]. Less experienced or inexperienced people prefer to ride on dedicated cycling lanes, while experienced cyclists do not attach particular importance to cycling lanes separated with obstacles [8].

2.4. Perceived environmental factors
Perceived environmental factors mainly include two indicators of comfort and safety.

By studying the geometry conditions of bicycles, physical environment status and traffic circumstance, the comfort of perception is evaluated [9-10]. Pavement quality and materials affect cycling comfort. [11-12]. Traffic flow and motor vehicle speed have an obvious influence on the safety perception of cyclists [13-14]. By studying the impact of perceived safety on cycling, it is pointed out that improving the safety performance of bicycle facilities can greatly promote the use of bicycles [14].

3. Data collection and processing

3.1. Data collection method
Taking the Xi'an bicycle travel survey as a data sample, this paper conducts data collection through a questionnaire survey. Using SP method, the personal attributes, bicycle types, cycling paths, travel purposes, reasons for choosing cycling paths, etc. of cyclists were collected to obtain the cyclist's perception factors. The cyclist's cycling OD and path are collected using the RP method, then the cycling distance and the distance of various bicycle facilities along the way were recorded.

Xi'an residents bicycle trip survey divides the whole city into 45 traffic zones, as shown in Figure 1. The sample selection takes population density and area factors in seven administrative districts of Xi'an into account. In each district, this survey chooses residential areas, schools, public bicycle spots, shopping malls and parks. Surveys in residential areas are for cyclists who use private bicycles and electric bicycles. At the public bicycle leased points, the survey is for cyclists who use public bicycles. Schools, shopping malls and parks asked non-public bicycle cyclists to be surveyed.

Figure 1. Scope of survey. Figure 2. Path diagram on GIS.
3.2. Data processing method

SP survey data are input by Epidata3.0 and exported by Excel. This paper uses general statistical tools to analyse bicycle facilities used by cyclists and considerations of path selection. After screening the samples, 2,593 valid questionnaires were obtained.

RP survey data are processed by GIS platform. Based on the map of Xi'an City, this paper provides the origin and the destination according to the questionnaire participants. According to the road segments provided by the riders, they can find and complete a complete travel path on the base map. When the road segment is incomplete, the vacant road segment is connected by the shortest path. When there is no road segment at all, the shortest path assignment is adopted directly. The cycling distance of each path is measured by GIS, then the field use survey records the distances of various types of bicycle facilities along the way. As the total amount of this questionnaire survey is too large, this paper selects the 30 and 31 zones to analyze the results of the survey. A total of 56 data were recorded. The path drawn on the GIS platform is shown in Figure 2.

4. Methods and results

4.1. Path selection factor

After classifying and describing 2593 samples, the following conclusions are drawn:

- In addition to the two indicators of short distance and less time, smooth, safe and road leveling are three factors that people care about.
- The phenomenon of mixed traffic is very common, and it is difficult to guarantee the safety of cycling. Cyclists are more likely to choose cycling lanes separated with obstacles, followed by cycling lanes separated with dashes. Cyclists are less acceptable to pass uphill sections, pedestrian crossings and overpasses.
- Regardless of the individual attribute analysis from gender, personal income, occupation, education, and cycling satisfaction, cyclists tend to choose cycling lanes separated with obstacles or cycling lanes separated with dashes, and have a low tolerance for mixed traffic.

To sum up, only by giving priority to solving the problem of non-mixing and improving bicycle facilities, can we better improve cycling environment, increase cycling distance and sharing rate.

4.2. Correlation test

Correlation analysis is a statistical analysis method that examines the linear relationship between variables. This section selects the actual cycling distance (SJ) as the dependent variable and checks the correlation with the distance travelled at different bicycle facilities. Bicycle facilities include cycling lanes separated with obstacles (WLGL), cycling lanes separated with vegetation (ZBGL), cycling lanes separated with dashes (HX), cycling lanes separated with dashes adjacent to bus lanes (GJHX) and cycling lanes without bicycle facilities (JFHX).

Inspections show that at a significant level of 0.01, the actual cycling distance is significantly related to the distance traveled on cycling lanes separated with obstacles, cycling lanes separated with dashes adjacent to bus lanes (GJHX) and cycling lanes without bicycle facilities (JFHX).

| Table 1. Correlation analysis between dependent variable and independent variable. |
|----------------------------------------|--------|--------|--------|--------|--------|
| SJ          | WLGL   | ZBGL   | HX     | GJHX   | JFHX   |
| SJ          | 1      | 0.551**| 0.231  | 0.262  | 0.521**| 0.406**|
| WLGL        | 0.551**| 1      | 0.118  | 0.237  | 0.016  | 0.11   |
| ZBGL        | 0.231  | 0.118  | 1      | 0.073  | -0.198 | -0.108 |
| HX          | 0.262  | 0.237  | 0.073  | 1      | -0.146 | -0.205 |
| GJHX        | 0.521**| 0.016  | -0.198 | -0.146 | 1      | -0.04  |
| JFGL        | 0.406**| 0.11   | -0.108 | -0.205 | -0.04  | 1      |

***. Significantly correlated at .01 level (both sides)
Table 2. Significant analysis of dependent variables and independent variables.

|       | SJ  | WLGL | ZBGL | HX   | GJHX | JFHX |
|-------|-----|------|------|------|------|------|
| SJ    | 0.000 | 0.089 | 0.056 | 0.000 | 0.002 |
| WLGL  | 0.000 | 0.395 | 0.085 | 0.909 | 0.423 |
| ZBGL  | 0.089 | 0.395 | 0.605 | 0.148 | 0.431 |
| HX    | 0.056 | 0.085 | 0.605 | 0.292 | 0.137 |
| GJHX  | 0.000 | 0.909 | 0.148 | 0.292 | 0.772 |
| JFGL  | 0.002 | 0.423 | 0.431 | 0.137 | 0.772 |

From the above results, it can be seen that under the 0.01 significance, the Pearson coefficients of the actual cycling distance and the distance traveled on cycling lanes separated with obstacles, cycling lanes separated with dashes adjacent to bus lanes, cycling lanes without bicycle facilities are 0.551, 0.521, and 0.406. It can be considered that the two are positively correlated and are moderately correlated, and the significant results are 0.000, 0.000, and 0.002 (both sides).

The result is explained as follows:
- 30.36% of the cycling distance is located in cycling lanes separated with obstacles.
- 27.14% of the cycling distance is located in cycling lanes separated with dashes adjacent to bus lanes.
- 16.48% of the cycling distance is located in cycling lanes without bicycle facilities.

It can be seen that in the urban road network, not all road sections need to be equipped with bicycle facilities, and the corresponding bicycle facilities are appropriately proportioned, which can effectively improve the bicycle cycling distance.

4.3. Model establishment

After the correlation test, the SPSS was used to establish the multiple linear regression model with the actual cycling distance as dependent variable and the cycling distance on bicycle facilities as independent variable.

Taking SJ as the dependent variable, WLGL, GJHX, and JFHX as independent variables, two attempts were made, with constant terms and no constant terms. The results show that the model with no constant term has better interpretation effect. However, the DW test value of SJ as dependent variable is 1.365, which fails to pass the test, so this section try to take SJ as logarithm. Taking InSJ as the dependent variable, WLGL, GJHX, and JFHX as independent variables, two same attempts were made, with constant terms and no constant terms. The results show that the model with no constant term has better interpretation effect and passed the DW test. The process of model checking is shown in Table 3.

Table 3. Inspection process of establishing optimal regression models.

| ATTEMPTS | Dependent variable-SJ | Dependent variable-lnSJ |
|-----------|-----------------------|-------------------------|
|           | A         | B         | A           | B           |
| F         | 43.570    | 97.071    | 24.894      | 57.366      |
| SIG       | 0.000     | 0.000     | 0.000       | 0.000       |
| Std.Err   | 0.892     | 1.153     | 0.472       | 0.471       |
| R Squart Adjusted | 0.703 | 0.840 | 0.570 | 0.755 |
| No.of Obs | 54        | 55        | 54          | 55          |
| DW        | 1.695     | 1.365     | 1.796       | 1.815       |
| Constant  | CO        | 1.024     | 0.08        | 0           |
|          | SE        | 0.171     | 0.090       |             |
|          | T         | 5.988     | 0.881       |             |
|          | SIG       | 0.000     | 0.382       |             |
| WLGL     | CO        | 1.755     | 2.195       | 0.643       | 0.677    |
|          | SE        | 0.262     | 0.325       | 0.138       | 0.133    |
|          | T         | 6.704     | 6.759       | 4.644       | 5.107    |
|          | SIG       | 0.000     | 0.000       | 0.000       | 0.000    |
Therefore, using lnSJ as the dependent variable, WLGL, GJHX, and JFHX as independent variables, a multivariate linear regression model with no constant term is established. The model test results are shown in Table 4.

Table 4. Model test results.

(a) Model summary

| Model | R | R square | Adjusted R square | Standard estimated error | Durbin-Watson |
|-------|---|----------|-------------------|--------------------------|---------------|
| 1     | 0.876² | 0.768 | 0.755 | 0.4706781 | 1.815 |

(b) Anova table

| Model | Sum of squares | df | Sum of squares of deviations from mean | F | Sig. |
|-------|----------------|----|--------------------------------------|---|------|
| Regression | 38.126 | 3  | 12.709 | 57.366 | 0.000 |
| Residual  | 11.520 | 52 | 0.222 |          |      |
| Total    | 49.646² | 55 |                      |          |      |

(c) Coefficient test

| Model | Non-standardized Coefficient | Standardized Coefficient | Collinear statistic |
|-------|-------------------------------|--------------------------|---------------------|
|       | B | Standard error | t | Sig. | Tolerance | VIF |
| 1     | WLGL | 0.677 | 0.133 | 0.365 | 5.107 | 0.000 | 0.873 | 1.145 |
|      | GLHX | 0.360 | 0.052 | 0.491 | 6.969 | 0.000 | 0.898 | 1.113 |
|      | JFGL | 0.340 | 0.068 | 0.360 | 5.025 | 0.000 | 0.871 | 1.149 |

The coefficient of determination R is 0.768, and the adjustment R² is 0.755, indicating that 75.5% of the variation of lnSJ can be explained by three independent variables: WLGL, GJHX, and JFHX. The DW value is 1.815, and it is necessary to look up the table to determine the correlation of the residual sequence. The model has 56 samples and 3 independent variables, so it is found that dₜ is 1.68. In this sample, when the DW value is greater than 1.68 and less than 2.32, the variables are irrelevant. The DW value is within this range. Therefore, the residual of this model is not correlated, and independence is established.

The equation significance of the F-test value is 57.366, and the probability p value of the model at the 0.01 level is 0.000, so the model can be judged to be significant. That is to say, the actual cycling distance is linearly related to the distance traveled on cycling lanes separated with obstacles, cycling lanes separated with dashes adjacent to bus lanes, cycling lanes without bicycle facilities.

The p value corresponding to each regression coefficient t value test is 0.000 at a significant level of 0.01, and the coefficient is significant. The TOL values are close to 1, and the VIF values are all less than the recommended value of 5. Therefore, there is basically no collinearity problem between the three variables.

Through the above tests, the multivariate regression model is established as follows:

\[
\text{InSJ} = 0.677WLGL + 0.360GJHX + 0.340JFGL
\]
5. Conclusion
As can be seen from the model, three bicycle facilities have a facilitating effect on the cycling distance. For every 1km increase in cycling lanes separated with obstacles, cycling lanes separated with dashes adjacent to bus lanes and cycling lanes without bicycle facilities, the actual cycling distance increases by $e^{0.677(1.968)}$km, $e^{0.360(1.433)}$km and $e^{0.340(1.405)}$km.

The model shows that bicycle facilities are not required for all sections of the study area. In terms of increasing the cycling distance, increasing the length of cycling lanes separated with obstacles has a greater impact, and increasing the length of cycling lanes separated with dashes adjacent to bus lanes and cycling lanes without bicycle facilities have little effect. The reason may be that the occupancy of cycling lanes separated with dashes adjacent to bus lanes in the study area is serious, and the bus line network is relatively dense, resulting in the bicycle and the bus mixed. Meanwhile, a small sample size may also lead to this conclusion.

To sum up, in the construction of urban bicycle lanes, the reasonable proportion of various types of bicycle facilities is conducive to increasing cycling distance, increasing the proportion of bicycle trips, and improving problems of urban traffic congestion and environmental pollution.

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