ANALYSIS OF THE INFLUENCING FACTORS OF SHARED BIKE TRANSFER TO RAIL TRANSIT

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ABSTRACT

Based on the field survey data of Nanjing Andemen subway station, from the perspective of travelers, this paper deeply analyzes the problems related to the transfer between shared bicycles and rail transit, obtains the influencing factors affecting the travelers of Andemen station to use shared bicycles to transfer to rail transit, and calculates the index weight of each influencing factor by analytic hierarchy process, It is concluded that the main influencing factors of shared single vehicle transfer to rail transit are vehicle condition and average transfer time in convenience. Finally, based on the evaluation results, the optimization suggestions are put forward.

1. INTRODUCTION

With the acceleration of urban development, the problems of traffic congestion and environmental pollution have become increasingly prominent. Domestic cities have implemented the "bus priority" strategy to encourage residents to travel green. Because of its advantages of environmental protection, convenience and low cost, shared bicycle has become one of the important transportation modes for rail transit travelers. However, there are many problems in the development of shared bicycle, such as the neglect of shared bicycle transfer to rail transit in some areas. Therefore, it is of great significance to study the influencing factors of travelers' choice of sharing bicycles to transfer to rail transit for the development of sharing bicycles and promoting the coordinated development of public transport system.

At present, there are relatively few studies on the influencing factors of shared single vehicle transfer rail transit at home and abroad. Elliot and others discussed the obstacles of setting public bicycle system from the perspective of passengers' personal attributes and perceived accessibility and safety (Elliot and Washington, 2012). Jiang analyzed the relationship between travelers' personal characteristics and their attitude towards public bicycles through RP + SP survey (Jiang and Du, 2013). Xie Yaqiu analyzed the shared single vehicle travel mode from the perspective of urban planning (Xie Yaqiu and Zhao Chuting, 2018); Sun Biao explored the travel mode of "sharing bicycle + public transport" and found that the travel mode of "sharing + public transport" can describe the characteristics from transfer reasons, production technology and interface interaction (Sun Biao and Wang Yan,2017). Lu Ximing described the problems and characteristics of sharing bicycles (Lu Ximing, 2017). Deng Lifan analyzed the big data and found that the riding behavior of shared bicycles is greatly affected by the weather. Most weekdays are commuter riding, showing a peak in the morning and evening; Rest days are mostly life riding, the peak phenomenon in the morning and evening is not obvious, and the riding time is evenly distributed (Deng Lifan and Xie Yonghong, 2017). Lin Ying analyzed the current situation of public transport in Fuzhou and put forward the development strategy of shared bicycles according to the existing problems of shared bicycles (Lin Ying, 2017).

Li Songfeng summarized two connection modes of transfer connection and through operation, constructed a multi-level evaluation model of "analytic hierarchy process entropy grey correlation", and comprehensively analyzed the connection mode between rail transit and suburban railway (Li Songfeng, 2016). Guo Qin studied the transfer between public bicycle and rail transit (hereinafter referred to as B + R) and constructed the B + r transfer efficiency evaluation system (Guo Qin, 2014). Wu Jing analyzed the existing models at home and abroad, established a layered logit utility function, obtained the basic data through the analysis of the questionnaire on bicycle travel in Chengdu line 5, and obtained the sharing rate of bicycle to subway (Wu Jing, 2016). Cao Ping et al analyzed the influencing factors of bicycle on subway transfer based on the analysis of domestic and foreign experience, and pointed out that perfect supporting infrastructure is conducive to improving the transfer attraction between bicycle and subway (Cao Ping and Chen Jun, 2008). Ma Pei used field investigation and statistical analysis to explore the impact of transfer hardware facilities on bicycle transfer mode (Ma Pei and Wu Haiyan, 2011).

At present, the research on shared bicycles mainly focuses on the number and location of shared bicycles, as well as the impact of shared bicycles on the passenger flow of rail transit, ignoring the influencing factors of users' travel behavior using shared bicycles at the micro level. Therefore, this study selects this as the starting point and uses RP and SP surveys to obtain data, Then the analytic hierarchy process is used to obtain the main influencing factors affecting travelers' use of shared single vehicle transfer rail transit, and the optimization measures are put forward.

2. DATA ACQUISITION AND PROCESSING

2.1 Investigation Content

Carry out a questionnaire survey on travelers. The questionnaire design content is mainly divided into four aspects: 1.Traveler characteristic information, such as gender, age, occupation, income, etc; 2.Travel characteristic indicators, such as travel purpose, travel mode, etc; 3.Shared bicycle usage indicators, such as weekly shared bicycle usage times, shared bicycle riding distance, etc; 4.Intention to use shared bicycles, such as the circumstances under which shared bicycles will be used (good road conditions, bicycle lanes, good weather conditions, close to the subway station), the attraction of the type of shared bicycles to travelers (comfort, old and new, deposit, safety), etc.

2.2 Questionnaire Design and Implementation

This questionnaire survey adopts the methods of online questionnaire survey and on-site questionnaire survey. The respondents are completely randomly selected and the survey is anonymous. At the initial stage of the questionnaire design, a pre survey was adopted, 50 people were randomly selected for the survey, and the questionnaire was modified and adjusted according to the problems found during the survey. Among them, the on-site questionnaire adopts the way that the investigator always asks questions to pedestrians, and the investigator sorts out the information obtained, summarizes and records it, combined with the degree of pedestrian cooperation, The inquiry time should be controlled within 2 minutes. The network questionnaire adopts the form of multiple choice questions, considering the rationality of the options, to provide the greatest convenience for the respondents, so as not to produce boredom and affect the data results.

The on-site investigation time is from April 2 to April 8, 2021, a total of 7 days. Andemen station is a transfer station between Nanjing Rail Transit Line 1 and line 10. There are

6 exits in total. There is a bus terminus, a bus station and several bus stops around it. The bus network density is large, and a large number of private bicycles are piled up at the subway entrance. According to the field investigation, about 200 shared bicycles are found within 500m around Andemen subway station, of which ofo, moBay and harrow bicycles account for the vast majority. Therefore, Andemen subway station was selected as the investigation site in this study, with a total of 12 investigators. Through preliminary screening, 606 questionnaires were collected, including 225 online questionnaires and 381 on-site questionnaires.

2.3 Questionnaire Validity and Reliability Test

The questionnaire was tested using the clonal Bach α coefficient, and the three potential variables were greater than 0.7, and the overall reliability of TPB scale is 0.751, indicating that the consistency reliability of the scale is good and meets the requirements of questionnaire design.

The common degree values corresponding to all studies were higher than 0.4, indicating that the study item information can be efficiently extracted. The KMO was 0.732, greater than 0.50; the variance interpretation value of 4 factors were 30.168%, 8.848%, 6.110% and 12.502%, and all the observed variables exceeded 0.5 on the respective potential variables, indicating good construction validity of the potential variables.

3. MODEL CONSTRUCTION AND SOLUTION

The advantage of analytic hierarchy process is that it needs less quantitative data. The overall importance of each element is determined by analyzing and judging the relative importance of each element. First, divide the problems to be solved according to the level, combine the expert opinions, survey results and the objective analysis of the researchers, and compare them respectively. Finally, use simple algebra to calculate the comprehensive weight, which is easy to master and understand. Because there are few indicators in this paper, and the relative weight of each element can be reflected according to the questionnaire, analytic hierarchy process is selected.

3.1 Construction of Evaluation Index System

Take the transfer efficiency of rail transit and shared bike-sharing P as the target layer for convenience P_1, Security P_2, Cost P_3 Comfort P_4 As the standard layer, the bike-sharing access means P_{11}, Non-motorized lane line network density is P_{12}, Shared bike car condition P_{13}, Average transfer time is P_{14} For the index layer. As shown in Figure 1.

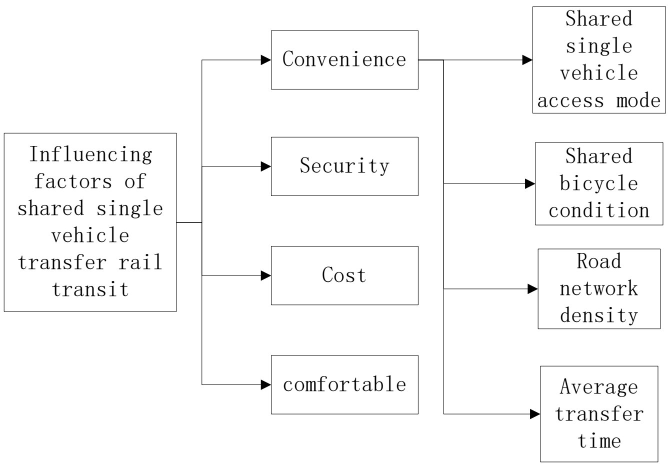

Figure 1: Transfer efficiency evaluation index system

3.2 Construction of Judgment Matrix

The key to hierarchical analysis is to build a judgment matrix and obtain the relative proportion of each element through the pairwise comparison between different elements.

$$P = \begin{bmatrix} P_{11} & P_{12} & P_{13} & P_{14} \\ P_{21} & P_{22} & P_{23} & P_{24} \\ P_{31} & P_{32} & P_{33} & P_{34} \\ P_{41} & P_{41} & P_{42} & P_{43} \end{bmatrix} \quad (1)$$

P is the judgment matrix, and the element P_{ij}. According to the findings, expert opinions and personal analysis are determined in Table 1.

Table 1: Comparison values of index significance

Size value P_{ij}	Importance
1	The i index is as important in the same layer as the j index
3	The i index is slightly important in the same layer
5	The i index was significantly important in the same layer as the j index
7	The i index is very important in the same layer as the j index
9	The i index is very important in the same layer as the j index

Note: The quantity value takes 2,4,6,8 as the median value of the two adjacent judgments

$$V_i = \sum_{j=1}^{n} P_{ij} \quad (i = 1,2,\ldots,n) \quad (2)$$

In the formula: n represents the matrix order. Eigen vector of the matrix, the relative weight Wi is:

$$W_i = \frac{V_i}{\sum_1^n V_i} \quad \text{(i=1,2,...,n)} \quad (3)$$

3.3 Consistency Test

The hierarchical analysis method needs to conduct the consistency test, whether the test calculation matrix is reasonable, and if it fails to pass, the judgment matrix needs to be re-optimized. λ_{max} is the largest eigenvalue of the judgment matrix:

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(PW)_i}{nW_i} \quad (4)$$

In the formula: the Wi is the eigenvector.

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (5)$$

In the formula: CI is the consistency index. RI took the values according to Table 2 (Saaty experiment results).

Table 2: RI takes the values

n	*RI*	*n*	*RI*
1	0	6	1.24
2	0	7	1.32
3	0.58	8	1.41
4	0.90	9	1.45
5	1.12	10	1.49

The judgment matrix was considered to pass the consistency test when the consistency ratio CR was less than 0.1 ($CR = \frac{CI}{RI}$ <0.1).

3.4 Model Solution

Using the data processed by this survey, the target layer judgment matrix of the transfer efficiency between shared bike and rail transit was constructed:

$$P = \begin{bmatrix} 1 & 8 & 9 & 2 \\ 1/8 & 1 & 2 & 1/5 \\ 1/9 & 1/2 & 1 & 1/6 \\ 1/2 & 5 & 6 & 1 \end{bmatrix} \quad 6)$$

Based on the above algorithm, to obtain the eigenvector value:
W= $(0.5321,0.0874,0.0472,0.3333)^T$. That is, the relative weight of convenience is 0.5321, safety relative weight is 0.0874, cost relative weight is 0.0472, and comfort relative weight is 0.3333. consistency test: λmax =4.0741, CI=0.0243, RI=0.9, CR =0.0272 <0.1, meet the test.

The second layer includes four sub-objectives of the standard layer: bike-sharing access mode, bike lane network density, condition of shared bike vehicles and average transfer time. The judgment matrix is as follows:

$$P = \begin{bmatrix} 1 & 1/3 & 1/5 & 1/5 \\ 3 & 1 & 1/2 & 1/2 \\ 5 & 2 & 1 & 1 \\ 5 & 2 & 1 & 1 \end{bmatrix} \quad (7)$$

The eigenvector W of the criterion layer was obtained$_1$=$(0.0445,0.1283,0.1796,0.1796)^T$. A consistency test was performed, and the λ_{max}=4.08773, CI =0.02924, RI = 0.9, CR =0.0324 <0.1, passed the inspection. The transfer efficiency of shared bikes and rail transit constructed in this paper meets the consistency test, and the total weight of each target is calculated. The results are shown in Table 3.

Table 3: Weight value calculation of each index category under the total target

Metric	**Level 1 Weight**	**Secondary Weight**	**Total Weight**
Way of shared bike access	0.5321	0.0836	0.0445
Non-motorized lane line network density		0.2414	0.1283
Bike-sharing car conditions		0.3376	0.1796
Mean transfer time		0.3376	0.1796
Safety	0.0874	-	0.0874
Cost	0.0472	-	0.0472
Comfort	0.3333	-	0.3333

In the process of shared bike transfer to rail transit, convenience is the most important, accounting for 0.5321, followed by comfort, accounting for 0.3333, and then safety and cost. In the sub-target layer of convenience, the vehicle condition and the average transfer time of shared bikes are equally more important, followed by the density of bicycle rail network and the access mode of shared bikes. From then on, it is not difficult to find that the most important thing for shared bikes is comfort and the least important cost. which shows that the charging of shared bikes is relatively reasonable, and it is particularly important to improve the bike-sharing cycling experience.

4. OPTIMIZATION AND SUGGESTIONS

Through the influence factors and questionnaire analysis, the following optimization is mainly proposed.

4.1 Bike-Sharing User Experience

In the above analysis, comfort is the most important for the process of shared bike transfer to rail transit, and the optimization of user experience has become the top priority.

Optimize the configuration of bike-sharing, and bike-sharing enterprises can improve users' cycling experience by continuously improving the configuration of sharing bikes, such as the optimization of object basket and the optimization of vehicle power, so as to make cycling more effort-saving;

Bike-sharing enterprises to improve the quality of service, in the cost of small increase, damaged shared bikes timely maintenance, low use rate of bikes timely checked to lack of resources, due to the morning and evening peak accumulation in subway stations or bus stations or residential areas around shared bikes timely transferred to short supply.

4.2 Bike-Sharing Parking Management

There are many bicycles near the subway station, and they are piled up indiscriminately. The government can plan special parking areas, assign special personnel to watch them, and place private bikes and shared bikes separately, so as to reduce the time that bike-sharing users use to find cars. For the placement of shared bikes, it is recommended to set up an electronic parking area, displayed on the mobile app, and stipulate users to park in the area, so as not to affect other modes of transportation.

5. CONCLUSION

From the perspective of individual travelers, taking Nanjing Andemen subway station as an example, this paper adopts the method of online and offline questionnaire survey, and uses analytic hierarchy process to analyze the main influencing factors of travelers using shared bicycles to transfer to rail transit. The results show that in the process of shared single car transfer to rail transit for travelers in Andemen subway station, the convenience has the greatest impact, followed by comfort, safety and cost. Among the sub objectives of convenience, the vehicle condition and average transfer time of shared bicycles are the most important. According to the above research results, combined with the current situation of Andemen subway station, this paper puts forward optimization measures. At the same time, Andemen subway station is only a practical case of this paper. The questionnaire, evaluation index system and evaluation model based on analytic hierarchy process designed in this paper can be used to analyze the influencing factors of sharing single vehicle to rail transit in other cities or stations, and improve the probability of sharing single vehicle to rail transit by optimizing the main influencing factors.

In addition, although the main influencing factors affecting the use of shared single vehicle transfer rail transit are obtained by analytic hierarchy process, there is no further study on how these factors affect travelers' use intention, and there is no quantitative analysis. At the same time, there is a lack of consideration of the different influencing factors of travelers' traffic behavior under the spatio-temporal characteristics. Therefore, this paper has some limitations and strives for further optimization in the follow-up research.

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