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Satisfaction and Usage Evaluation of City Shared Bicycle

Xin Zhu

College of Transport & Communications, Shanghai Maritime University,201306, Shanghai, China.

Abstract

In order to analyze the influencing factors of usage and satisfaction of shared bicycle, the questionnaire was used to collect 1212 effective samples of shared bicycle users in Ningbo, and the Bivariate Ordered Probit (BOP) model was used to analyze the relationship of influencing factors of usage and satisfaction of shared bicycle, calculates the marginal effect of significant factors, quantitatively analyzes their impact on usage and satisfaction of shared bicycle, and test the potential connection between the two. The results shows that the BOP model can not only explore the relationship of influencing factors of usage and satisfaction of shared bicycle, but also effectively describe the potential connection between the two; the correlation coefficient between the two is 0.1451, indicating that the shared bicycle usage will be improved with the increase of satisfaction; the model results show that usage and satisfaction of shared bicycle are influenced by factors such as gender, age, the number of household vehicles, travel mode, and travel distance, etc. On this basis, practical and effective improvement measures are proposed to increase the use of shared bicycles in Ningbo.

Keywords

Shared bicycle; satisfaction; usage; Bivariate Ordered Probit (BOP).

1. Introduction

In recent years, with the rapid development of urban economy and the continuous improvement of motorization level, serious environmental pollution problems and increasing traffic pressure are not conducive to the sustainable development of cities. The launch of shared bicycles can take advantage of the convenience and privileges when renting in connection, etc., attract more those to choose public transportation, so as to improve the urban traffic environment and accelerate the sustainable development of the cities. Ten departments including the Ministry of Transport jointly announced the "Guideline on Encouraging and Regulating the Development of Internet Rental Bicycles", it defined that shared bicycle is an important part of the urban green transportation system and implemented policies to encourage development.

Guo et al. [3] used the BOP model conduct an in-depth analysis on the influencing factors of public bicycle usage and satisfaction in usage characteristics, the study showed that public bicycle use were significantly positively correlated with satisfaction; Shaheen et al. [4] investigated the use cases of public bicycles in North America, the study showed that the travel purpose of public bicycles is related to work and school and is usually used for commuting; Wu Yao et al. [5] proposed to build the Logit model to analyze the demand forecast of public bicycles in demand forecast,; Xie Xiaoping [6] constructed the demand forecast model of public bicycle stations based on Elman neural network.

Campbell et al. [7] conducted the study on comfort in influencing factors, and found that the demand for shared bicycles was adversely affected by travel distance, temperature, precipitation and poor air quality; Fishman et al. [8] concluded that the system background service lacks accessibility/spontaneity the system shut down overnight, and the credit cards

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cannot be used to easily register, they are major obstacles of shared bicycle usage; Bachand-Marleau et al. [14] and Faghih-Imani et al. [15] found that when the shared bicycles were far away from the central business district (CBD), the usage will be reduced; Bachand-Marleau et al. [11] found that the existence of subway and bus stations, restaurants and universities promoted the use of shared bicycles.

Table 1. summary statistics of variables

variable	description	frequency	ratio(%)
personal attribute			
gender	male	629	49.88
	female	632	50.12
age group	young those (<30)	1090	86.44
	middle-aged those (30-50)	147	11.66
	elderly those(>50)	24	1.9
education level	below junior high school	21	1.67
	high school and junior high school	156	12.37
	junior college and undergraduate	953	75.57
	master and above	131	10.39
occupation	student	820	65.03
	company/enterprise staff	212	16.81
	organ/public institution staff	89	7.06
	private owner	32	2.54
	freelance work	44	3.49
	retire	11	0.87
	others	53	4.2
monthly income	<2000	738	58.52
	2000-5000	280	22.2
	5000-8000	148	11.74
	>8000	95	7.53
household attribute			
household have car	yes	856	67.88
	no	405	32.12
household have bicycle or electric bicycle	yes	822	65.19
	no	439	34.81
travel characteristics			
travel method	walk	762	60.43
	shared bicycle	646	51.23
	private bicycle	316	25.06
	electromobile	162	12.85
	public bicycle	132	10.47
	bus or subway	835	66.22
	private car	352	27.91
	taxi or ride-hailing	410	32.51
travel distance	<3km	437	34.66
	3-5km	449	35.61
	5-10km	246	19.51

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	10-20km	72	5.71
	>20km	57	4.52
main application	experience	231	18.32
	bus/subway transfer	545	43.22
	go to work or get off work/go to school or leave school	542	42.98
	shopping/travel	284	22.52
	recreation and sports entertainment	282	22.36
	public affairs and business affairs	56	4.44
	others	297	23.55
service perception			
usage	use every day	142	11.26
	1-3 times every week	354	28.07
	1-3 times every month	97	7.69
	irregular use	655	51.94
	never use	13	1.03
use reason	novelty	137	10.86
	easy to rent/return the car	793	62.89
	transfer	352	27.91
	exercise	253	20.06
	economical and practical	633	50.2
	environmental protection	418	33.15
	Others	139	11.02
present condition problem	chaotic parking	973	77.16
	excessive occupation of public parking resources	490	38.86
	too many faulty cars	843	66.85
	inconvenient unlock	358	28.39
	unsafe ride	217	17.21
	others	107	8.49
satisfaction with the service quality of shared bicycle	fully satisfied	96	7.61
	relatively satisfied	669	53.05
	ordinary	439	34.81
	poor	45	3.57
	dissatisfied	12	0.95

2. Data Acquisition

2.1. Contents of Questionnaire

In this paper, on the basis of results of extensive reference reviews and member discussion, the questionnaire was designed, the contents of the questionnaire contain 54 indicators, these indicators involves personal attributes, household attributes, travel characteristics, service perception and user expectation.

Personal attributes include gender, age, education level and other characteristics; household attributes mainly are vehicle ownership; travel characteristics reflect user requirements and personal preferences, including usual travel mode, travel distance, main purposes of using shared bicycles, and commonly used pick-up locations, etc.; service perception is the users'

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feelings about the current shared bicycle service, mainly involve use frequency, reason for use, status quo, and satisfaction; user expectation is the areas where users expect improvements in shared bicycles, and provide guidance for further optimizing service modes for shared bicycles, and solicit opinions on whether to set up electronic fences and increase non-motor vehicle parking spaces that are currently hotter.

2.2. Survey Results

There are totally 1395 questionnaires through a two-month survey. The results were screened; the logical questions and invalid data in the questionnaire were used to exclude invalid samples, such as young but retired respondents. There are totally 1212 samples after data screening. The survey results are shown in the table below.

In order to prove the credibility and validity of data collected in this questionnaire and ensure the accuracy of calculation results, the reliability and validity of sample data were tested, the α coefficient of usage and satisfaction were both greater than 0.7, the KMO value was 0.986, the significance of Bartlett's sphericity test was 0.000, less than 0.01, passed the test, therefore, it can be concluded that all the indicators of the questionnaire design in the research are valid.

3. Model Building

3.1. BOP Model Building

The BOP model was used to identify factors that affect both the usage and satisfaction of shared bicycles. The purpose of the BOP model was to simulate explanatory variables that can be determined simultaneously. The BOP model first defines the observation ordinal number of each observation, as follows:

$$\begin{cases} y_{i,1}^{*} = \beta_1 X_{i,1} + \varepsilon_{i,1}, \quad y_{i,1} = j \ \ if \ \ \mu_{j-1} < y_{i,1}^{*} < \mu_j, \ j = 0, \cdots J_1 \\ y_{i,2}^{*} = \beta_2 X_{i,2} + \varepsilon_{i,2}, \ \ y_{i,2} = k \ \ if \ \ \theta_{k-1} < y_{i,2}^{*} < \theta_k, \ \mathrm{k} = 0, \cdots K_2 \end{cases} \tag{1}$$

$y_{i,1}^{*}$ and $y_{i,2}^{*}$ represent the independent variables corresponding to the usage and satisfaction of shared bicycles; $y_{i,1}$ and $y_{i,2}$ represent the ordinal data (1,2,3,4,5) of the usage and satisfaction of shared bicycles; $X_{i,1}$ and $X_{i,2}$ represent the explanatory variables in the simultaneous equation model; β_1 and β_2 represent the estimated parameters of the explanatory variable; μ and θ represent the estimated threshold parameters of $y_{i,1}$ and $y_{i,2}$; $\varepsilon_{i,1}$ and $\varepsilon_{i,2}$ obey the random error term of the two-dimensional normal distribution, obey the mean value 0, the variance is 1, and the correlation coefficient is normal distribution. ρ is the correlation coefficient; i represents observation, j and k represents the usage and satisfaction of shared bicycles.

The related error term of the cross equation in the BOP model is given by the formula:

$$\begin{bmatrix} \varepsilon_{i,1} \\ \varepsilon_{i,2} \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix} \right) \tag{2}$$

In the formula, ρ represents the correlation coefficient between $\varepsilon_{i,1}$ and $\varepsilon_{i,2}$.

The maximum likelihood estimation was used to estimate the parameters of the BOP model, as shown in formula (3).

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$$LL=\sum_{i=1}^{n}\left(\sum_{j=0}^{J}\sum_{k=0}^{K}\xi_{jk}\begin{bmatrix}\phi_2\left[\left(\mu_j-\beta_1X_{i,1}\right),\left(\theta_k-\beta_2X_{i,2}\right),\rho\right]-\phi_2\left[\left(\mu_{j-1}-\beta_1X_{i,1}\right),\left(\theta_k-\beta_2X_{i,2}\right),\rho\right]\\-\phi_2\left[\left(\mu_j-\beta_1X_{i,1}\right),\left(\theta_{k-1}-\beta_2X_{i,2}\right),\rho\right]+\phi_2\left[\left(\mu_{j-1}-\beta_1X_{i,1}\right),\left(\theta_{k-1}-\beta_2X_{i,2}\right),\rho\right]\end{bmatrix}\right) \tag{3}$$

In the formula, $i=1,2,\cdots,n$ (sample size); if the observed results $y_{i,1}=j$ and $y_{i,2}=k$, then ξ_{jk} is defined as equal to 1, otherwise it is 0.

3.1. BOP Model Building

After model estimation, the signs of the coefficients associated with the explanatory variables were correlated. These signs showed the positive or negative influence of the variable on the results. However, the coefficients could not quantify the influence of these variables, nor could they intuitively explain it. In order to quantify the influence of each type of result, the marginal effects of relevant variables in the BOP model were calculated.

The marginal effect of explanatory variables $X_{i,1}$ to $y_{i,1}$ is:

$$\frac{P\left(y_{i,1}=j\right)}{\partial X_{i,1}}=\left[\phi\left(\mu_{j-1}-\beta_1X_{i,1}\right)-\phi\left(\mu_j-\beta_1X_{i,1}\right)\right]\beta_1 \tag{4}$$

$\varphi_2(\cdot)$ is a function of standard normal distribution. Similarly, the marginal effect of explanatory variables $X_{i,2}$ to $y_{i,2}$ is:

$$\frac{P\left(y_{i,2}=k\right)}{\partial X_{i,2}}=\left[\phi\left(\theta_{k-1}-\beta_2X_{i,2}\right)-\phi\left(\theta_k-\beta_2X_{i,2}\right)\right]\beta_2 \tag{5}$$

3.2. Model Solving Method

The BOP model can be modeled and solved in accordance with the following steps.

(1) Two independent Probit models were built—Probit model of influencing factors of shared bicycle usage and Probit model of influencing factors shared bicycles satisfaction, these models were calibrated with STATA14, and the significant variables in the two models are retained;

(2) The significant variables in (1) were used to build the BOP model and conduct regression analysis;

(3) STATA14 was used to calculate the marginal effects of significant variables in the BOP model.

4. Analysis of Results

4.1. Model Evaluation Result

The variables in Table 1 were used as the explanatory variables of models, and STATA14 software was used to calibrate the BOP model, the results were shown in Table.2, the model results only retained the significant variables at the 95% confidence level. The results showed that the correlation coefficient between the satisfaction and usage of shared bicycles is positive (ρ=0.1451), indicating that there is the positive correlation between the two dependent variables, and it showed that increasing the satisfaction of shared bicycles could increase its usage.

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Table 2. Evaluation results of the BOP model

variable	usage Y_1			satisfaction Y_2		
	β	S.E.	ρ-value	β	S.E.	ρ-value
gender X_1	0.386	0.072	0.05	0.094	0.070	0.176
age X_2	-0.152	0.099	0.125	0.204	0.114	0.074
education level X_3	0.117	0.072	0.104	0.100	0.070	0.156
monthly income X_4	0.097	0.054	0.075	0.016	0.056	0.779
occupation X_5	-0.057	0.029	0.052	-0.071	0.035	0.042
household ownership of vehicles (one car) X_6	-0.013	0.100	0.897	-0.042	0.100	0.677
household ownership of vehicles (two cars) X_7	0.090	0.134	0.501	-0.192	0.144	0.183
household ownership of vehicles (≥three cars) X_8	-0.131	0.251	0.600	-0.201	0.232	0.387
household ownership of vehicles(electromobile) X_9	0.171	0.090	0.059	-0.046	0.091	0.610
household ownership of vehicles(bicycle)X_{10}	0.026	0.092	0.775	-0.165	0.085	0.052
household ownership of vehicles(no)X_{11}	0.001	0.151	0.996	-0.078	0.136	0.568
usual travel way (shared bicycle) X_{12}	-0.795	0.079	0.052	-0.095	0.077	0.213
usual travel way (electromobile) X_{13}	-0.055	0.107	0.610	0.149	0.113	0.187
usual travel way (public bicycle) X_{14}	-0.055	0.115	0.634	-0.024	0.111	0.827
usual travel way (bus or subway) X_{15}	-0.003	0.078	0.966	0.111	0.080	0.169
usual travel distance X_{16}	0.049	0.039	0.204	-0.050	0.038	0.185
main purpose of using shared bicycles (go to work or get off work/go to school or leave school) X_{17}	-0.290	0.077	0.000	0.061	0.075	0.413
main purpose of using shared bicycles (shopping and travel) X_{18}	0.049	0.083	0.367	-0.164	0.087	0.061
use reason (easy to rent and return the car) X_{19}	-0.038	0.080	0.635	-0.293	0.082	0.000
use reason (economical and practical) X_{20}	-0.150	0.079	0.059	-0.324	0.073	0.000
use reason (environmental protection) X_{21}	-0.037	0.081	0.648	-0.300	0.077	0.000
problems (chaotic parking) X_{22}	0.234	0.094	0.012	0.329	0.096	0.001
problems (too many faulty vehicles) X_{23}	-0.113	0.086	0.191	0.239	0.088	0.007
traffic accident X_{24}	-0.210	0.146	0.151	-0.405	0.177	0.022
improvement (illegal parking phenomenon) X_{25}	0.021	0.083	0.803	-0.068	0.072	0.343
improvement (broken bicycle) X_{26}	-0.001	0.096	0.995	0.053	0.094	0.572
improvement (bicycle advertisement) X_{27}	-0.014	0.097	0.885	0.039	0.085	0.642
improvement (positioning system) X_{28}	-0.146	0.085	0.084	-0.017	0.079	0.826
improvement (passenger service) X_{29}	0.049	0.094	0.603	0.184	0.092	0.047
electronic fence X_{30}	-0.034	0.073	0.064	0.060	0.067	0.372
ρ	0.1451					

The variable values in the evaluation results have three situations: all are positive, one positive and one negative, and all are negative, indicating that a certain variable has different effects on the usage and satisfaction of shared bicycles. When is positive, it can show that each

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explanatory variable is positively correlated with the usage and satisfaction of shared bicycles, namely the usage and satisfaction of shared bicycles will improve as the variables increase, moreover, in order to better describe the influence of various variables on satisfaction and usage, the marginal effects were calculated, as shown in the following table.

Table 3. Marginal effects of the BOP model

variable	usage (frequent) Y_1	Satisfaction (relatively satisfied) Y_2
gender X_1	-0.042	0.0003
age X_2	0.011	-0.021
education level X_3	-0.003	-0.004
monthly income X_4	-0.041	-0.001
occupation X_5	0.005	0.004
household ownership of vehicles (one car) X_6	-0.005	0.017
household ownership of vehicles (two cars) X_7	-0.014	0.04
household ownership of vehicles (≥three cars) X_8	0.009	0.036
household ownership of vehicles (electromobile) X_9	-0.024	0.013
household ownership of vehicles (bicycle) X_{10}	-0.006	0.02
household ownership of vehicles (no) X_{11}	-0.011	0.013
usual travel way (shared bicycle) X_{12}	0.09	-0.003
usual travel way (electromobile) X_{13}	0.011	-0.016
usual travel way (public bicycle) X_{14}	0.007	-0.001
usual travel way (bus or subway) X_{15}	0.003	-0.01
usual travel distance X_{16}	-0.006	0.005
main purpose of using shared bicycles (go to work or get off work/go to school or leave school) X_{17}	0.035	-0.016
main purpose of using shared bicycles (shopping and travel) X_{18}	-0.012	0.019
use reason (easy to rent and return the car) X_{19}	-0.0002	0.026
use reason (economical and practical) X_{20}	0.009	0.032
use reason (environmental protection) X_{21}	-0.004	0.03
problems (chaotic parking) X_{22}	-0.025	-0.029
problems (too many faulty vehicles) X_{23}	-0.021	-0.022
traffic accident X_{24}	-0.025	-0.042
improvement (illegal parking phenomenon) X_{25}	-0.004	0.006
improvement (broken bicycle) X_{26}	0.006	-0.005
improvement (bicycle advertisement) X_{27}	-0.0005	-0.005
improvement (positioning system) X_{28}	0.013	0.001
improvement (passenger service) X_{29}	-0.0004	-0.019
electronic fence X_{30}	0.001	-0.007

From the above table, the marginal effects of various significant factors can be obtained, and the influence law of various influencing factors on the usage (frequent) and satisfaction (relatively satisfied) of shared bicycle can be obtained intuitively.

4.2. Analysis of Influencing Factors

According to the results in Table.3, it is possible to quantitatively analyze the effect of various influencing factors on the usage (often) and satisfaction (relatively satisfied) of shared bicycles.

(1) Personal attributes

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Men use shared bicycles more frequently than women, usually 4% higher than women; moreover, men are slightly more satisfied than women. The users with higher education level, their usage and satisfaction are slightly lower than those with relatively low education level. The usage of high-income users is 4% lower than other users, and their satisfaction will be relatively low.

(2) Household attributes

The shared bicycle usage of household with car, electromobile, and bicycles is 9% lower than that of household without vehicles, and their satisfaction is 7% higher. This finding shows that those without cars and bicycles are more likely to use shared bicycles, and the results are consistent with expectations. The reason may be that bicycle/e-bike owners are more likely to use their own vehicle to prevent travel time longer due to the use of shared bicycles. And the usage of household with cars is 3% lower than that of household without cars. The number of vehicles owned will also lead to differences in usage and satisfaction. This finding indicates that those without cars and bicycles are more likely to use shared bicycles. The reason may be that owners of cars, bicycles, and electromobile are more likely to use their own vehicles, prevent travel time longer due to the use of shared bicycles.

(3) Travel characteristics

Those questioned who travel by bus or subway or use electromobile or bicycle often use shared bicycles. This finding is obvious, because those who are accustomed to riding bicycles are more easily touch bicycles. The marginal effect shows that those who use these travel modes, their shared bicycle usage has increased by about 11%, and it shows that these users prefer to use shared bicycles. In addition, the results show that those whose travel distance is less than 3km are 5% more likely to use shared bicycles than those whose travel distance is longer (over 20km). These research results show that the travel distance of users who use shared bicycles to travel is generally less than 5km. The results show that users' common pick-up and return places are concentrated in residential areas, schools and hospitals.

(4) Service perception

The usage of users who use shared bicycles to commute to work or school is 3.5%. At present, there are many problems with shared bicycles; the usage of shared bicycles has been reduced by about 5% due to factors such as chaotic parking and too many broken vehicles. The occurrence of traffic accidents will also affect the usage and satisfaction of shared bicycles. Traffic accidents will reduce the usage by 2.5% and reduce the satisfaction by 4.2%.

5. Conclusion

In this paper, the questionnaire was used to collect data, a total of 1212 valid samples were collected to build the BOP model. The results of the BOP model show 30 significant factors related to the usage and satisfaction of shared bicycles in Ningbo. The BOP model can better analyze the correlation between usage and satisfaction of shared bicycle. The evaluation results show that the correlation coefficient between the two is 0.1451, indicating that the two independent variables are positively correlated, it means that a higher degree of satisfaction of shared bicycles can increase the possibility of shared bicycle use. Therefore, we must improve the shared bicycle facilities as much as possible, thus improving the usage and satisfaction of shared bicycles. In addition, the marginal effects of significant factors were calculated to quantify their influence on the results. On the basis of the analysis results, this paper suggests:

(1) The usage of shared bicycles near schools, hospitals, and residential areas is relatively high, therefore, shared bicycles should be placed within a reasonable range near schools and residential areas, so help the use of users, and it will not reduce users satisfaction when using the vehicle due to not find the vehicle.

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(2) Owing to the chaotic parking of shared bicycles and too many faulty vehicles,
they causes decrease in satisfaction, therefore, electronic fences and additional parking spaces for non-motor vehicles can also be set up to restrain the phenomenon of chaotic parking of shared bicycles.
Moreover, users who use shared bicycles should have more social awareness, take good care of shared bicycles, and not destroy or randomly park shared bicycles. Enterprise managers should arrange more managers to conduct inspections, so as to timely repair faulty vehicles.

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