The Comprehensive Benefit Evaluation of Take Shared Bicycles as Connecting to Public Transit

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Abstract: Shared bicycles as an important way of connecting public transport, have few literature to evaluate its effectiveness.This paper taking Beijing city as an example, make anevaluationfor the six types of travel combinations which are commonly used by the citizens. The author selects four quantitative indicators: fuel consumption, economic cost, total time spent, and CO2 emission. And two qualitative indicators: degree of comfort and convenience. The relative efficiency of quantitative indicators is obtained by data envelopment analysis (DEA) and fuzzification and then take fuzzy synthetic evaluation with qualitative indicators.It was found that the choice of shared bicycles +subway+ shared bicycles and shared bicycles has good comprehensive benefits in medium distance travel. The findings also suggest that shared bicycles +subway+ shared bicycles is the best choice in the utilitarian trips. The conclusions not only provide suggestions for the travellers to select travel modes, but also can adjust the relevant factors to increase the proportion of green travel.

1. Introduction

As a new mode of transport in recent years, shared bicycles has been welcomed by people.Research shows that riding could reduce the use of fossil fuels, ease the land tension and completedseamlessly switch between modes. After the sharing of bicycles in China, the proportion of bicycle travel increased from 5.5% to 11.6% [1]. In recent years, domestic and foreignexpertsdid a lot of researcharound the bike's service quality, safety, environmental impact, travel efficiency and the overall contribution to urban traffic.KjartanScensminde analysed the cost-effectiveness of the bicycle network[2]; Börjesson M and Eliasson J from the time value and the environment and other external interests of the perspective of the bike cost-effectiveness[3].

There is also a lot of research focus on the bikes in the country. Liu Chen used the DEA to evaluate the urban public bicycle system synthetically[4]; Based on the system operation efficiency and user satisfaction index, Wang Wenjing analysed the cost and benefit of the

bicycle life cycle[5]; Tang Wenqian calculates the economic, environmental and transportation benefits generated by the public bicycle system through the establishment of a benefit analysis model[6]

In general, due to the sharing of no-pile-sharing cycle form the scale of the time is not long，existing papers do not takeinto account the impact of the characteristics of the pile on the pedestrian, the lack of a shared bicycle on the first and last mile solution" the specific impact of the study. This article aims at people commonly used six kinds of travel modes: shared bicycles + bus + shared bicycles(B+B+B)、private car(P)、shared bicycles(S)、walk + subway + walk(W+S+W)、shared bicycles + subway + shared bicycles(B+S+B)、walk + bus + walk(W+B+W)[7].First of all, the author selects six kinds of evaluation indexes.Secondly using the DEA analysed quantitative indexes, And the take the result as the input evaluate again. Finally, take fuzzy synthetic evaluation with qualitative indicators.

2. Background

As early as 2005, the first public transportation system was established in Beijing. But in 2010, because the system site was unreasonable, the experience was not good, and finally announced defeat[8]. In 2016, China's smart phone users reached 680 million, more than 70% of national consumption using mobile payment. At the same time, with the help of advanced positioning technology, no-pile-sharing cycle without piles has gained rapid development in China.

Studies show that China's private car growth rate is more than 18%, and is the world's largest car consumer [9]. At the same time, increased travel time, increased road congestion, longer queuing length. The latest research findings show that sharing bicycles, less than a year into the city, has become the car, bus, subway outside the fourth major modes of travel. Bikes-haring schemes are associated with environmental bene6fits through the diminished usage of motor vehicles and the associated reduction in fuel use and traffic congestion. Shared bicycles represent the perfect combination of "Internet +" and the real economy.

3. Selection of evaluation indicators

Too many evaluation indicators not only increase the amount of calculation, but also may lead to duplication, resulting in a large proportion of an evaluation index. In this paper, according to the characteristics of shared bicycles and related literatures selected four quantitative indicators and two non-quantitative indicators[10].

1. Fuel consumption: Refers to the energy consumption of the travel vehicle under the premise of full load, different transportation vehicles, each hundred people travel a kilometre, the standard coal consumption statistics [11].

2. Economic cost: Indicate the sum of the costs of traveling through various means of transportation throughout the process.

3. Total time spent: The time spent from the departure to the destination of the passenger. It usually includes waiting time, ride time and transfer time. The Total time spent takes the following functional form:

$$T_n = \frac{L}{S} + t_w + t_b \quad (1)$$

Where L is the on the vehicle, S is the vehicle speed, t_w is the waiting time, t_b is the transfer time.

4. Emission of carbon dioxide: The carbon dioxide produced by taking the vehicle. Table 1 is the different vehicles' emission of carbon dioxide in per kilometre [12].

Table 1 Beijing passenger transport carbon dioxide emissions statistics

Travel mode	Carbon dioxide emissions g/km
bicycle	0
car	50.5
bus	13.14
subway	10.7

5. Degree of comfort andDegree of convenience: From the competent feelings of passengers.

4. Methodology

The evaluation of objective things is the advantage of DEA. It can effectively avoid the potential errors caused by human factors[13]. However, many factors in real life are difficult to represent with specific data[14]. In order to solve such problems, we can make use of fuzzy comprehensive evaluation. The research methods are as follows: Using the DEA analysed quantitative indexes. And the take the result as the input and Fuzzy. At last, take fuzzysyntheticevaluationwith qualitative indicators. We can finally obtained the evaluation results.

Assuming the comment set is $\mathrm{V} = (v_0, v_1, \cdots v_{p-1})$, where p is the degree,and then the output of DEA can be interpreted as the membership grade of V.Assuming the $\mathrm{r} = (r_0, r_1, \cdots r_{p-1})$ is the membership grade, which can be expressed as

$$r_j = \begin{cases} \dfrac{x-(j-1)\frac{1}{p-1}}{\frac{1}{p-1}}, (j-1)\dfrac{1}{p-1} \le x < j\dfrac{1}{p-1} \\ \dfrac{(j+1)\frac{1}{p-1}-x}{\frac{1}{p-1}}, j\dfrac{1}{p-1} \le x < (j+1)\dfrac{1}{p-1} \\ 0, \quad \text{others} \end{cases}, \quad r_j \in [0,1], j = 0,1,2 \cdots p-1 \quad (2)$$

Where x is the result of DEA; j is decision unit; p is the degree.

At the same time, the fuzzy results of quantitative indexes and the fuzzy evaluation results of qualitative indexes are obtained. And then make a comprehensive evaluation. As the following equation:

$$B = A°R \rightarrow B_j = (a_{j1}, a_{j2}, \cdots a_{jk}) ° \begin{bmatrix} B_{j1} \\ B_{j2} \\ \cdots \\ B_{jk} \end{bmatrix} = (b_{j1}, b_{j2}, \cdots, b_{jp}), j = 1,2, \cdots, n, \quad (3)$$

Where A is weight coefficient of the quantitative indexes and qualitative indexes; R is a matrix consist of the result of DEA and Fuzzy; k is number of the branch.

5. Modelling results

This paper takes Beijing city as an example. According to the average travel distance of 13.2km people in Beijing, the authors carried out statistical data as Table 2. The statistical methods have been mentioned in the Part 2.

Table 2 Evaluation indicators value

Level 1 indicators	Social consumption				Service management	
Weights	0.6				0.4	
Level 2 indicators	Energy consumption (kg) (input)	Total cost of economy / Yuan (input)	Time total cost per second (output)	Co2 total discharge / kga (output)	Comfort	Convenience
Weights	DEA adjustment	DEA adjustment	DEA adjustment	DEA adjustment	0.4	0.6
B+B+B	0.112	4	1/2263	1/0.173	（0.5,0.3,0.2）	（0.5,0.2,0.3）
P	0.452	6	1/1670	1/0.667	（1,0,0）	（0.7,0.2,0.1）
B	0	1.5	1/3223	0	（0.6,0.2,0.2）	（0.6,0.2,0.2）
W+S+W	0.032	5	1/1542	1/0.141	（0.7,0.2,0.1）	（0.5,0.2,0.3）
B+S+B	0.032	6	1/1129	1/0.141	（0.6,0.3,0.1）	（0.4,0.5,0.1）
W+B+W	0.112	3	1/2396	1/0.173	（0.6,0.2,0.2）	（0.5,0.3,0.2）

[a]In DEA, the higher the conversion efficiency is, the better the result is. In this paper, we hope to get less solution and less carbon dioxide emissions. So take the reciprocal.

In this paper, the comment set is$V = (good, \text{medium}, \text{poor})$. Using DEA、Fuzzy and equation (2) are used to analyse the date from Table 3. And the results are shown in the following Table 3.

Table 3 Quantitative and qualitative indexes processing results

Travel modes	Social consumption performance				Service management performance		
	DEA results	DEA score fuzzy membership (Bj1)			Fuzzy membership (Bj2)		
		good	Medium	Poor	good	Medium	Poor
B+B+B	0.8149	0.37	0.63	0.00	0.5	0.24	0.26

P	0.5429	0.09	0.91	0.00	0.82	0.12	0.06
B	1	1.00	0.00	0.00	0.60	0.2	0.2
W+S+W	1	1.00	0.00	0.00	0.58	0.20	0.22
B+S+B	1	1.00	0.00	0.00	0.48	0.42	0.1
W+B+W	1	1.00	0.00	0.00	0.54	0.26	0.20

According to the web- surveys, this paper definite Social consumption and Service management weight vector is $A = (0.6,0.2)$.Though the equation (3). Table 4 can be obtained:

Table 4 Comprehensive review matrix and evaluation results

Travel modes	Comprehensive evaluation matrix (T)						Comprehensive evaluation results membership degree			Evaluation results
	community resource			Service management			good	Medium	poor	
	excellent	good	poor	excellent	good	poor				
B+B+B	0.37	0.63	0.00	0.5	0.24	0.26	0.42	0.47	0.11	Medium
P	0.09	0.91	0.00	0.82	0.12	0.06	0.38	0.59	0.03	Medium
B	1.00	0.00	0.00	0.66	0.2	0.14	0.84	0.08	0.08	good
W+S+W	1.00	0.00	0.00	0.58	0.20	0.22	0.83	0.08	0.09	good
B+S+B	1.00	0.00	0.00	0.48	0.36	0.16	0.79	0.17	0.04	good
W+B+W	1.00	0.00	0.00	0.54	0.26	0.20	0.82	0.10	0.08	good

Finally, making the results Uniformization (Assuming good = 100, medium = 60, poor = 10), Table 5 is the comprehensive evaluation result.

Table.5. Ranking of travel modes

Travel modes	B+B+B	P	B	W+S+W	B+S+B	W+B+W
Mark	71.3	73.7	89.6	88.7	89.6	88.8
Ranking	5	4	1	3	1	2

6.Conclusion

Although sharing bike is a new way of solving the problem of first and ‘last mile solution.’ However, there is a lack of researches on the utility of travel combination patterns involving shared bicycles. This paper studies that issue taking Beijing as an example. The author focuses on the benefit study of various travel modes of Beijing residents traveling by public transport. The results of the mathematical model showed that the B+S+B and B in whole travel have good benefits. Considering the traveling purposes of residents,theauthor recommend a kind of travel combination pattern the B+S+B in the utilitarian trips.

These findings have important policy implications, the government departments and enterprises to formulate policies and operational plans.And this paper has a guiding significance for short and medium distance travel of residents.

To extend the research, the authors need to strengthen the studies of following dimensions:(1).Increase the evaluation factors. Because the past studies have shown that the environment has a great impact on the travel mode choices of residents.(2) Then we need to further study the role of shared bicycles to solve traffic congestion.

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References

[1] Mobike, Beijing Tsinghua TongHeng Planning and Design Institute. Shared bicycle and urban development white paper in 2017[R].2017.4

[2] Kjartan Scelensminde.Analysis about walking and bicycle lanes network's cost benefit based on safety, health effects and external costs of motorized traffic[J]. International Urban Planning, 2012, 27(5): 18-25.

[3] Börjesson M., Eliasson J. The value of time and external benefits in bicycle cost-benefit analysis [J] Working Papers in Transport Economics, 2011, 46(4):673-683

[4] Liu Chen, Shang Li-Yuan Zhu Yun. Comprehensive evaluation of public bicycle system based on data envelopment method [J]. Journal of Transportation Engineering and Information, 2016, (03):119-128

[5] Wang Wenjing, Ma Shifeng.Analysis on the evaluation model of public bicycle service system. [J] Value Engineering, 2015, (08):127-128

[6] Tang Wengqian, Li Wenquan, Chen Qian. Efficiency analysis of the public bicycle free-service system [J].Journal of Transportation Engineering and Information, 2014, (03):87-93.

[7] Ofo, Ministry of Transport and Science Research Institute. 2017 Major cities in China Cycling Report [R] .2017.4

[8] Liu, Z., Jia, X., Cheng, W., 2012. Solving the last mile problem: ensure the success of public bicycle system in Beijing. Procardia – Soc. Behav. Sci. 43, 73–78.

[9] Wang, Y., Teter, J., Sperling, D., 2011. China's soaring vehicle population: even greater than forecasted? Energy Pol. 39 (6), 3296–3306.

[10] BigDate-Research. China SharingBicycle Market Research Report [R] 2017.2

[11] Zhang TieYing.Study on different urban transport modes' energy consumption [D].Beijing Jiaotong University, 2010.

[12] Zhang Xiuyuan,Yang Xinmiao,Yan yan.Statistical estimation method for energy consumption and carbon emissions by urban transport[J].China Soft Science, 2014, (06): 142-150.

[13] Charnes A,Cooper W W.Rhodes E. Measuring the efficiency of decision making units .European Journal of operational Reasearch,1978,2:429~444

[14] Chen Shuili, Li Jinggong, Wang Xianggong.Application of Fuzzy Set Theory [M]. Beijing: Science Press, 2005.