The influence of bike sharing on urban traffic

summary

The problem of this paper is to evaluate quantitatively the impact of shared bicycles on urban traffic and the economic, social and environmental impacts related to urban traffic. To solve this problem, it is necessary to quantitatively analyze the changes of the economic, social and environmental aspects of urban traffic caused by shared bicycle before and after use under the corresponding indicators.

Based on the panel data of New York City from 1993 to 2015, using *BP artificial neural network*, *multiple regression analysis* and other theories, this paper constructs models of travel mode selection, gasoline gas emission reduction and so on, and analyzes the impact of shared bicycles on all *aspects of urban traffic* from a quantitative point of view With the implementation of the project, the number of car trips in New York City decreased in 2015, the use of public transport and cycling increased significantly, and the number of urban employees increased significantly than expected, reducing the emission of air pollution.

Keyword：*BP artificial neural network*, *multiple regression analysis*, *aspects of urban traffic*

Catalog

I. Restatement of problems

Shared bicycles have changed the urban traffic conditions in many cities, and many large cities have introduced shared bicycles to solve traffic problems. We need to quantitatively assess the impact of shared bicycles on urban traffic, as well as the associated economic, social and environmental impacts. The key to this problem is to establish a reasonable model to predict people's traffic behav-ior if there is no shared bicycles in a city. For example, comparing all travels using shared bicycles with driving cars is not credible. As an attachment to the paper, we need to submit a formal report to the transportation department on the changes that the shared bicycle caused to the city. You can use data from the citibike in New York, or collect data from other cities.

II. Analysis of problems

To analyze the impact of bike sharing project on society, the key is to predict how people's travel structure should evolve if there is no bike sharing project, and then compare and analyze the impact of bike sharing on the travel structure, so as to make basic preparations for the later analysis of its impact on traffic, economy and environment.

The impact of bike sharing on the economy is mainly through the number of trips and the way people travel. From the micro point of view, the number of trips is related to people's economic behaviors such as dining, shopping, tourism and work; from the macro point of view, the way of travel will affect the scale of car sales and the development of public transport system. By analyzing the data of city bicycle users, we analyze the impact of shared bicycle on the economy from three aspects: *city economy*, *membership economy* and *social economy*.

Shared bicycles reduce harmful gas emissions by reducing the use of gasoline in the traffic, which is conducive to resource saving and environmental optimization. It is achieved through two ways: first, shared bicycles reduce the driving of motor vehicles by increasing the riding, directly reducing the consumption of gasoline, and reducing the amount of gasoline can be converted through the mileage of riding; second, shared bicycles change people's willingness to travel, so that For the whole society, public transport consumes less gasoline than private cars, thus reducing the generation of harmful substances. This is the indirect impact of sharing bicycles on the reduction of gasoline, and also the main way of action.

III. General Assumptions

(1) After the implementation of bike sharing, the proportion of changes in travel modes inside and outside the central urban area is the same

(2) Travel mode has habit preference, and the travel mode outside the central city will affect the travel mode entering the central city

IV. Symbolic explanation

Symbol	***Description***
Y_1	Number of vehicles entering the central urban area (1000 per day)
Y_2	Passenger volume of public transport system entering the central urban area (1000 times per day)
Y_3	Number of rides into the central city (1000 times per day)
X_1	Vehicle travel volume outside the central urban area (1000 per day)
X_2	Passenger volume of public transport system outside the central urban area (1000 per day)
β	The average fuel consumption of a family car for one mile (kg)
m_1	Increased cycling mileage from bike sharing (miles per day)
m_2	Reduce the driving mileage caused by sharing bicycles (miles per day)
L_1	Average mileage of a ride (miles)
L_2	Average mileage of a car in one trip (miles)
w_1	Bike sharing increases cycling times (1000 per day)
w_2	Reduced car usage due to shared cycling (1000 per day)
Q	Total reduced gasoline consumption of shared single vehicle project

V. Model establishment and solution

5.1. The impact of Citibike on society

Because people's travel mode generally has a habit preference, the travel mode in the peripheral area of the central urban area is likely to be the way to enter the central urban area, and there may be a certain connection between the travel structures divided by regions. Based on the above analysis, the number of car trips and public transport trips outside the central urban area are selected as independent variables, and the number of cars entering the central urban area, the number of public transport and the number of cycling are used as dependent variables, respectively. *BP neural network* is used to predict the dependent variables.

By drawing the scatter diagram of Y_1, X_1 and X_2, as shown in Figure 1, there is no obvious linear relationship between them, and the single-layer *BP neural network* can approximate any nonlinear continuous function with any accuracy, so we can use the strong nonlinear mapping ability of *BP neural network* to reflect the comprehensive impact of X_1 and X_2 on Y_1. The high discreteness of sample data will reduce the approximation effect of BP neural network, so interpolation is needed to make the data smoother. The interpolation method is used, with X_1 as x axis, X_2 as y axis, and Y_1, Y_2 and Y_3 as z axis respectively. Then use the data after interpolation to train *BP neural network*, and use the network after training to simulate. The simulation situation is shown in Figure 2. As shown in Figure 2, the predicted data are distributed near the fit line and most of the points fall on the line, indicating that the fitting effect is good. The Gaussian distribution of error term is obtained by JB test, which shows that the prediction model has good stability and can predict the data outside the sample.

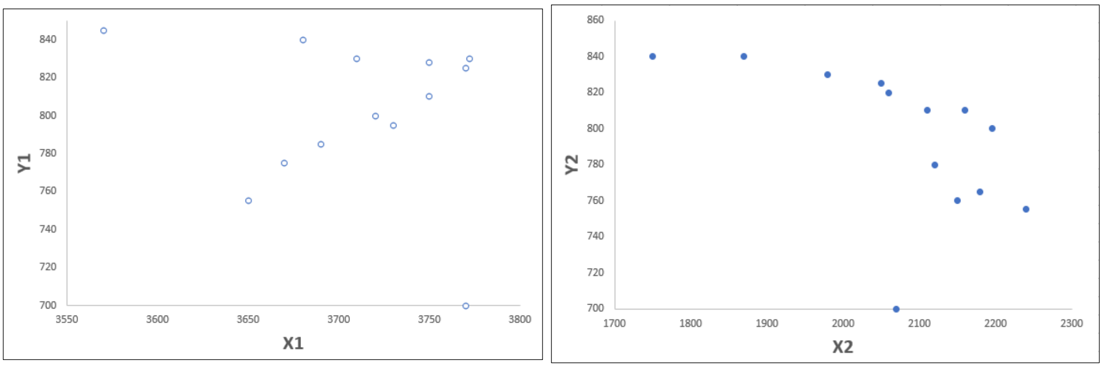

figure 1 Relationship between the number of vehicles entering the central city and the traffic mode of the surrounding areas

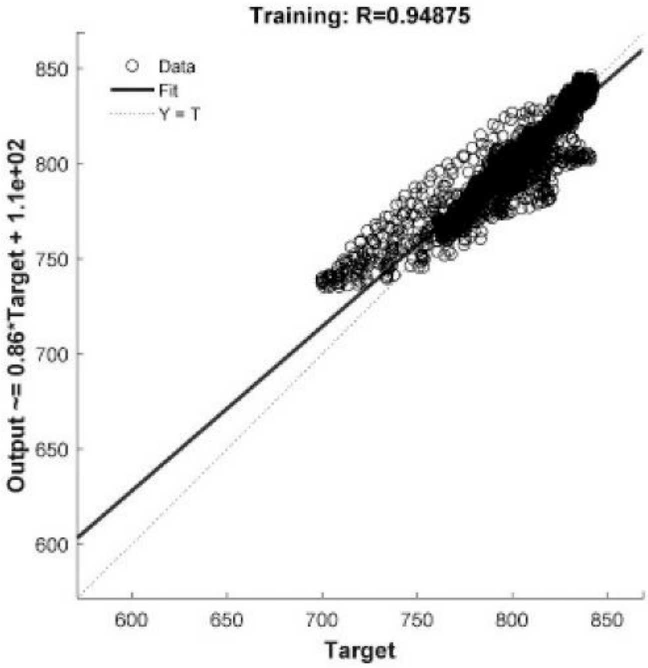

figure 2 Simulation of BP neural network

Using the trained neural network to predict the results, the data in Table 1 is as follows:

Table 1: Analysis table of simulation results of vehicle consumption

Year	Y_1	simulation result	error	error *N (%)*
1998	842	841	0.74	0
1999	842	840	2.29	0
2000	700	738	4.39	1
2001	700	738	-37.98	-5
2002	797	795	1.54	0
2003	832	802	30.16	4

2004	825	824	1.35	0
2005	810	803	6.89	1
2006	806	803	3.35	0
2007	795	794	1.30	0
2008	759	765	-6.08	-1
2009	770	773	-3.25	0
2010	776	771	5.32	1

Compare the simulation results in Table 1 with the actual data, and get the data comparison as shown in Figure 3 below:

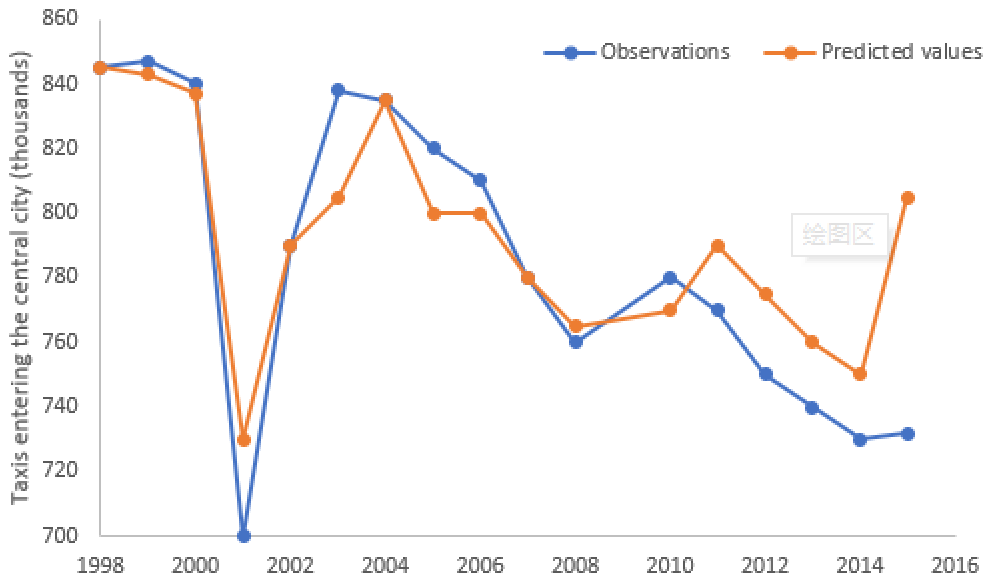

Figure 3 Comparison and analysis diagram of automobile usage prediction model

According to table 1 and figure 3, the predicted number of vehicles entering the central urban area in 2011-2015 is 794, 779, 784, 778 and 800, with the maximum error rate of only 5%. It can be seen directly in Figure 3 that if the shared bicycle plan is not implemented, the vehicle usage should have been on the rise, reaching 800 thousand vehicles per day in 2015, accounting for 20.84% of the total traffic volume; however, in fact, the number of vehicles going to the central urban area is declining year by year, only 731 vehicles per day in 2015, accounting for 19.04% of the total traffic volume, although the vehicle usage is in the total amount of all vehicles However, the proportion of shared bicycles has decreased by 9.4% compared with the theoretical expectation in 2015, which shows that shared bicycles do inhibit the use of automobiles.

Based on the above BP neural network prediction method, the use of public transport system is simulated, and the simulation results are shown in Table 2.

Table 2 Analysis table of simulation results of public transport

Year	Y_1	**simulation result**	**error**	**error** N **(%)**
1998	2294	2303	-9.29	-0.41
1999	2431	2451	-19.99	-0.82
2000	2517	2505	11.92	0.47
2001	2390	2423	-33.03	-1.38
2002	2441	2496	-54.85	-2.25
2003	2392	2419	-26.89	-1.12
2004	2454	2421	32.70	1.33
2005	2472	2446	26.17	1.06
2006	2566	2531	35.26	1.37
2007	2683	2647	36.05	1.34
2008	2743	2657	85.98	3.13
2009	2586	2608	-22.02	-0.85
2010	2662	2663	-0.57	-0.02

The simulation results in Table 2 are compared with the actual data, as shown in Figure 4:

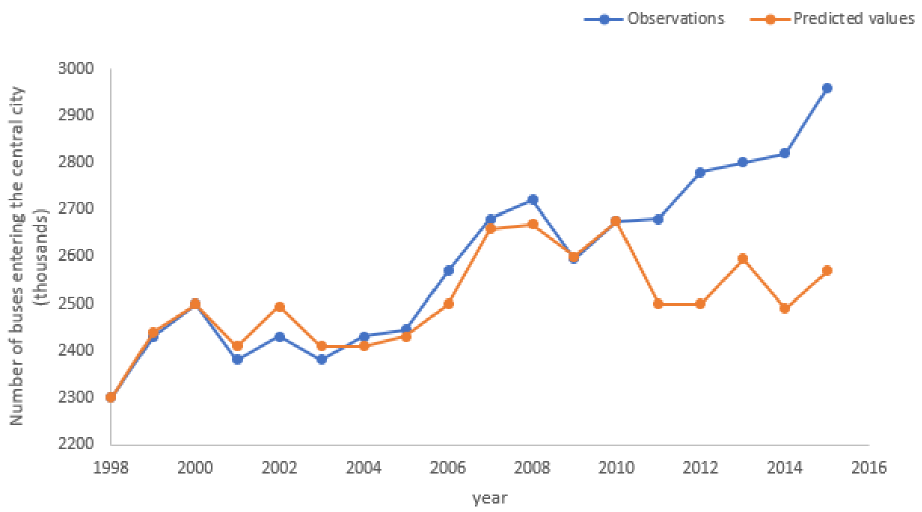

Figure 4 Comparison and analysis of public transport usage prediction models

It is predicted that the usage from 2011 to 2015 will be 2513, 2532, 2582, 2522 and 2546. It can be seen from Figure 4 that, in the absence of a shared bicycle system, the theoretical expectation for the use of public transport system shows a downward trend. In 2015, it dropped to 2546 thousand times per day, which should account for 66.34% of the total traffic volume. However, in fact, the number of public transport to the central city increased significantly. In 2015, the actual value reached 2983 thousand times per day, accounting for 77.71% of the total traffic volume. Its market share in the field of transportation has increased significantly, and its theoretical expected value has also increased by 17.20% compared with its own, which shows that shared bicycles play a very important role in promoting the use of public transport.

In the same way, the simulation data are obtained by simulation of the use of riding, as shown in Table 3 below:

Table 3 Analysis table of simulation results of riding quantity

year	Y_1	**simulation result**	**error**	**error *N (%)***
1998	2.8	2.8	0.01	0.49
1999	2.9	2.7	-0.18	-6.93
2000	2	2.2	-0.20	-9.83
2001	2.5	2.6	-0.14	-5.71
2002	3.2	3.6	-0.36	-11.21
2003	4.4	3.8	0.58	13.22
2004	4.4	4.2	0.15	3.51
2005	4.8	4.3	0.49	10.20
2006	6.6	6.3	0.29	4.35
2007	6.5	7.5	-0.99	-15.23
2008	8.5	8.8	-0.31	-3.61
2009	10.9	10.5	0.40	3.65
2010	11.7	11.8	-0.05	-0.44

The simulation results in Table 3 are compared with the actual data, and the results are as follows figure 5:

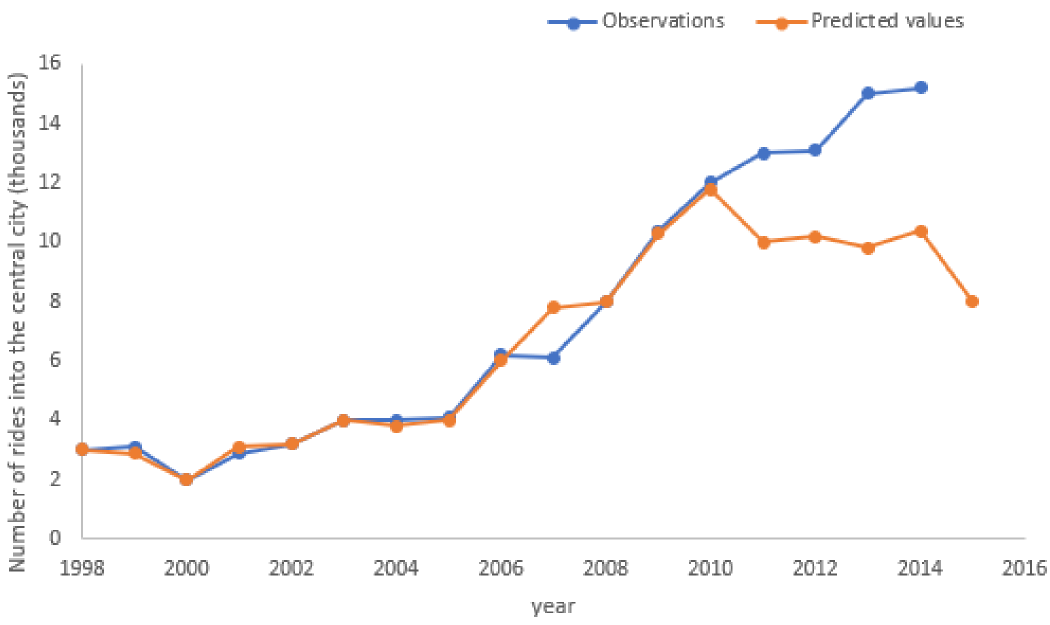

Figure 5 comparative analysis of the prediction model of riding quantity

It is predicted that the usage in 2011-2015 will be 41, 101, 94, 102 and 70. It can be seen from the above figure that, in the absence of shared bicycles, the forecast on the use of cycling shows a downward trend. In 2015, it dropped to 70 thousand times per day, which should account for 0.18% of the total traffic volume. However, in fact, the number of cycling to the central urban area increased steadily. In 2015, the actual value was 154 thousand times per day, accounting for 0.40% of the total public transport volume, which also increased compared with its theoretical expectation The increase of 120% indicates that shared bicycles directly promote the number of riders, which is in line with the expectation of most people.

5.2. The impact of Citibike on economic

After analyzing the data of Citi bike, we will analyze the impact of bike sharing on the economy from three aspects: *city economy*, *member economy* and *social economy*.

5.2.1 Economic impact on Citibike

After corresponding processing of the obtained data, the monthly income of Citigroup in 2013-2018 is obtained, as shown in Figure 6.

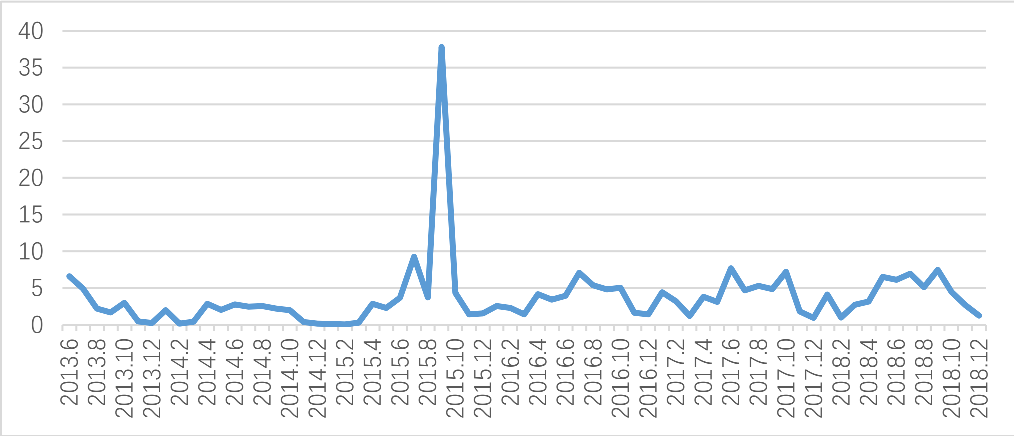

Figure 6 Monthly Citi Revenue 2013-2018

It can be seen from Figure 6 that Citigroup's revenue is basically in a stable state, and there is no obvious trend of revenue growth, and the revenue source is all from membership fee, user fee and sponsorship fee.

After integrating the number of temporary members in the data, the number of annual members and the corresponding monthly income, figure 2 is obtained.

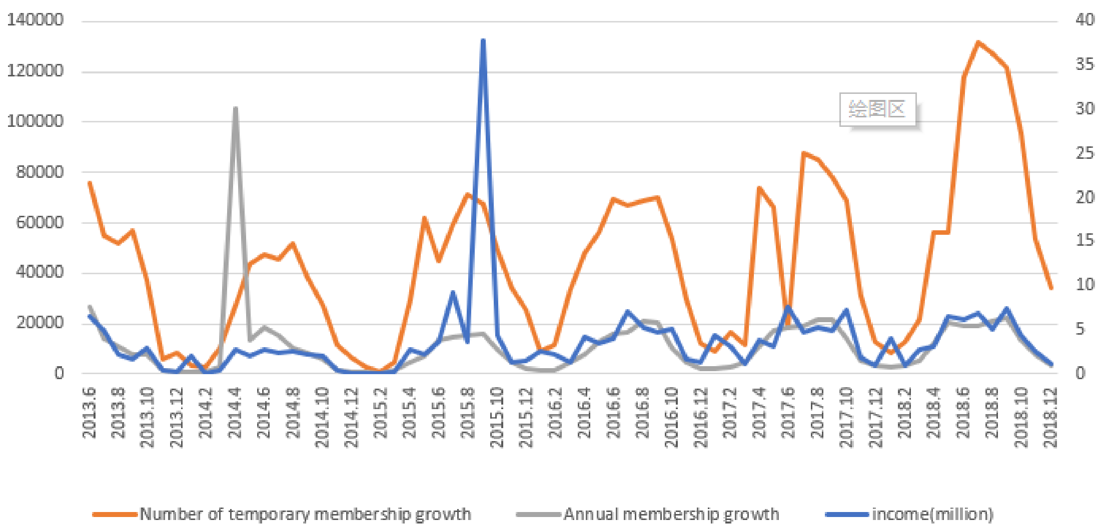

Figure 7 Changes in membership growth and company revenue

It can be seen from Figure 7 that for Citigroup, the growth of temporary members is more conducive to the company's revenue growth and can bring greater benefits than that of annual members.

5.2.2 Economic impact on membership

From the perspective of users, this paper compares the travel distance, travel times, travel time, travel speed and cost of shared bicycles and taxis in the city center. For all trips from and to the city center, Citi bike is at least 2 miles faster and \$6 cheaper than a taxi. More than two-thirds of taxi trips are entirely in the middle of the city, while for a 1-1.5-mile trip, Citi bikes are generally faster than taxis by more than five minutes, and the price is \$11.75 cheaper than ordinary taxis.

5.2.3 Economic impact on society

The impact of bike sharing on social economy is selected as five first-class indicators[1] which are: 36% of business income of bicycle manufacturing industry, 21% of business income of bicycle retail industry, 15% of employment rate, 9% of GDP, and 17% of business income of online car Hailing industry. By analyzing the proportion of the above-mentioned income, it can be found that the impact of shared bicycle on the business income of bicycle manufacturing industry is the largest, followed by that of bicycle retail industry, while the impact on the employment rate and GDP is relatively small.

5.3 The impact of Citibike on environment

After the above analysis, the following formula is obtained:

$$\begin{cases} Q = \beta(m1 + m2) \\ m1 = w1 \cdot L1 \\ m2 = w2 \cdot L2 \end{cases} \tag{2}$$

According to the relevant data, every liter of gasoline burned by an automobile engine will consume 15 liters of fresh air, and exhaust 150-200ml of carbon monoxide (CO), 4-8ml of hydrocarbons (CH), 4-20ml of nitrogen oxides(NO) and other pollutants. Here we take the median value of the range of pollutants generated, i.e. consumption of one liter of gasoline will generate 175ml of CO, 6ml of CH and 12ml of NO, and bring it into the formula(2). The emissions of various pollutants are:

$$\begin{cases} CO = 175Q \\ CH = 6Q \\ NO = 12Q \end{cases}$$

The following results can be obtained by using the data in "Citi Bike & taxis in midtown" of New York mobile bulletin to bring into formula (2)

$$\begin{cases} \beta = 0.132 \\ L1 = 0.959 \\ L2 = 0.834 \end{cases}$$

Combined with the solution results of the travel mode selection model, the gasoline consumption reduction is calculated as follows:

Table 7 Gasoline reduction table

year	w_1	m_1	w_2	m_2	$Q(L)$
2011	9.13	8753.29	30.14	25134.43	4473.18
2012	3.24	3104.03	28.43	23707.17	3539.08
2013	5.28	5059.60	36.76	30657.53	4714.66
2014	4.80	4600.52	46.85	39069.15	5764.40
2015	8.41	8064.45	68.88	57448.51	5647.71

Taking the results in Table 7 into formula (2), the contribution of shared single vehicle project to the reduction of environmental pollutants in the past five years can be obtained. The results are summarized in Table 8 as follows:

Table 8 Contribution of shared bicycles to the environment (L)

year	*CO*	*CH*	*NO*
2011	3401	116	233
2012	3152	108	216
2013	4107	140	281
2015	7496	257	514

It can be seen from table 8 that by 2015, the *CO* emissions, *CH* emissions and *NO* emissions of New York City will be reduced by 7496 L, 257 L and 514 L respectively, and the gas emissions will be reduced to alleviate the environmental pollution with a good trend of increasing year by year.

To sum up, first of all, use *BP neural network* to predict the travel mode, describe the travel structure of people assuming that there is no shared bicycle system, and draw a conclusion by comparing with the actual situation: shared bicycle reduces people's willingness to choose car travel, increases the willingness to take public transport tools, the number of rides has a huge rise, and the conclusion is in line with people's expectations. Among them, the actual car travel is 9.4% less than the expected value, the public transport system is 17.2% more, and the number of rides is 120% more than the expected value. The change of the travel structure, that is, the travel mode with less cars and more buses, will obviously reduce traffic congestion and improve road smoothness. Secondly, through the Granger causality test to determine several variables that affect the number of employees, regression analysis is done to quantitatively describe their impact on the number of employees. The results show that: the actual number of employees is 13% more than the theoretical expectation, and the shared bicycle system has played a role in promoting the economy. Finally, based on the analysis of the impact of travel mode on the air environment, taking gasoline as an intermediate variable, we find that the shared bicycle reduces CO, CH and NO by 7496 L, 257 L and 514 L respectively, and this effect is strengthened year by year.

VI. Model evaluation and improvement

When analyzing the social level of shared bicycle, the BP neural network model is used, which is particularly suitable for solving the internal mechanism complex problems, that is, BP neural network has strong nonlinear mapping ability, which is more suitable for solving the complex social level problems, but we can not judge whether the training makes the results accurately reflect the problems.

References

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Appendix

	临时会员增长数	年度会员增长数	当前总年度会员量	临时会员使用人次	客服电话数	电子邮件数
2013 年 6 月	75838	26515	52130	250947	55271	13973
2013 年 7 月	55001	14185	66315	193440	49831	10726
2013 年 8 月	51637	10823	77138	202563	65798	10825
2013 年 9 月	56579	8103	85241	152,800	41807	7366
2013 年 10 月	37620	7901	93142	100653	32040	5550
2013 年 11 月	5900	1813	94955	44947	18534	2805
2013 年 12 月	8217	1170	96125	19754	9866	1632
2014 年 1 月	3183	1013	97138	7412	5384	1516
2014 年 2 月	2695	726	97864	7247	9979	890
2014 年 3 月	10387	2736	100600	23368	15336	1274
2014 年 4 月	27512	4,767	105367	63197	8631	2016
2014 年 5 月	43878	13303	105359	7979	45997	3547
2014 年 6 月	47516	18364	96318	129223	47289	3621
2014 年 7 月	45830	15359	93501	129339	39297	2738
2014 年 8 月	51744	10055	93184	148422	45566	2456
2014 年 9 月	38415	8387	90879	108816	31962	2262
2014 年 10 月	27421	6043	89286	77189	19545	2627
2014 年 11 月	11566	1262	88495	30909	15034	1306
2014 年 12 月	6808	702	88405	17990	10799	1101
2015 年 1 月	2506	651	88010	6223	6862	1578
2015 年 2 月	1003	402	87898	2345	4646	566
2015 年 3 月	4461	1589	87910	11293	11695	1513
2015 年 4 月	29251	4799	86193	73516	24534	2350
2015 年 5 月	61699	7268	84335	186089	23032	2351
2015 年 6 月	44837	13528	86743	130364	17880	2371
2015 年 7 月	59660	15073	80885	180277	19803	2437
2015 年 8 月	71519	15638	81406	216412	21906	3056
2015 年 9 月	67764	16081	87842	210140	32027	4052
2015 年 10 月	49605	9949	90585	146508	27575	4128
2015 年 11 月	34376	4633	91901	100598	18396	2655
2015 年 12 月	25173	2221	92781	67870	14710	1892
2016 年 1 月	9200	1435	93366	24453	7990	1396
2016 年 2 月	11629	1543	94324	29820	9138	313
2016 年 3 月	33844	4607	97302	93233	17796	1898
2016 年 4 月	48173	7598	100171	130449	22047	2267
2016 年 5 月	56238	12791	105465	175933	25348	3008
2016 年 6 月	69231	16322	108601	192211	33496	3594
2016 年 7 月	66781	16670	109961	201882	24904	3546
2016 年 8 月	68944	20884	114517	218229	27278	3346
2016 年 9 月	70320	20307	118568	221215	28537	4213

2016 年 10 月	53952	10167	118950	171115	20125	4456
2016 年 11 月	29994	4939	119467	85937	15679	3414
2016 年 12 月	12497	2495	119681	32525	9475	5409
2017 年 1 月	8,803	2,353	120,460	23,016	7,046	1,796
2017 年 2 月	16,750	2,634	121,592	42,915	8,512	1,648
2017 年 3 月	11,851	4,617	121,743	26,777	7,046	1,796
2017 年 4 月	74,065	11,019	124,450	188,840	18,001	3,652
2017 年 5 月	66,069	17,363	128,438	189,756	18,192	4,211
2017 年 6 月	18,521	18,521	130,301	214,537	19,239	3,734
2017 年 7 月	87,507	18,968	132,265	261,743	22,865	4,033
2017 年 8 月	85016	21699	132,679	258,006	23835	4236
2017 年 9 月	78082	21912	133944	235038	19692	3994
2017 年 10 月	68782	14049	136,499	207946	15444	7827
2017 年 11 月	31005	5636	136510	90145	10690	5261
2017 年 12 月	13160	3178	136702	34609	5568	3317
2018 年 1 月	8629	3002	137003	22098	6030	2434
2018 年 2 月	12703	3388	138109	33343	6184	2,468
2018 年 3 月	21832	5323	138109	59023	6274	2158
2018 年 4 月	56165	12139	140462	149283	12655	3986
2018 年 5 月	56165	20306	144,590	1242035	20739	6640
2018 年 6 月	117680	19355	146533	258213	22760	6209
2018 年 7 月	131846	19151	147040	284844	23159	7,872
2018 年 8 月	127198	20936	146567	273066	22495	6593
2018 年 9 月	121854	22516	146,437	260890	19654	6685
2018 年 10 月	95519	13569	146760	193371	17887	5979
2018 年 11 月	53455	7980	147090	96224	10878	4034
2018 年 12 月	33965	3653	150743	61598	8261	2,501

	年度会员使用人次	当月使用人次	平均单次使用时间	当月行驶总里程	当月抵消(offset)碳排放量（磅）
2013 年 6 月	367625	618572	21.44	1684574	1,128,665
2013 年 7 月	760432	953872	18.17	1881929	1,260,892
2013 年 8 月	906865	1109428	15.43	2165952	1,451,188
2013 年 9 月	951,727	1104527		2000200	1340134
2013 年 10 月	986517	1087170		1809330	
2013 年 11 月	656672	701619		1082328	562810.56
2013 年 12 月	441117	460871		698298	363114.96
2014 年 1 月	305316	#REF!		456539	237400
2014 年 2 月	240105	#REF!		417577	217140
2014 年 3 月	428064	#REF!		703956	366057.15
2014 年 4 月	608429	#REF!		1231877	640575.88
2014 年 5 月	240105	#REF!		1686310	876881.36
2014 年 6 月	906255	#REF!		1870986	972912.72
2014 年 7 月	932040	#REF!		1850555	962288.6

2014年8月	910641	#REF!		1907282	991786.64
2014年9月	943337	#REF!		1798856	935405.12
2014年10月	846989	#REF!		1496213	778030.76
2014年11月	552801	583710		858608	446476.16
2014年12月	419466	#REF!		615387	320001
2015年1月	307481	#REF!		409152	212759
2015年2月	207441	209795		276296	143673
2015年3月	301422	312715		281461	146359.72
2015年4月	632399	707915		1122050	146359
2015年5月	853586	1039675		1877843	976478
2015年6月	810753	941117		1683557	875450
2015年7月	905200	1085477		2016652	1048659
2015年8月	948121	1164533		2218900	1153828
2015年9月	1079569	1289709		2495965	1297902
2015年10月	1065761	1212269		2505898	1303067
2015年11月	886661	987259		1096567	991415
2015年12月	736242	804112		1500519	780270
2016年1月	484935	509478	12	862931	448724
2016年2月	531045	560865	12	993521	516631
2016年3月	826678	919911	14	1779332	925253
2016年4月	882677	1013126	14	2277315	1184204
2016年5月	1036409	1212342	14.81	2789146	1450356
2016年6月	1268092	146033	14.71	3432044	1784663
2016年7月	1177989	1379871	14.7	3264223	1697396
2016年8月	1339175	1557404	14.72	3482235	1810762
2016年9月	1427310	1648525	14.73	3715405	1932011
2016年10月	1402538	1573653	13.83	3359566	1746974
2016年11月	1098277	1184214	13.22	2692134	1339910
2016年12月	774125	806650	11.64	1732563	900933
2017年1月	700,238	723,254	12	1,606,368	835,311
2017年2月	740,739	783,654	12	1,987,851	1,033,683
2017年3月	695,752	722,529	11.81	1,727,669	898,388
2017年4月	1,126,530	1,315,370	12	3,427,151	1,782,119
2017年5月	1,333,493	1,523,249	14	3,803,981	1,978,070
2017年6月	1,516,618	1,731,155	15	4,126,207	2,145,628
2017年7月	1,473,894	1,735,637	15	4,234,279	2,201,825
2017年8月	1558376	1816382	14.88	4360292	2,267,352
2017年9月	1643120	1878158	14.5	4320996	2,246,918
2017年10月	1689364	1897310	13.9	4062340	2,112,417
2017年11月	1240486	1330631	12.6	2673757	1,390,354
2017年12月	855346	889955	11.6	1814150	943,358
2018年1月	696882	718980	11.3	1410002	733,201
2018年2月	809754	843097	11.6	1749467	909,723
2018年3月	917726	976749	12	2079919	1,081,558

2018 年 4 月	1158268	1307551	13	3124193	1,624,580
2018 年 5 月	1582441	1824476	15	4438017	2,717,882
2018 年 6 月	1694737	1952950	15	3590472	2,915,823
2018 年 7 月	1628795	1913639	15	3532821	2,868,954
2018 年 8 月	1702825	1975891	14.3	3549619	2,807,238
2018 年 9 月	1616389	1877279	14.3	3370028	2,740,649
2018 年 10 月	1702031	1895402	13.24	3160086	2,565,990
2018 年 11 月	1180064	1180064	12.3	2028127	1,628,133
2018 年 12 月	968170	1,276,332	29.41	1829942	951,570