The competition of passenger flow between urban rail transit and conventional bus

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Keywords: Urban rail transit; Conventional bus; Market share; Competition; Logit model

Abstract. Although the rise of urban rail transit will not completely replace the original public transport market, the perfection of the future urban rail network is bound to cause huge impact on the original transport market. This paper analyzes the role and significance of competition and it discusses the existence of competition between urban rail transit and conventional bus. By analyzing the composition of the total cost of residents travel traffic, it quantifies the total transportation cost of traveling of conventional bus and urban rail transit and it uses the improved model of Logit to determine the competition result of urban rail transit and public transportation.

Introduction

Competition is immutable law in nature. In biology, the two groups for the same limited resource will make cruel competition for survival, this is the theory of evolution – “natural selection, survival of the fittest”, which Darwin had put forward.The main function of competition is to optimize the allocation of resources in economics. Specifically competition can arouse the enthusiasm of operators up to the hilt, and make operators provide products with high quality and low price to the market by making them improve their management continually develop and adopt new technology. Through relentless evolution, competition makes the social resources get reasonable configuration and bring the biggest benefit to the consumers and whole society.Meanwhile, many things in the world achieve a certain state of equilibrium through competition.So the competition is an effective means of balance.

Existence of Competition between Them

With the speeding up of urbanization, the problem of urban traffic congestion is increasingly prominent in our country. The construction of urban subway is the better solution to a traffic jam for a long time, which has become the important measure of urban public transportation system which has the development function completely.Obviously, both of them are for the urban residents travel services, it’s not only their original intention for construction, but the goal eventually to achieve. If the urban rail transit and conventional bus are seen as two different manufacturers respectively, their products are the same which is “The spatial displacement” and they are still in the same city scope which is the same market[1]. Therefore, for a city in which are there both urban rail transit and conventional bus, there are competition between them inevitably.

Competition Model between Them

Introduction ofMinimum Generalized Travel Cost Model. People's choice of transportation is determined by its generalized travel cost, which is the comprehensive reflection on quantifying the cost of travel cost、travel time and other factors. The concrete mathematical models are as

follows[6]:

$$\begin{cases} Q = Q(C_i) \\ C_i \le C_i^{'} \end{cases}, \text{ and } C_i = M_i + K_i T_i + S_i \quad (1)$$

In the type, the travel demand of residents is Q;$C_i$means the generalized travel cost when choose transportation i; $C_i^{'}$means the random generalized travel cost;M_i meansthe travel price when choose the transportation i; $T_i$means the travel time when choose the transportation i; $K_i$means the evaluation of time value when choose the transportation i; $S_i$means the quantitative cost equivalent of other factors.

Introduction of Traditional Model of Logit. The share rate curve method and function model method are two ways to research the share rate problems among different modes of transportations. At the same time, the Logit model method is the most common way which is showed as follows:

$$P_i = \frac{\exp(V_i)}{\sum_{J=1}^{J} \exp(V_j)}, V_i = \sum_k a_k X_{ik} \quad (2)$$

In this type, $P_i$means passenger flow share ratio of transportation i; V_i means the utility function of transportation i; J means the number of transportation; means the element of k in the transportation i (the required time、the cost and so on).Obviously, there is a relationship that $0 \le P_i \le 1$and $\sum_i P_i = 1$in the model.

The Improved Model of Logit. The utility function $V_i$of the original model is represented by the total transportation cost $U_i$which different models of transportation i produced. This paper only studies the total transportation cost of urban rail transit and conventional bus, so might as well the urban rail transit traffic cost is represented as U_1; the conventional bus traffic cost is represented as U_2.By improving the Logit model, we get the urban rail transit passenger flow share rate:

$$P_1 = \frac{\exp(-\theta U_1)}{\exp(-\theta U_1) + \exp(-\theta U_2)} = \frac{1}{1 + \exp\theta(U_1 - U_2)} \quad (3)$$

and the conventional bus passenger flow share rate:

$$P_2 = \frac{\exp(-\theta U_2)}{\exp(-\theta U_1) + \exp(-\theta U_2)} = \frac{1}{1 + \exp\theta(U_2 - U_1)} \quad (4)$$

Where θmeans the total cost of transportation right weight coefficients and it’s generally determined by travel survey or parameter estimation method.

It indicates that we must reduce the difference between the total cost of urban rail transit traffic cost and conventional bus transport total cost to improve the urban rail transport in urban transportation system market share when the value of θis a certain.

Through combination (1-6) and (1-7), it shows that when the value ofθ is a certain (might as well take the 0.2218 which paper estimates), we can get the scatter diagram of passenger share rate betweenurban rail transit and conventional bus:

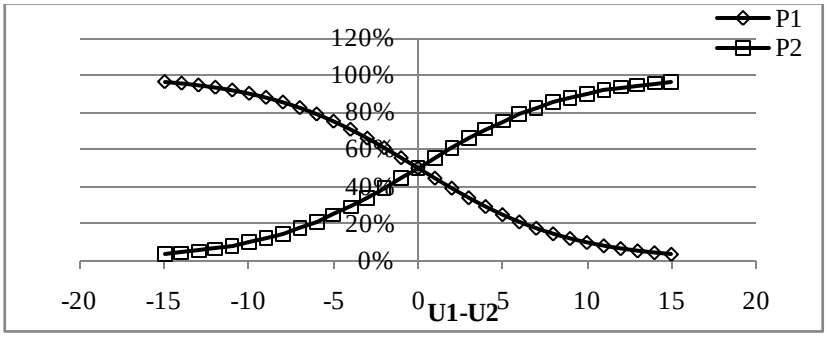

Figure1. the scatter diagram of passenger share rate between urban rail transit and conventional bus

Estimate of Model Parameter

The calibration of the model parameters mainly refers to the results of determining the weight, the weights determined directly affect the accuracy of the model to the actual problem analysis.This paper uses the maximum likelihood estimation method for model parameter calibration. The behavior which people choose the transportation model when they travel can be regarded as independent of each other. So if the number of people who choose the traffic tools is N, it can be seen that the number of Bernoulli trials which has been done is N too. This paper just consider two kinds of transportation: urban rail transit and conventional bus ,so might as well take the number of rail transportation for $N_1$and select the number of bus transportation for N_2. So the likelihood function of$\theta$is

$$f(\theta|P)=P(N_1,N_2|\theta)=\frac{N!}{N_1!N_2!}\prod_{i=1}^{2}P_i^{N_i}=\frac{N!}{N_1!N_2!}P_1^{N_1}P_2^{N_2} \quad (5)$$

In order to get the maximum likelihood estimator ofθ, we can take the logarithm of the likelihood estimation function, so the new function can be presented as:

$$f*=\ln(\frac{N!}{N_1!N_2!})+N_1\ln P_1+N_2\ln P_2 \quad (6)$$

We take the derived first-order to the function, that is

$$\frac{\partial f*}{\partial\theta}=N_1\frac{1}{P_1}\frac{\partial P_1}{\partial\theta}+N_2\frac{1}{P_2}\frac{\partial P_2}{\partial\theta} \quad (7)$$

We take the derived first-order condition to be zero, that is $\frac{\partial f^*}{\partial\theta}=0$; then take the arrangement of the type and simplify it,

$$\ln\frac{N_1}{N_2}=\theta(U_2-U_1)\Rightarrow\theta=\frac{\ln\frac{N_2}{N_1}}{U_1-U_2} \quad (8)$$

Analysis of Urban Rail Transit's Market Share

The Total Cost of Transportation. The total cost of transportation is usually divided into time cost and monetary cost. This article mainly analyzes the total cost of urban rail transit and conventional bus.

Collection cost means the consumed cost in the process from starting point to the selected transport platform and it only considers time cost in general. For a single trip by bus this way, the collection cost means the time cost walk to the platform; for a single trip by urban rail transit, the collection cost means the time cost walk to the rail transit station. Because of the urban rail transit's direct appealed range is not wide enough and the station spacing is too large, residents usually walk a distant way from the starting point to the platform, and this process consumes much time. So the collection cost of urban rail transit is higher than conventional bus when residents walk to the rail station.

Driving cost means the consumed cost through driving on the way when passengers choose a kind of vehicle and it is usually divided into the cost of travel time and the cost of travel monetary. Conventional bus is often interfered by other kinds of transportation and the platform distribution is intensive、the parking is too frequent, so the travel cost is higher. While urban rail transit has a special way and has a high speed, so the travel cost is lower. Driving monetary cost generally refers to the ticket price of the chosen transportation. Obviously, the ticket of both is different. In general, the lower driving cost is at the cost of the higher monetary cost.

Evacuation cost means the cost which is taken in the process from getting off the model of transportation to the destination and it also only consider the evacuation time cost.According to the psychological analysis of the residents, the closer the place in which get off the model of transportation from the destination, the better they will feel when they need to choose the travel route. So the evacuation cost of the above two is almost the same.

Quantify the Total Cost of Transportation. We can quantify the total cost of different transportation after understanding the major components of the total cost of transportation. Clearly, the unit time value of both is different for walking、waiting and driving process.

At present, the domestic quantitative research and the conclusion is less. Referring to the scale factor which has been in use abroad, the conversion value of walking and waiting time is set for 1.5 times wages per unit time, and the conversion value of traveling time is set for half wage per unit time[6].

In addition, according to the current domestic economic level, the national town of private sector employment personnel average annual salary is 46769 Yuan, convert it to pay can we get resident's average income is set to 20Yuan per hour. So the residents are willing to spend 30Yuan to save one hour of walking and waiting time and are also willing to spend 10Yuan to save one hour of driving time. So it is concluded that walking and waiting time cost is 0.50Yuan per minute and driving time cost is 0.17Yuan per minute. According to the current macroeconomic situation in the domestic traffic and vehicle performance, it might as well set the total travel distance L = 10km. Among them, the collection distance of bus is 0.8 kilometers and the collection distance of rail transit is 2 kilometers; walking speed is 4.4 km/h; the bus speed is 20km/h; the rail speed is 40km/h.

So when the residents arrive the platform and the rail station both on foot, we can get the total cost of the two modes of transportation which is shown in Table1.

Table1. The total cost of the two modes of transportation

Components of cost	*Conventional bus*	*Urban rail transit*
Collection cost	—	—
Collection time(min)	10.9	27.3
Cost per minute(Yuan)	0.5	0.5
Collection time cost(Yuan)	5.45	13.65
Driving cost	—	—
Driving time(min)	27.6	12
Cost per minute(Yuan)	0.17	0.17
Driving time cost(Yuan)	4.69	2.04
Ticket cost(Yuan)	1.0	4.0
Driving monetary cost(Yuan)	1.0	4.0
Driving cost(Yuan)	5.69	6.04
Evacuation cost	—	—
Evacuation time(min)	5	5
Cost per minute(Yuan)	0.5	0.5
Evacuation time cost(Yuan)	2.5	2.5
Total cost (Yuan)	13.64	22.19

Now, U_1-U_2=8.55 (9)

Demonstration of the Specific City. By the end of 2012, there are seventeen cities where urban rail transit is on operation in mainland china. Due to the relevant data of Changchun and Kunming is not available and the operation time of Hangzhou rail transit is too late(24 November 2012), so we just get the two models of transport traffic in 2012 which is shown in Table 2:

Table2. The passenger transportation in the city where the urban rail transit has been on operation in our country by the end of 2012

Region	GDP(one hundred million)	Public bus and trams(ten thousand per time)	Urban rail transit(ten thousand per time)	Share rate of Rail transit
Shanghai	20,181.72	280,360	227,573	44.8%
Beijing	17,879.40	515,416	246,162	32.3%
Guangzhou	13,551.21	262,306	185,610	41.4%
Shenzhen	12,950.06	228,305	78,129	25.5%
Tianjin	12,893.88	118,721	11,230	8.6%
Suzhou	12,011.65	44,434	2594.8	5.5%
Chongqing	11,409.60	176,968	24,363	12.1%
Chengdu	8138.94	150,046	10,308	6.4%
Wuhan	8003.82	141,243	8288	5.5%
Nanjing	7201.57	107,118	39,768	27.1%
Dalian	7002.80	82,976	4380	5.1%
Shenyang	6980.53	118,375	22,530	15.9%
Foshan	6613.02	54,230	4388	7.5%
Xi'an	4369.37	174,575	5912	3.3%

(Source: 2013 China Statistical Yearbook Database - sub-regional public transport situation; 2013 provinces, municipalities Statistical Yearbook - regional public transport situation)

At this time, in conjunction with the formula 8 and formula 9 can we get :θ_1=0.0244;θ_2=0.0864;θ_3=0.0405;θ_4=0.1254;θ_5=0.2758;θ_6=0.3322;θ_7=0.2319;θ_8=0.3132;θ9=0.3317;θ_{10}=0.1158;θ_{11}=0.3440;θ_{12}=0.1940;θ_{13}=0.2941;θ_{14}=0.3959; So take the average worth:

$$\bar{\theta}=\frac{\sum_{i=1}^{14}\theta_i}{14}=0.2218 \text{ then, } P_1=\frac{1}{1+e^{\bar{\theta}(U_1-U_2)}}=13.05\% \quad , P_2=\frac{1}{1+e^{\bar{\theta}(U_2-U_1)}}=86.95\%$$

Conclusion

The paper explores the impact on the conventional public traffic after the urban rail transit has

been put into operation mainly from the angle of competition. First of all, the article expounds the role of competition and show the existence of the competition; secondly, the traditional Logit model is improved and the parameter is demarcated by using maximum likelihood estimation method and the parameter estimation has been got through the reality of our country opened rail transit city as an example by the end of 2012. To eliminate the random data, the paper takes the average for the real parameter estimate and gets passenger share rate of urban rail transit and conventional public traffic from macro respective eventually. Finally, we get the scatter diagram of passenger share rate between urban rail transit and conventional bus by using the estimated parameter and it's more intuitive for us to view the share rate of both.

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