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The Model of Supply and Demand Matching of Taxi Resources in Different Time and Space

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Abstract

With the rapid development of the Internet, the taxi-hailing apps is gradually popular. The difficulty of taking taxi problem is getting more and more serious, in order to solve this problem，reasonable adjustments must be made to the supply and demand of taxi resources. So it is necessary to carry out a detailed analysis and Research on the problem of taxi resource allocation. Firstly, the influence factors of supply and demand matching degree are determined, the urban area, the per capita GDP, the third industry value, the proportion of the peak travel, the proportion of people traveling by taxi, and the average daily passenger number in a taxi, and then the relationship between the ratio of taxi demand and supply and the various influence factors are constructed. Secondly, through linear analysis, the weight of total urban area, per capita GDP and third industrial values for the resident travel amount was obtained by using MATLAB Overdetermined Equations solution, and through comprehensive analysis of the relationship between the factors above, deduce the expression of the ratio of taxi demand and supply. Then analyze the ratio of taxi demand and supply, obtained the supply and demand matching degree of taxi in different period of our country. Finally, based on the ratio of taxi demand and supply model, the matching problem of taxi resources in 5 cities was analyzed, and then draws a conclusion.

Keywords: *Probability of Full Taxi; Overdetermined Equations; Weight.*

1. Introduction

Traveling by taxi is one of the most important option for the citizens, but the “difficulty of taking a taxi” problems appeared frequently in life[1]. With the emergence of taxi-hailing apps, a new ages has come for citizens to take a taxi, but whether the supply and demand of the resources of taxis will be reasonable has become the hot topic in society[2]. With the improvement of people's living standards, traveling by taxi is accepted by more and more people. However, in many big cities, the “difficulty of taking a taxi” problems is serious[3], especially during rush hour and bad weather. The “difficulty of taking a taxi” problems has greatly affect the happiness index of people, and it have already become the focus of people's livelihood of the attention from all over the world. This phenomenon exists in many cities, generally with intermittent and regional characteristics[4]. This can be viewed from two aspects: time and area. Time is: The most difficult time to take a taxi are Rush hours, the day which has bad weathers or big events, holiday, etc. Area is: City Center, remote sites, and the area which always has Traffic congestions are also difficult to take a taxi[5]. Therefore, to solve it reasonable, use the resource of taxi properly, match taxis and passengers greatly, analyzing and evaluating the factor which influence. The supply and demand matching degree of taxi is the most important.

2. Different Time and Space the Residents Travel Amount Model of Supply and Demand

Supply and demand relationship according to the supply and demand of taxi directly compares the differences of, so two aspects from different time and different cities were analyzed. Because of taxi supply in each city and each time were no obvious difference, according to the collected data can be obtained directly, and the demand of taxi is influenced by residents travel amount, downtown area, per capita GDP and the third industry value, need to indirectly by limited data to draw other more demand for urban taxi, so the following demand of taxi model is established and the reaction load factors of supply and demand model.

2.1 The influence of different urban taxi demand

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Through the collection of 10 cities, the number of per people out (R) and the urban population (P) can know the residents travel amount from each city:

$$S = R \times P \quad (1)$$

Collection of R, P, G, D and calculation data of residents travel amount S_i see shown in the table below:

Tab.1 Residents travel amount and indexes

cities	the number of per people out R_i	urban population P_i (ten thousand)	residents travel amount S_i (ten thousand every times)
Nanjing	2.44	371.90	907.44
Suzhou	2.43	209.50	509.09
Changzhou	2.86	89.50	255.97
Shanghai	1.95	1262.40	2461.68
Beijing	2.64	676.80	1786.75
Tianjin	2.44	748.00	1825.12
Fuzhou	2.72	153.80	418.34
Zhuhai	3.04	75.90	230.74
Changchun	2.54	298.00	756.92
Wuhan	2.56	341.50	874.24
cities	downtown area C_i	per capita GDP G_i	he third industry value D_i (One hundred million yuan)
Nanjing	2599	20597	544.5
Suzhou	1650	30384	669.0
Changzhou	280	19704	39.1
Shanghai	5300	37382	2509.8
Beijing	1041	25300	1660.9
Tianjin	7417	19986	856.6
Fuzhou	1043	18034	436.0
Zhuhai	1633	48931	148.6
Changchun	3583	14274	423.5
Wuhan	1418	14665	667.9

Residents travel amount is influenced by downtown area (C), per capita GDP (G) and the third industry value (D), so use residents travel amount show the other three factors:

$$S_i = x_1 C_i + x_2 G_i + x_3 D_i \quad (2)$$

Into the data of table 1 can get ten 3 element equation, due to the number of equations is greater than the number of unknowns, constitute the overdetermined system of equations:

$$\begin{cases} 2599x_1+20597x_2+544.5x_3 = 907.44 \\ 1650x_1+30384x_2+669x_3 = 509.09 \\ 280x_1+19704x_2+39.1x_3 = 255.97 \\ 5300x_1+37382x_2+2509.8x_3 = 2461.68 \\ 1041x_1+25300x_2+1660.9x_3 = 1786.75 \\ 7417x_1+19986x_2+856.6x_3 = 1825.12 \\ 1043x_1+18034x_2+436x_3 = 418.34 \\ 1633x_1+48931x_2+148.6x_3 = 230.74 \\ 3583x_1+14274x_2+423.5x_3 = 756.92 \\ 1418x_1+14665x_2+667.9x_3 = 874.24 \end{cases}$$

Overdetermined system of equations is the contradiction system of equations, it's no solution, so need to find a similar solution recently. Through MATLAB solution least squares solution to determine the optimal solution, solve the equations of coefficient can get residents travel amount and expression of three parameters, as long as you know C, G, D, can come to the city's S. This makes with limited data collected by more and more not to collect data by calculating, thus can analyze any taxi resources supply and demand matching degree of a city.

Through the MATLAB solution of overdetermined system of equations is:

$$x_1 = 0.1355, x_2 = -0.0013, x_3 = 0.8171$$

So the formula of residents travel amount is:

$$S_i = 0.1355C_i - 0.0013G_i + 0.8171D_i \quad (3)$$

By collecting all kinds of city residents average way to travel, get a taxi travel proportion, shown in the following table. And with $M_i(i=1,2,3,4)$ represents the first-tier cities, second-tier cities, third-tier cities, forth-tier cities residents travel mode in the proportion of taking a taxi.

Tab.2 The proportion of taxis travel

cities	first-tier cities	second-tier cities	third-tier cities	forth-tier cities
Rate of taxi travel	6%	10%	8%	6%

By the above-mentioned can be obtained: $M_1 = 6\%, M_2 = 10\%, M_3 = 8\%, M_4 = 6\%$

2.2 The influence of different time demand for a taxi

To analyze the impact of travel time demand for taxi, collected all time points in a single day of the urban residents travel rate, as shown in the figure below:

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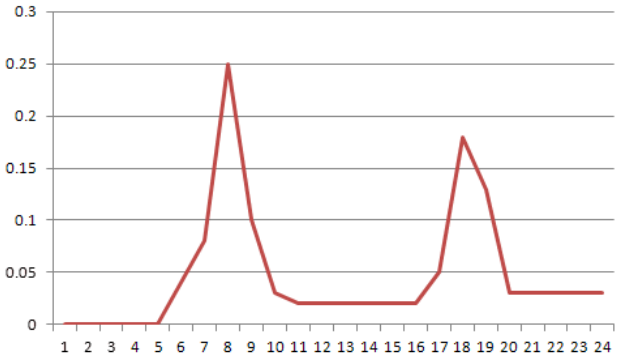

Fig.1 Changing proportion of urban residents travel time distribution pattern

According to the curve to calculate the area of the probability of each time period of urban residents travel, thus it is concluded that the peak (α_1) and off-peak (α_2) proportion of residents. By above clearly know the peak period of a day are 7 to 9, 17 to 19 points, off-peak periods are others, and calculate the peak and off-peak ratio for travel: $\alpha_1 = 55.71\%, \alpha_2 = 44.29\%$

The number of per taxi passengers a day by taxi operation analysis platform, according to its 24 hours on the number of passengers, collected from 8 taxi passenger number during rush hour and the average number of passengers is 30, expressed in Z. Data as shown in the table below shows, the average of Taxi passenger number is 60 a day, the peak average passenger are 30 and the average number of passengers for off-peak are 30 too.

Tab.3 The number of peak passenger

License plate number	Passenger numbers	License plate number	Passenger numbers
Su A8**0	29	Su A4**J	32
Su AD**2	28	Su A6**6	30
Chuan A9**1	34	Chuan AK**8	25
Chuan AP**D	26	Chuan A5**3	37
average		30	

Based on analysis the taxi demand expression is:

$$X_i = \frac{S_i \times \alpha_i \times M_i}{Z} = \frac{(0.1355C_i - 0.0013G_i + 0.8171D_i) \times \alpha_i \times M_i}{Z}$$

$$X_i = \frac{S_i \times \alpha_i \times M_i}{Z} = \frac{(0.1355C_i - 0.0013G_i + 0.8171D_i) \times \alpha_i \times M_i}{Z} \quad (4)$$

The ratio of taxi demand and supply expression is:

$$N_i = \frac{X_i}{Y_i} = \frac{(0.1355C_i - 0.0013G_i + 0.8171D_i) \times \alpha_i \times M_i}{ZY_i} \quad (5)$$

Among them, the type of Y_i is the taxi ownership for each city.

2.3 Based on the ratio of taxi demand and supply of supply and demand matching degree

As can be seen from the ratio of taxi demand and supply the formula: While $N_i = 1$, supply equals demand and the theory of supply and demand balance. But from practical considerations, not all users can be easy to get on the bus. Through the access to information and analysis, the ratio of taxi demand and supply are in good condition is 85%. So, get the following conclusions:

(1) While $N_i \geq 85\%$, taking a taxi is more difficult, demand greater than supply, the matching degree of supply and demand is not reasonable.

(2) While $N_i < 85\%$, taking a taxi is more easy, supply greater than demand, the matching degree of supply and demand is reasonable.

3. The Ratio of Taxi Demand and Supply Model Application Example and Analysis

On the basis of the ratio of taxi demand and supply model, as long as know all unknown variables in the model of the relevant data, you can know the ratio of taxi demand and supply of each city. Finally determine the matching of supply and demand is reasonable. The article collected five city's downtown area, per capita GDP, the third industry value and the supply of the taxi, shown in the following table:

Tab.4 The relevant data of 5 cities

cities	downtown area	per capita GDP	the third industry value	the supply of the taxi
Hangzhou	3068	25074	613	8923
Guangzhou	3719	38000	1452.6	20300
Shenzhen	392	43344	879.6	11433
Dalian	2415	22348	550	12929
Chengdu	1418	14665	682.2	14898

The probability of all kinds of city residents to take a taxi (M_i) according to figure 1, the data generation into the demand and the ratio of taxi demand and supply expression, and calculate the peak and off-peak period of the demand of taxi and the ratio of taxi demand and supply. The date shown in the following table:

Tab.5 The ratio of taxi demand and supply

cities	The number of the taxi (Y)	the peak period of the demand of taxi (X_1)	the off-peak period of the demand of taxi (X_2)	X_1/Y	X_2/Y
Hangzhou	8923	16417	13050.0	1.830	1.460

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Guangzhou	20300	18290	14540.0	0.901	0.716
Shenzhen	11433	7973	6337.0	0.700	0.554
Dalian	12929	13883	11036.7	1.074	0.854
Chengdu	14898	13567	10783.3	0.911	0.724

According to the above data, first analysis of different time the ratio of taxi demand and supply. From table can be seen the ratio of taxi demand and supply for peak were higher than off-peak, this show that it’ s difficult to take taxis relatively in the rush hour. Then analysis of the ratio of taxi demand and supply from 5 cities respectively. In tourist city of Hangzhou and Dalian, the ratio of demand and supply more than 1, showed taxis are in short supply. This is due to the tourist city of foot traffic is more and the taxi ownership is relatively small, increase the number of taxis can reduce its the ratio of taxi demand and supply are appropriately. The taxi matching supply and demand is more reasonable in first-tier cities of Guangzhou and Shenzhen, because of the number of taxis is bigger. Second-tier cities of Chengdu, the ratio of taxi demand and supply is bigger in peak, but in off-peak is reasonable, this is due to the city's taxi resources utilization rate is low, the matching degree of supply and demand is just so so.

4. Conclusions

In the establishment of the model of the matching degree of taxi resources, the factors that affect the taxi demand are too more to choose. This article first from the urban area, per capita GDP, third industry value and other factors that directly affect the city taxi demand, and then deeply analyze peak and non-peak travel ratio, the proportion of taxi passengers and the number of per taxi passengers a day, obtained the expression of the demand, this is based on the assumption that all taxi are in operation each time of a day, taxi amounts remained unchanged and there is no extreme weather conditions and no special holiday conditions.

In the calculation of the weight, which plays a key role is that the least square solution of over-determined equations, the optimal solution is obtained by using MATLAB software. Although the least squares solution has some errors, the expression of the demand can explain problem well. The over-determined equations can be applied to the problem of taxi resource allocation, and the effect is good. The establishment of the model accords with the actual situation, it is advantageous to promote the allocation of the taxi resources in various cities, and get the optimal integration of taxi resources, then promote the development of urban traffic. The model is easy to solve and has good application prospect and popularization value.

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