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Airport Taxi Decision and Management Model based on Maximum Benefits

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Abstract. Airport taxis are an important means of transportation for airport passengers. In order to avoid the waste of airport taxi capacity, we will establish a judgment formula based on the comprehensive supply and demand relationship and profit relationship. And we will select other important factors by cluster analysis as a supplement to establish a judgment algorithm and validated the algorithm by multiple linear regression and examples. Then we use the queuing theory to determine the position of optimal taxi pick-up point and achieve the long-distance and short-distance taxi driver income balance by dividing the level.

Keywords: queuing theory; Multiple linear regression; Cluster analysis; BP neural network.

1. Introduction

After the taxi drivers arrive at the airport and customers get off the car, drivers usually face two choices: to return to urban area with empty taxi or to queue up in the storage pool and return to urban area with new customers. The factors that influence decision-making are multi-faceted. If drivers can't make a reasonable decision, it will lead to a waste of taxi resources. Due to the unreasonable setting of the pick-up point, sometimes there will be a phenomenon in which the taxi queues to carry passengers or the passengers line up to ride in the boarding area, which wastes the time of the passenger or the driver. Short-distance passengers who cannot be refused have caused inconvenience to airport taxis, resulting in uneven income.

We will study the above problems, and take Shanghai *Pudong Airport* as an example to propose solutions from three aspects: driver decision algorithm, car parking area setting, and short-distance passenger taxi priority policy.

Table 1. Symbol table

Abbreviation	Description	Unit
t_i	Time	Hour
F_i	Fuel cost	RMB
M_i	Taxi income	RMB
y	Number of flights arriving within a certain period of time	frame
x	Number of taxis in the storage pool	vehicle
α	Average number of passengers per aircraft	people/frame
γ	Average proportion of the number of person who choose taxis per aircraft to the total number of people	%
P_i	Taxi income	RMB
W_0	Taxi driver's average hourly earnings	RMB/hour
l	Distance from the airport to the city	Kilometer

2. Process and Method

2.1 Decision Algorithm

2.1.1 Pre-judgment

Assuming that the number of passengers at the airport is greater than the number of passengers in the storage pool, the supply is in short supply, the driver has reason to enter the storage pool to wait, otherwise the decision can be made without comparison. It is known that each taxi carries an average of 2 passengers, and the number of vehicles required is:

$$x_0 = \frac{y*\alpha*\gamma}{2} \tag{1}$$

When the actual number of parking spaces in the storage pool is $x>x_0$, the taxi driver returns to the urban area, otherwise he or she enters the storage pool.

2.1.2 Determination of Queuing Time

Assuming that the queue time is t and it takes 20 seconds for the passenger to get on a taxi. So, the t required is:

$$t = \frac{x}{180} \tag{2}$$

2.1.3 Profit Calculation for Two Options

Method1: Enter the storage pool to queue. The waiting time in the storage pool is t, the gas consumption per kilometer in the queue is c, the fuel consumption cost in the urban area is F_1, and the passenger fee is M_1. The profit in this period is P_1. So, the P_1 and M_1 required are:

$$\begin{cases} P_1 = M_1 - F_1 \\ F_1 = cl \end{cases} \tag{3}$$

Method2: Empty back to the city. On the basis of Method1, the average hourly income of the taxi driver is W_0, and the passenger fee is M_2, then the profit P_2 during this period is:

$$\begin{cases} P_2 = M_2 - F_1 \\ M_2 = W_0 t \end{cases} \tag{4}$$

Let P_1=P_2, when the waiting time is t_0, you can get:

$$t_0 = \frac{M_1}{W_0} \quad . \tag{5}$$

$t_0$is the decision time for the two choices. If the real waiting time is t<t0, then the airport waits for the same time to make more profit, and driver should choose to enter the storage pool to queue.

And we transform the above model into a decision algorithm. In addition, we also trained BP neural network algorithm through data, and used Monte Carlo method to generate random number series for verification, but the effect is not good, and will not be described here.

2.1.4 Impact of Other Factors on Decision Outcomes

This paper analyzes the impact of weather factors and time period factors on passenger capacity. We selected 3 days of data and used *matlab* for cluster analysis to explore relevance. The result of the decision is further revised, and the result is shown as follows:

Table 2. Clustering results of related factors and passenger capacity

table	Two types	Three types
Frist type	Time, passenger capacity, temperature	time
Second type	Weather, rainfall	Passenger capacity, temperature
Thrid type	/	Weather, rainfall

According to the clustering results, the following conclusions can be drawn: It is recommended that the taxi driver evaluate the weather conditions. When the outside temperature is extreme in the summer and winter seasons, the passenger load is higher, the chance of receiving the order is larger, and the passenger may be inclined to return to the city.

2.2 Decision Algorithm Verification

2.2.1 Instance Verification

We selected Shanghai *Pudong Airport* as a verification example and obtained information about *Pudong Airport.* Through the above decision algorithm, we have reached the conclusion as shown in Table 2. The 14 periods covered by the color, that is, the supply shortage period. The value in the last column is 1 for the choice to stay. The final decision to stay is basically consistent with the pre-judgment and the actual situation, which proves that the pre-judgment model and calculation are reasonable. The pre-judgment and final result error rate are about 8%, which is acceptable

time	supple<de	t1	P1	P2	P1-P2	leave/stay
5: 30-6: 30	1	0.16	147	10.31	136.69	1
6: 30-7: 30	0	1.18	147	75.38	71.62	0
7: 30-8: 30	1	0.62	147	39.47	107.53	1
8: 30-9: 30	0	1.31	147	83.56	63.44	0
9: 30-10: 30	1	0.93	147	59.38	87.62	1
10: 30-11: 30	1	1.53	147	97.78	49.22	1
11: 30-12: 30	0	2.57	147	164.27	-17.27	0
12: 30-13: 30	1	1.92	147	122.67	24.33	1
~~13: 30-14: 30~~	~~1~~	~~2.31~~	~~147~~	~~147.91~~	~~-0.91~~	~~0~~
14: 30-15: 30	1	1.97	147	126.22	20.78	1
15: 30-16: 30	0	3.17	147	203.02	-56.02	0
16: 30-17: 30	0	3.93	147	251.73	-104.73	0
17: 30-18: 30	0	3.19	147	204.44	-57.44	0
18: 30-19: 30	0	2.71	147	173.16	-26.16	0
19: 30-20: 30	0	2.97	147	189.87	-42.87	0
20: 30-21: 30	1	2.31	147	147.56	-0.56	0
21: 30-22: 30	0	4.09	147	262.04	-115.04	0
~~22: 30-23: 30~~	~~1~~	~~4.23~~	~~196~~	~~295.94~~	~~-99.94~~	~~0~~
23: 30-0: 30	1	2.34	196	163.72	32.28	1
0: 30-1: 30	1	1.24	196	87.11	108.89	1
1: 30-2: 30	1	0.83	196	57.94	138.06	1
3: 30-4: 30	1	0.00	196	0.00	196.00	1
4: 30-5: 30	1	0.22	196	15.17	180.83	1

Fig 1. Relevant basis and results of the judgment.

2.2.2 Correlation Analysis of Related Factors

We performed multiple linear regression analysis on the main factors on which the algorithm relied by SPSS. We use var1-var5 to represent the number of vehicles in the storage pool, the number of flights entering the port, the relationship between supply and demand, P1, P2, and use var7 to indicate the decision result. The results are as follows:

model	R	R^2	adjusted R^2	Standard estimated error
1	.861[a]	.741	.665	.29561

a. Predictor: VAR00005, VAR00004, VAR00003, VAR00002, VAR00001

Fig 2. Model comprehensive fitting degree

ANOVA[a]

Model		sum of square	Degree of freedom	Mean square	F	Significant
1	return	4.254	5	.851	9.735	.000[b]
	Residual	1.486	17	.087		
	total	5.739	22			

a.Dependent variable: VAR00007
b. Predictor: VAR00005, VAR00004, VAR00003, VAR00002, VAR00001

Fig 3. Model Synthesis Degree of Freedom

It can be seen from the above chart that the multi-factor fitting degree reaches 0.741, which indicates that the algorithm has a high degree of rationality and high dependence on the influencing factors. The comprehensive degree of freedom indicates the flexibility of the algorithm, which is 9.735, indicating high flexibility.

2.3 Determine the Location of the Pick-up Point in the Taxi Area

2.3.1 Determination of the Number of Parking Spaces

Assuming that the condition for the vehicle to enter the passenger zone from the storage pool is that there are free parking spaces. From the time the first car enters the passenger zone, the time it takes to stop at the parking space obeys uniform distributions whose mean is 5s and deviation is 2s. After the vehicle in front stops at the parking position, the time required for the vehicle to stop at the rear berth obeys uniform distribution whose mean is 3s and deviation is 1s. We calculated the full passenger time of the passengers carried in 231 taxis. The analysis shows that the passengers' boarding time is approximately obeying the exponential distribution whose mean is 15s. The capacity of the airport taxi pick-up system C can be expressed by the formula:

$$C = \frac{\mu \times \mathrm{n} \times \mathrm{k}}{t} \times 3600 \tag{6}$$

μ is the passenger coefficient; n is the number of berths; k is the total number of simulated rounds; t is the sum of the simulation times. When the number of parking spaces increases from 1 to 10, the following table is available:

Table 3. The relationship between the number of parking spaces and capacity

Number of parking spaces	the last parking space utilization	t	C
1	78.5	23089	227
2	77.2	32410	326
3	75.9	40968	387
4	74.9	48689	438
5	73.1	62662	480
6	72.5	62663	508
7	72.2	71895	512
8	72.8	81461	521
9	72.4	91063	526
10	73.3	103329	492

When the number of berths is 7, the improvement of traffic capacity is not obvious, and the increase of the number of berths leads to an increase in management difficulty. Therefore, the simulation experiment shows that the optimal number of berths in the passenger zone of a single-lane taxi is 6.

2.3.2 Comparison of the Efficiency of the Combination of the Pick-up Points

Considering the difficulty of regulation and the efficiency of riding, this paper sets the upper limit of the number of boarding points to be the same as the number of parking spaces and gets the optimal ride efficiency of different combinations by queuing theory algorithm as follows.

Table 4. Optimal combination of parking spots

Number of points	Efficient arrangement	Maximum efficiency(Vehicle/hour)
1	R1	180
2	R1,R2;R2,R1	313
3	R1,R2,R3 R1,R3,R5 R1,R4,R5	415
4	R1,R2,R3,R4 R1,R3,R4.R6 R1,R3,R5,R6	497
5	R1,R3,R4,R5,R6	563
6	R1,R2,R3,R4,R5,R6	617

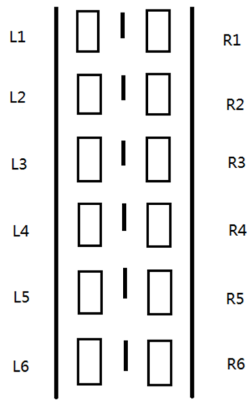

Fig 4. Parking space planning model

2.4 Driver Income Equalization

2.4.1 Queue Time under the Balance of Income

Assuming a mileage of less than 25 kilometers and a journey time of less than one hour is called a short trip. Taking *Pudong Airport* as an example, we have four towns that meet short-term conditions: Zhangjiang Town, Caolu Town, Heqing Town, and Chuansha Town.

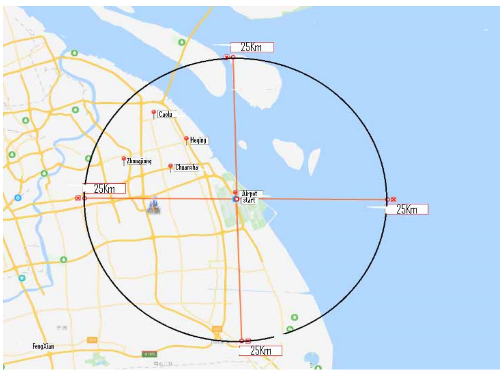

Fig 5. Short-range map

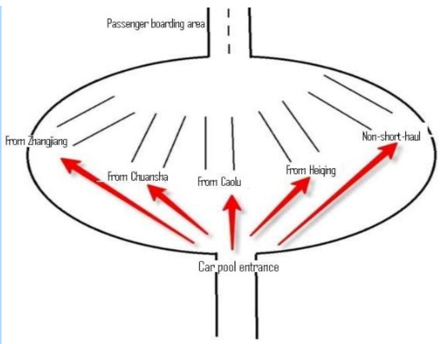

Fig 6. Schematic diagram of storage pool management

Divide taxis into two categories:

Short-distance route: airport - (short-haul) destination - airport (queuing) - (long distance) urban area. Long-distance route: Airport - (long distance) urban area. Let C be the income from sending passengers back to the city center. $\overline{C}$ is the income after returning to the urban area. $\hbar_0$ is the time to arrive at a short destination. $\hbar_1$ is a normal queue time. $\hbar_2$ is the priority queue time. $\hbar_3$ is the time from the airport to the urban area. R is a short-term gain. When the profit of the two types of routes is equal:

$$\mathrm{C} + \overline{C}(2\hbar_0 + \hbar_2) = R + C \tag{7}$$

We can get:

$$\hbar_2 = \frac{R}{C} - 2\hbar_0 \tag{8}$$

Let the total duration is: $2\hbar_0 + \hbar_3 + \hbar_1$

The short-distance route (normal queue) benefits are: $R + C$

The short-distance route (priority queuing) benefits are: $R + C + \overline{C}(\hbar_1 + \hbar_2)$

Long-distance route revenue is: $\mathrm{C} + \overline{C}(2\hbar_0 - \hbar_2)$

2.4.2 Priority Arrangement Planning in the Storage Pool

Electronic checkpoints are set at the entrance and exit of the storage pool. When the taxi enters the storage pool, the electronic monitoring records its license plate number and starts timing. The vehicles returning from different locations are diverted in the storage pool. Each town return vehicle has a different waiting time, and when it is reached, it can be preferentially entered the parking space. According to the distance from Pudong Airport to different locations, the priority will be arranged: Zhangjiang Town> Chuansha Town> Caolu Town> Heqing Town. When multiple vehicles are allowed to enter the parking space at the same time, they are released according to the priority from large to small. Schematic diagram of storage pool management is shown in Figure 6.

2.4.3 Model Verification

In order to verify the practicability of the model, this paper has entered relevant data according to the actual situation, as follows:

Table 5. Taxi to townships related data

Town	Time/h	Distance /km	Income/￥	Night Income/￥	h1/h	h0/h
Caolu Towm	0.48	22.9	76	98.8	1.41	0.54
ZhangjiangTown	0.37	17.1	54	70.2	0.95	0.29
Chuansha Town	0.33	18	58	75.4	1.146	0.55
Heiqing Towm	0.47	24.9	84	109.2	1.70	0.86

We brought it into the model to get the taxi revenue. The results are as follows:

Table 6. Comparison of taxi income

Caolu	Long-	Short-distance	Short-distance	Increase in
12:30-13:30	283	231	283	22.63%
13:30-14:30	316	231	316	36.59%
14:30-15:30	290	231	290	25.74%
ZhangjiangTow	Long-	Short-distance(normal)	Short-distance	Increase in
12:30-13:30	276	209	276	31.96%
13:30-14:30	308	209	308	47.40%
14:30-15:30	283	209	283	35.41%
Chuansha Town	Long-	Short-distance(normal)	Short-distance	Increase in
12:30-13:30	274	213	274	28.48%
13:30-14:30	306	209	306	46.38%
14:30-15:30	281	209	281	34.39%
Heiqing Towm	Long-	Short-distance(normal)	Short-distance	Increase in
12:30-13:30	282	239	283	18.34%
13:30-14:30	314	239	315	31.84%
14:30-15:30	289	239	290	21.36%

As can be seen from the chart, after the priority policy, the profit received by drivers who received short-term orders increased by at least 18%. This policy is good for balancing taxi revenue.

3. Summary

In this paper, we have established a decision-making suggestion algorithm based on the relationship between supply and demand and income of airport taxis. Then we analyze the influence of weather, temperature and other factors on decision-making through clustering algorithm and use it to supplement the suggestion. We validated the algorithm with Shanghai *Pudong Airport* as an example, and demonstrated the reliability of the model by using SPSS to perform multiple linear regression analysis on the influencing factors of the model. Based on the algorithm of queuing theory, we calculated that the optimal parking space in the waiting area is 6 and the optimal combination of the boarding points in different situations is obtained. By classifying short-distance vehicles, we established a short-haul priority mechanism and brought the data from Pudong Airport for verification. The verification results were good and the profit of short-haul vehicles increased by at least 18%.

In summary, an airport Taxi Decision and Management Model Based on Maximum Benefits is established and the model will be used to increase the revenue of airport taxi drivers and the efficiency of airport taxi rides, reducing the waste of taxi resources.

References

[1]. Zhongbo Geng, Guohua Song, Qi Zhao, et al. This model will be used to increase the revenue of airport taxi drivers and the efficiency of airport taxi rides, reducing the waste of taxi resources. Journal of Civil Aviation University of China. Vol. 31 (2013) No. 6, p. 55-59.

[2]. Jian Sun, Rijia Ding, Yanyan Chen, et al. Modeling and Simulation of Single Lane Taxi Boarding System Based on Queuing Theory. Journal of System Simulation. Vol. 29 (2017) No. 996, p.1004.

[3]. Weiyan Meng, Hongda Jin, Fan Dai, et al. Application of Intelligent Monitoring Technology in the Taxi Queue Management System at Airport. The 9th China Intelligent Transportation Conference. Guangdong, 2014.11, p 1014-1018.

[4]. Heng Jiang, Haijun Wu, Zhengquan Zhou, et al. Research on large hub taxis to the grid and turnover parking spaces. China Urban Transport Planning 2012 Annual Meeting. Fuzhou, 2012.11.8, p. 1239-1247.

[5]. Academic papers(Chao Yan: Research on Public Traffic Management on the Road Side of Shanghai Hub Airport (Master's degree, East China Normal University, China 2015). p.1-101.)