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Research Paper

Optimization Model of Airport Taxi Management

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ABSTRACT: *Considering the situation in which airport taxis line up passengers and passengers to queue up, this paper has two parallel lanes in the airport "car area", establishes M/M/n queuing model, and optimizes the setting of "cashing point". Under the condition of ensuring the safety of vehicles and passengers, the total riding efficiency is the highest. Secondly, considering that the revenue of the rental car passengers at the airport is related to the mileage of the passengers, the destination of the passengers is far or near, and the taxi driver cannot select passengers or refuse to carry the passengers, but allows the taxi to travel to and from the passengers multiple times. In order to make the income of the taxi driver as balanced as possible, establish a wait time model for drivers with priority and no priority, the specific "priority" given to the taxis returned by some short-haul passengers is given, and the plan is simulated by Monte Carlo algorithm to verify the feasibility of the plan.*

KEYWORDS: *Airport taxi; Decision-making plan; Optimization model; Monte Carlo algorithm*

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I. INTRODUCTION

Combined with the actual situation, the mathematical model is established to solve the following problems:

(i) There are two parallel lanes in the "ride area" of an airport. The management how should set up the passenger "boarding point" and reasonably arrange the taxis and passengers so as to make the overall ride efficiency the highest.

(ii) It is stipulated that taxi drivers are not allowed to choose passengers or refuse to take them, in order to balance the income of some taxi drivers who return from short distances, please give a reasonable "priority" arrangement.

II. ANALYSIS OF THE PROBLEM

2.1 Analysis of problem (i)

The setting of boarding point should make the satisfaction of passengers or drivers as much as possible, we take the driver as an example to analyze. The satisfaction of the driver depends to a large extent on the income, and the sooner the driver is arranged to pull the customer, the more likely the driver will get more profit, so we take the shortest waiting time as the optimization goal, establish the optimization model according to the idea of queuing theory, and solve the most suitable number of boarding points with the help of Lingo. For the arrangement scheme of taxi and driver in the driving area, it is necessary to meet the total ride efficiency, but the constraints given in the problem are so limited that it is difficult to establish a model from the positive to obtain the overall riding efficiency and arrange the plan, so this paper considers the idea of backstepping to solve the problem. Transforming the riding efficiency into the matching degree between taxis and passengers, and analyzing the conditions that need to be met when the matching degree reaches a maximum of 1, then rolling out the taxis and passengers arrangement plan.

2.2 Analysis of problem (ii)

Problem (ii) requires us to develop a priority plan for taxis returning for short-haul passengers, as there is no phenomenon of the driver in the middle of the queue upon return, so this paper considers the short-distance taxi return to the airport directly first priority program. However, we need to verify whether this plan is reasonable or not, this paper considers the driver's earnings equilibrium as a benchmark to verify the rationality of the model. First, we need to give the "use" threshold of priority; secondly, give the number of times of use of priority; Finally, based on Monte Carlo algorithm to the driver's income multiple times, to judge whether the benefits of using priority drivers and those of "long-distance" drivers have reached an equilibrium value, then roll out whether the model is reasonable.

III. MODELING AND SOLVING OF THE PROBLEM (I)

3.1 Establishment and solution of the optimization model for boarding point

According to the requirements of the problem, we should first determine the number of "boarding points" under the two parallel lanes and the location arrangement, that is, to determine the number of taxi and passenger service desks in the airport. The constructed service desk should not waste resources, but also shorten the waiting time of drivers and passengers. Because the number of drivers and passengers is unlimited and obeys Poisson distribution, both drivers and passengers can be regarded as customers, and the M/M/n queuing model can be used [4]. Here, we take the driver as the customer as the example to carry on the analysis. The average waiting time of the driver under the model is:

$$J_q = J_s - \frac{1}{\mu},$$

where the length of stay of the driver $J_p = C_s / \lambda$, λ represents the average number of taxis arriving at the airport storage pool per unit time, μ represents the average number of drivers to be received within a unit time, and the average length of time for each driver to receive a passenger is $1/\mu$. Combined with the above analysis, you can get $\lambda = 285$, $\mu = 5785$.

1) Determination of objective function

The purpose of setting up a "boarding point" is to enable the airport to better serve everyone, so that the satisfaction of the people is higher, and taxi drivers naturally yearn for higher benefits, that is, the cost of time consumed is lower, so the shortest waiting time of the driver is the optimization objective, that is:

$$\min \ J_q = J_s - \frac{1}{\mu}.$$

2) Determination of constraint conditions

Constraint condition I: Driver waiting probability constraint

When the system reaches the load of λ / μ, there are n service desks in the service system.

Constraint condition II: Average waiting time constraint for drivers

$$J_q = P_{wait} \frac{1}{\mu (n - load)},$$

where $load = \lambda / \mu$.

Constraint condition III: Average captain constraint of taxi

$$C_s = C_q + \frac{\lambda}{\mu}.$$

Constraint condition IV: Average waiting time constraint for drivers

$$C_q = \lambda J_q.$$

To sum up, the following optimization models can be established:

$$\min \ J_q = J_s - \frac{1}{\mu}.$$

$$s.t.\begin{cases} J_q = P_{wait}\dfrac{1}{\mu(n-load)}, \\ C_q = \lambda J_q, \\ C_s = C_q + \dfrac{\lambda}{\mu}, \\ n \in N. \end{cases} \quad (1)$$

The model (1) is solved by Lingo software programming. When the number of service desks is 4, the average waiting time of the driver is the least, and the minimum waiting time is 2.07 hours. Therefore, the management department should set up 4 boarding points reasonably.

3.2 Taxi and passenger arrangement scheme

According to the above, we need to set up 4 "Pick-up point" on two parallel roads, taking into account that if two " Pick-up point " are set on both sides of the road, the taxi on the front " Pick-up point " on each lane will block the taxi driving of the rear " Pick-up point ", Therefore, a number of " Pick-up point " are not set before and after a lane. In order to avoid this problem, the four " Pick-up point " positions set in this paper are as follows:

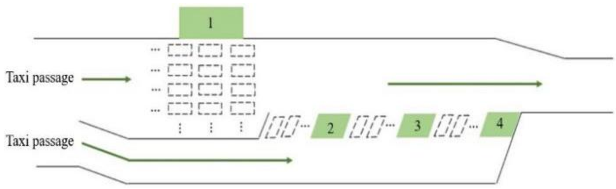

Figure 1. Location distribution map of boarding points

This paper stipulates that passengers take taxis in the boarding area. The specific process of the driver picking up passengers is as follows: Airport bus area staff in unit time to release a certain number of taxis waiting for passengers in the bus area, while allowing some passengers waiting in the queue to enter and taking a taxi at the pick-up point in the bus area. When this part of the passengers leave by taxi, the taxis waiting in line continue to enter the bus area by a certain number, while the other passengers can enter the boarding point to take a taxi as a cycle. However, it should be noted that before entering the boarding point, passengers can choose the corresponding team at different boarding points waited in line and when you are allowed to take a taxi, go to your own boarding point to take a taxi.

Through the above process, it is necessary to establish a model for the classification of taxis and passengers, so that the total ride efficiency can reach the maximum, that is, the greater the matching degree between taxis and passengers. When the matching degree between taxi and passenger reaches 1, there will be no scene of taxi queuing to pick up passengers and passengers queuing to wait for the car, that is, the time between driver and passenger will be made the best use, and the expectation of ride efficiency will be met. According to the idea of reverse analysis, this paper puts forward a reasonable taxi and passenger arrangement scheme.

When the matching degree is 1, it represents the released all taxis $N(t)$ succeeded in carrying passengers, and the corresponding passengers who chose to travel by taxi were also pulled away, that is:

$$\phi(N, Q) = 1.$$

According to the actual living conditions, it is possible for one of the passengers who take a taxi to take the bus alone, or for many people (greater than or equal to 2) to accompany each other. The statistical analysis of the data of Beijing taxi carrying passengers at the airport is obtained by consulting the literature. It is concluded that the number of passengers taking taxis accounts for the proportion of passengers. The specific results are as follows:

Table 1. Proportion of taxi passengers carried

Number of passengers carried	1	2	≥ 3
Proportion	78.26%	17.39%	4.35%

Therefore, based on the matching degree and the data found, the constraint conditions corresponding to the number of taxis released and the number of passengers are established:

$$x_1 + x_2 + x_3 + x_4 = \mu_1^{'}P + \frac{\mu_2^{'}P}{2} + \frac{\mu_3^{'}P}{3.5}, \quad (2)$$

where x_1, x_2, x_3, x_4 represent the number of taxi release of the entry points 1,2,3,4, respectively, $\mu_1^{'}, \mu_2^{'}, \mu_3^{'}$ indicate the proportion of passengers with $1, 2, \geq 3$ passengers. According to the location distribution map of the boarding point, it can be seen that the taxi carrying capacity of boarding point 1 is larger than that of boarding point 2, 3, 4, so the passenger distribution capacity of boarding point 1 is also increased. It may be useful to make the proportion of passengers allocated as follows:

$$x_1 : x_2 : x_3 : x_4 = 2:1:1:1 \quad (3)$$

Combining the specific data of a certain time with formula (2) and formula (3), the number of taxis and the number of passengers can be obtained. Taking 0:43:00 on September 2 as an example, the number of flights arriving at this time is 3, the average carrying capacity is 186, and the proportion of passengers who choose to take a taxi is 0.3, that is to say, 168 people choose to take a taxi at this time. According to Table 1, 131 people took taxis alone, 15 groups of two took taxis together, one group of three people and one group of four people. At this time, 148 taxis should be released to the boarding area. Passengers who need to take a taxi together will certainly go to the same station to take a taxi, so that they may all go to the station. May as well let them all go to the site 1. Then the final allocation is shown in the following table:

Table 2. Taxi and passenger arrangements

Site	Number of taxis (vehicles)	Number of passengers (persons)
1	49	69
2	33	33
3	33	33
4	33	33

Similarly, when we know the passenger data information at a certain time, we can get the taxi and passenger distribution scheme of each station.

IV. MODELING AND SOLVING OF THE PROBLEM (II)

For the problem, combined with the actual situation, considering that if the short-distance passenger driver returns and inserts it in the middle of the team, it will cause traffic jams. Therefore, the "priority" scheme assumes that the taxi that the short-haul passenger returns again directly goes to the front of the team, that is, the first place. Under this kind of "priority" scheme, the income of taxis with "priority" and taxis without "priority" should be balanced as much as possible. Based on this, the paper analyzes the following.

4.1 Determining the threshold of priority

The driver's income after a complete passenger load is set as a percentage of his daily income. When it is greater than a certain value, it is not short-distance and does not have “priority”. Assuming that a driver is only active near the airport for one day, the driver's income can be expressed as:

$$M = \frac{Q}{k} p_k$$

where Q represents the number of taxi drivers; k represents the number of taxis in the vicinity of the airport, p_k represents the income per order of the k driver. According to historical experience, when the driver's income is less than 5% of his full-day income, that is thinks he is running a short distance, then he can get "priority".

4.2 Calculating the stay time of a taxi

（1）Have "priority" taxi stay time

Regarding the length of stay of the taxi in the car storage pool, first of all, the taxi with "priority", the waiting time required to reach the storage pool is composed of two parts: one is the service time of the "priority" taxi waiting for service; and the other is the waiting time for the service desk to be free. Therefore, the duration of the taxi with "priority" in the storage pool is:

$$j_{q1} = \frac{\lambda_1}{\mu(\mu - \lambda_1)}.$$

where λ_1 is the average number of priority taxis arriving at the storage pool per unit time, μ is the average number of drivers who receive passengers within a unit time, that is, the average time each driver receives a passenger is $1/\mu$.

（2）No "priority" taxi stay time

When a taxi without "priority" arrives at the storage pool, its stay time is affected by the "priority" taxi. Therefore, the average stay time of a taxi that does not have "priority" is:

$$J_{s2} = (1 + \frac{\lambda_1}{\lambda_2})\frac{1}{\mu - (\lambda_1 + \lambda_2)} - \frac{\lambda_1}{\lambda_2}\frac{1}{\mu - \lambda_1}.$$

where λ_2 is the average number of on "priority" taxis arriving at the storage pool per unit time.

Therefore, it is concluded that there is no "priority" to stay in the pool with the following time:

$$J_{q2} = J_{s2} - \frac{1}{\mu}.$$

4.3 Setting the number of uses of priority

In order to balance the income of taxi and take into account the fairness among taxi drivers, the number of "priority" usage is limited in this paper. In this paper, it is assumed that the profit of a driver in two short trips is less than the income of one long distance, and the number of times of use of "priority" is 2, otherwise, the number of settings is 1. Combine the income calculation formula left by the taxi selection in problem 1 with the above-mentioned stay time to get the income calculation formula of this problem, that is:

$$J_{q2} = J_{s2} - \frac{1}{\mu} p_1 = \begin{cases} \dfrac{11 - \alpha d_k}{J_{q2} + \dfrac{d_k}{v}}, & d_k < 3; \\ \dfrac{11 + 2.5(d_k - 3) - \alpha d_k}{J_{q2} + \dfrac{d_k}{v}}, & 3 < d_k < 10; \\ \dfrac{11 + 2.5 \times 7 + 3.75(d_k - 10) - \alpha d_k}{J_{q2} + \dfrac{d_k}{v}}, & d_k > 10. \end{cases}$$

where J_{q2} indicates the initial waiting time for a taxi without "priority" in the car storage pool.

It is assumed that the distance is 0-10 km for short distance and the distance over 10 km is long distance. Calculate the values of two short-term gains and one long-distance return, respectively. Part of the values are shown in the table below:

Table 3. Statement of taxi driver income

Two short-distance income	6.38	8.35	5.31	9.28	5.25
A long-distance income	12.48	11.15	16.69	12.12	19.44

The value of the above table shows that two short-term gains are not as good as a long-distance return, and so on, the more the number of short trips, the greater the difference in revenue. Therefore, each taxi has a maximum of two "priority" opportunities, so that each driver's income will not be too large.

4.4 Calculating the average return of a taxi

The problem requires that the income of the "priority" taxi and the "priority-free" taxi should be kept as balanced as possible. We can think of the revenue balance of the taxi, that is, the difference between the average driver's earnings is not large. This paper uses Monte Carlo algorithm to simulate the multiple journeys of the same driver, including the driver using "priority" and not having "priority". The results are as follows:

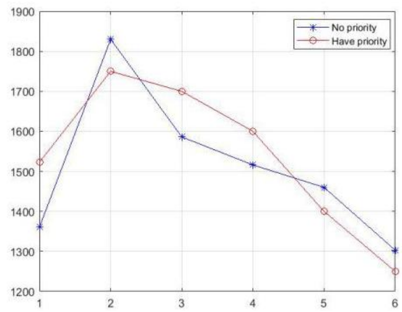

Figure 2. Comparison of income with priority and no priority

As can be seen from the above Fig.2, have "priority" and no "priority" when the priority scheme is set to be used twice per driver, the average income of the driver is kept balanced. The income of taxis does not differ much, so it can be considered that the "priority" scheme set in this paper is more reasonable.

REFERENCES

[1] Yu Xue, Location selection of foreign direct investment of Chinese steel enterprises based on multi-criteria decision-making, Jiangsu University, 2016.
[2] Zhonggeng Han, Yiqing Lu, Sujing Zhou, Practical Mathematical Modeling Course, Higher Education Press, Beijing, 2012.
[3] Liping Yu, Yuntao Pan, Yishan Wu, "Sensitivity analysis of scientific and technological evaluation," Science and Technology and Economy, vol. 23, no. 8, pp1-4, 2009.
[4] Yanping Yue, "Customer Equilibrium Behavior Based on Priority Queuing," Economic Research Guide, vol.8, pp118-119, 2018.
[5] Juntong Li, and Tao Li, "An M/M/1 Retrial Queue with Working Vacation, Orbit Search and Balking," Engineering Letters, vol. 27, no.1, pp97-102, 2019.