Taxi Operation Strategy Based on Queuing Theory

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Abstract: Economic growth and the improvement of residents' consumption levels have stimulated the growth of air passenger transport demand, provided a population base for the development of large airports, and also put greater pressure on the airport's diversified transportation capacity. As a more flexible means of transportation, taxi occupies a more important position in travel. Therefore, this article focuses on Airport rent Car problem Perform analysis. Combining the data of Jinan Yaoqiang Airport and the taxi driver's decision model get when taxi drivers wait in line Between $t_1 = 66$ Minute bell, using queuing theory to stochastically simulate the waiting process of taxi drivers, and further simplify the decision-making model of taxi drivers. Simulate the number of taxis in line R for 34 Vehicles, Which simulates Number of taxis in line $R <$ Average number of taxis in the storage tank N , so the driver should choose plan *A*.

1. problem analysis

In order to establish a taxi driver selection decision-making model and give the driver's selection strategy, we first analyze the relevant factors that affect the taxi driver's decision-making, and queue up to the arrival area to wait for passengers to return to the urban area and directly return to the urban area to solicit passengers. Cost analysis is carried out in the two cases separately, and the taxi driver's decision model is established by comparing the costs of the two schemes.

We can judge the evaluation model based on the data of actual cases, and then combine the decision model obtained in question one, and substitute the collected data into the decision model of question one to give the airport taxi driver's choice plan. Both can be used. Group data for analysis and decision-making, and analyze the rationality of the model and the dependence on related factors by comparing the two decisions.

Considering that this is a problem of setting up a pick-up point in two parallel lanes, we drafted different schemes and comprehensively considered the efficiency and safety of the schemes to screen out the best scheme.

In order to balance the problem of uneven passenger revenue and passenger mileage at the airport, a road-colored channel can be opened for taxis that meet certain conditions for short-distance passengers and return, and the taxi can enter the green channel without waiting. Carry short-distance passengers. Combine the model and existing data to draw up different schemes, and compare the best schemes.

2. Model establishment

2.1 Build a decision model

2.1.1 Convert factors that influence decision making

The taxi driver’s decision is determined by the revenue, but since the revenue is unknown, we can attribute the taxi driver’s decision to a cost issue. Considering the changes in the number of passengers at the airport and the income of taxi drivers, to analyze the problem of taxi driver selection decision-making model, there are two options:

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Option A: When taxi drivers go to the passenger area and wait in line to carry passengers back to the city, considering that taxis need a certain amount of time and fuel consumption when waiting in line, we believe that taxi drivers need to pay when waiting in the "car pool" Certain time cost and fuel consumption cost.

Scenario B When the taxi driver returns to the urban area to solicit passengers directly, the taxi driver has to pay no-load fees and may lose potential passenger income.

2.1.2 Based on the scheme A Cost analysis

When a taxi driver waits in line, the taxi driver has to pay for fuel consumption and time. We assume that the total cost of waiting in line for taxi drivers is $W_{等}$, The fuel consumption cost of waiting taxi is W_u , The time cost of queuing is W_t , The average fuel consumption per minute when idling is m_1 , The gasoline price is n , The average profit per minute is x , The waiting time in queue is t_1 .

Establish a cost model for taxi drivers waiting in line:

$$\begin{cases} W_{等} = W_u + W_t \\ W_u = m_1 n t_1 \\ W_t = x t_1 \end{cases} \tag{1}$$

Simplified:

$$W_{等} = \mathrm{m}_1 n t_1 + x t_1 \tag{2}$$

2.1.3 Based on the scheme B Analysis

When the taxi driver returns directly to the urban area, the taxi driver has to pay no-load charges and may lose potential passenger income.

Let us suppose The taxi driver left and returned to the city The total cost is $W_{离}$, The passenger-carrying income lost by the taxi back to the city is W_{f1} , The loss of no passengers in the urban area is W_{f2} , The potential passenger income after arriving in the city is W_{f3} ,The cost of idling fuel consumption when a taxi is waiting is W_u , The fuel consumption cost during normal driving is W_n , The average profit per minute is x , The waiting time in queue is t_1, The average time from the airport to the city is t_2 , The no-load rate p .

Establish a cost model for taxi drivers returning to the city:

$$\begin{cases} W_{离} = W_{f1} + W_{f2} - W_{f3} \\ W_{f1} = t_2 x + W_n \\ W_u = m_2 n t_1 \\ W_{f2} = (t_1 - t_2) p x \\ W_{f3} = (t_1 - t_2)(1 - p) x \end{cases} \tag{3}$$

Simplified:

$$W_{离} = (t_1 - t_2)(2p - 1) x + m_2 m t_1 \tag{4}$$

2.1.4 Establish a decision-making model for taxi drivers

We compare the total cost of waiting in line for taxi drivers $W_{等}$ with The taxi driver left and returned to the city Total cost $W_{离}$ To determine the taxi driver's decision-making plan.
Program *A* Taxi drivers go to the passenger area and wait in line to take passengers back to the city
Program *B* The taxi driver directly returned to the city to solicit customers

(1) when $W_{离} > W_{等}$ When $\frac{t_2 - t_1}{t_2} > \frac{(m_2 - m_1)n}{2(1-p)x}$ When, the taxi driver should choose option A

(2) when $W_{离} = W_{等}$ When $\frac{t_2 - t_1}{t_2} = \frac{(m_2 - m_1)n}{2(1-p)x}$ When the taxi driver can choose option A or option B

(3) when $W_{离} < W_{等}$ When $\frac{t_2 - t_1}{t_2} < \frac{(m_2 - m_1)n}{2(1-p)x}$ When, the taxi driver should choose option B

2.2 A Decision Model Taking Jinan Yaoqiang Airport as an Example

2.2.1 Establish a waiting model based on queuing theory

1. Determine the queuing system. In a period of time, each passenger taking a taxi is a random independent event, and the frequency of this event is relatively stable. When the smaller the time slices, the smaller the time slice Probability p Will Proportional to the reduction. That is: the number of time slices divided into a specific time period n With the probability of an event occurring within each time slice p Product of np For one Constant, assuming *lamda*. This constant expresses the frequency of occurrence of the event in a specified time period (that is, mathematical expectation). which is

$$E(x) = np = \lambda \tag{5}$$

Further, n Tends to infinity, p Tendin*0*, We know that the probability of the event at this time obeys the Poisson distribution [1]. Therefore, we studied the Poisson distribution of passengers in taxis, established a waiting model based on queuing theory, and simulated the waiting process of taxi drivers randomly. Using this model, we can randomly simulate the waiting time for the taxi driver through the number of passengers.

The queuing system is mainly composed of three parts, namely the input process, queuing rules and service desk [2].

The queuing system model has the following characteristics:
(1) Input process: passengers taking a taxi are random
(2) Queuing and service rules: first come first serve, no loss flow
(3) Service time distribution: The service time for each passenger is a random variable.

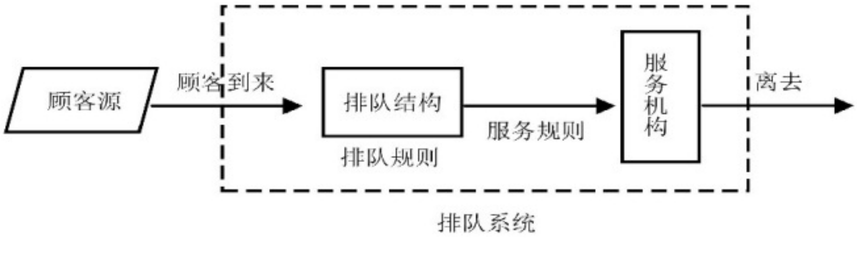

Figure 1. Queuing system model

2. Establishment of a simulated waiting queue system. Use Monte Carlo simulation method [3] to simulate the queuing system and calculate the operating parameters of the queuing system.

The taxi is abstracted as a service desk, and the time spent by passengers in the taxi is abstracted as service time. In the simulation, follow the given Poisson distribution of *lamuda* Follow the arrival time of passengers is generated by the aircraft to simulate the arrival of passengers; the service time is randomly generated according to the law of Poisson distribution. When a passenger arrives at the system, first consider whether there is an idle service counter in the system. If there is an idle service counter at this time, the passenger will enter an idle service counter arbitrarily, and the service counter will be marked at the same time; if not, the passenger will enter Wait in the queue until there is an idle service desk, and then receive services in the order of entering the waiting queue. When the set simulation event is reached, the simulation ends and the result is output. And while the system is simulating, it records the time point of the event, the number of people in the system and the queue status of vehicles [4].

3. Simplify the decision-making model through the waiting queue system. By bringing relevant data into the decision-making model, we can get the result that taxi drivers wait in line when the costs of the two options are equal. time t_1. Will get t_1 as The parameters of the waiting queuing system simulate the waiting process and get the waiting in the tank Number of taxis R, By comparing the number of taxis simulated by the waiting queue system R And the number of taxis actually observed by the driver R do Compare, and then get the optimized decision model

(1) when $N < R$ When the taxi driver should choose the plan B

(2) when $N = R$ When the taxi driver can choose AOr scheme B

(3) when $N > R$ When the taxi driver should choose the plan A

2.2.2 According to the data obtained from the survey, substitute the decision model to give a specific plan

We combine the driver's decision-making model obtained in problem one, and combine the actual data to give the airport taxi driver's choice plan. Suppose the total number of passengers in a certain period of time is R, The total time of this period is T, The probability of passengers arriving at the airport taking a taxi P_0, To establish a model of the rate of passengers taking a taxi:

$$\lambda = \frac{RPo}{T} \tag{6}$$

We start from *CSDN* Obtained by blog network*2016*September 22Part of the data of Jinan Yaoqiang Airport and taxis, and process the data and select from them*10:00-12:00*Data within the time period. Get the average fuel consumption of the taxi at idle speed (l/min) $m_1 = 0.05$, Average fuel consumption in normal driving (liters/minute) $m_2 = 0.02$, Gasoline prices $n = 6$, Average revenue per minute $x = 0.7$, The taxi no-load rate in the area $p = 0.3$, The probability of passengers arriving at the airport taking a taxi $P_0 = 0.35$, The time required for Jinan Yaoqiang Airport to reach the city (minutes) $t_2 = 67$.

Table 1. Airport data information

Number of passengers	time	Number of taxis in storage tank
68	2016-9-22 10:00	43
75	2016-9-22 10:00	41
90	2016-9-22 10:00	42
109	2016-9-22 10:00	44
86.2	2016-9-22 10:00	43
…	…	…
58.973	2016-9-22 12:00	34
49.9381	2016-9-22 12:00	36
48.2	2016-9-22 12:00	37
64.0625	2016-9-22 12:00	35

The total number of passengers calculated based on the airport data $R = 696$, The total time of the period $T = 120$, To get the average number of passengers arriving by taxi in this period of time $\lambda = 2.03$, The average number of taxis in the storage tank $N = 38$.

when $W_{离} = W_{等}$ When $\frac{t_2 - t_1}{t_2} = \frac{(m_2 - m_1)n}{2(1-p)x}$ When, get Waiting time for taxi drivers $t_1 = 66$,will $t_1 = 66$ Substitute into the waiting queue system to simulate the number of taxis in queue R for 34 At this time, simulate the number of taxis in line $R <$ Average number of taxis in the storage tank N , So the driver should choose option one during this time period. Waiting in line at the airport.

2.2.3 Dependency analysis

We analyze when $W_{离} = W_{等}$ When $\frac{t_2 - t_1}{t_2} = \frac{(m_2 - m_1)n}{2(1-p)x}$ Time, The impact of the decision model has load factor p, Queuing time t_1 , The time taken by the taxi from the airport to the city t_2, Vehicle idling fuel consumption m_1, Normal driving fuel consumption m_2 And gasoline prices n ,Average revenue per minute of taxi drivers x.

According to the actual situation, in a certain continuous time, the load factor p ,Average revenue per minute of taxi drivers x ,Vehicle idling fuel consumption m_1, Normal driving fuel consumption m_2 And gasoline prices n Are basically stable, so this decision has an impact on load factor p ,Average revenue per minute of taxi drivers x ,Vehicle idling fuel consumption m_1, Normal driving fuel consumption m_2 And gasoline prices n The dependence is small.

Waiting time t_1, The time taken by the taxi from the airport to the city t_2 It is a variable and has a greater impact on decision-making. The waiting time in line is affected by the number of passengers in the airport and the number of vehicles in the storage pool; the time taken by taxis from the airport to the city is affected by the distance from the airport to the city. Therefore, we believe that the decision model has R, The number of vehicles in the storage tank N Distance from airport to city D The dependence is greater.

2.3 Pick-up point design problem

For this question, we set up three different programs, and judge the efficiency difference of different programs by comparing the time taken by the three programs under the premise of carrying the same number of people.

Option 1: Set up a pick-up point at the front of the parallel lanes, and passengers can pick up the front-most taxi in the two lanes after entering the pick-up point.

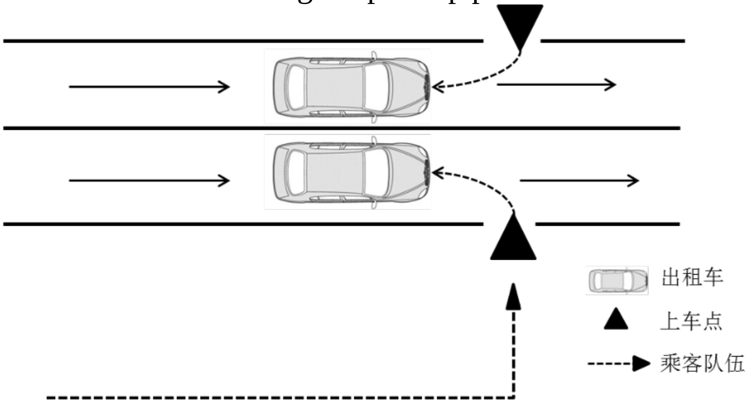

Figure 2. Schematic diagram of Scheme 1

Option 2: Set up three pick-up points on one side of the parallel lane. When there is no taxi waiting at the pick-up point, the driving taxi can change lanes from the other side of the pick-up point and enter the pick-up point to wait for passengers to rent. The car waits for passengers to board at the boarding point of the lane; it can also drive directly into the boarding point from the side of the waiting point [5]. When the taxi is carrying passengers, the taxi can continue to drive on one side of the boarding point, or change lanes to enter the other side.

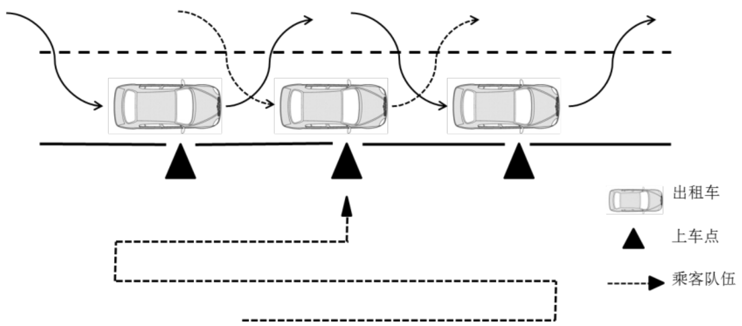

Figure 3. Schematic diagram of Scheme 2

Solution 3: Set up two pick-up points on one side of the parallel lane and one pick-up point on the other side. When a taxi stops waiting for passengers in a lane with two boarding points, the driving state of the preceding vehicle affects the driving state of the following vehicle.

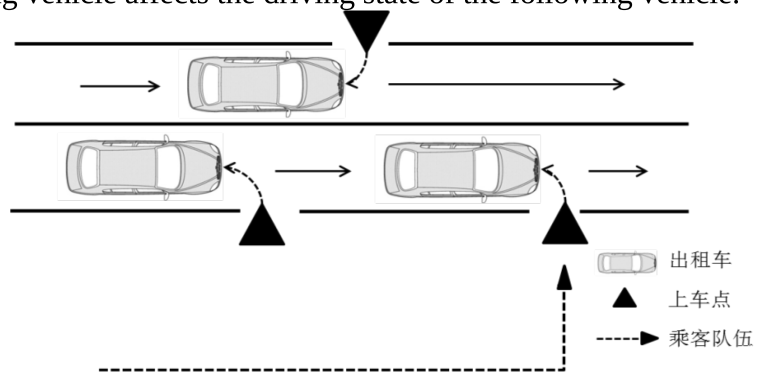

Figure 4. Schematic diagram of scheme three

From the above three design schemes, it can be seen that the second scheme only has Any one of the three pick-up points on the same side can Receive service, And the taxi can Drive into the harbor-style pick-up point from the inner lane for passenger service To avoid traffic congestion, The safety factor is relatively high.

Taking into account the factors of riding efficiency, we assume that there are 72 passengers waiting for the bus. The three design schemes are respectively subjected to Monte Carlo random simulations through the waiting queuing system to generate data that meets our model settings. After processing the obtained data, the average time required to obtain the three solutions through random simulation is as follows:

Table 2. The average time required for the program

Program	**Time (min)**
Option One	50
Option II	40
third solution	45

It can be seen from the above table that the average time required in the simulation is the longest, that is, the longest time it takes for the driver to leave the boarding point from receiving the passenger, indicating the lowest efficiency at this time. From the perspective of efficiency, it can be seen that Option 2 is the most efficient in riding. In summary, Under the conditions of ensuring the safety of vehicles and passengers, the overall ride efficiency is the highest, and the second scheme is the most in line with the requirements.

2.4 The balance of distance

In order to make up for the loss of taxis returning short-distance passengers, we decided to open green lanes for these short-distance passengers returning taxis [7]. When the taxi enters the green channel, the taxi can take a short-distance passenger and leave without waiting in line. The schematic diagram of the green channel is as follows:

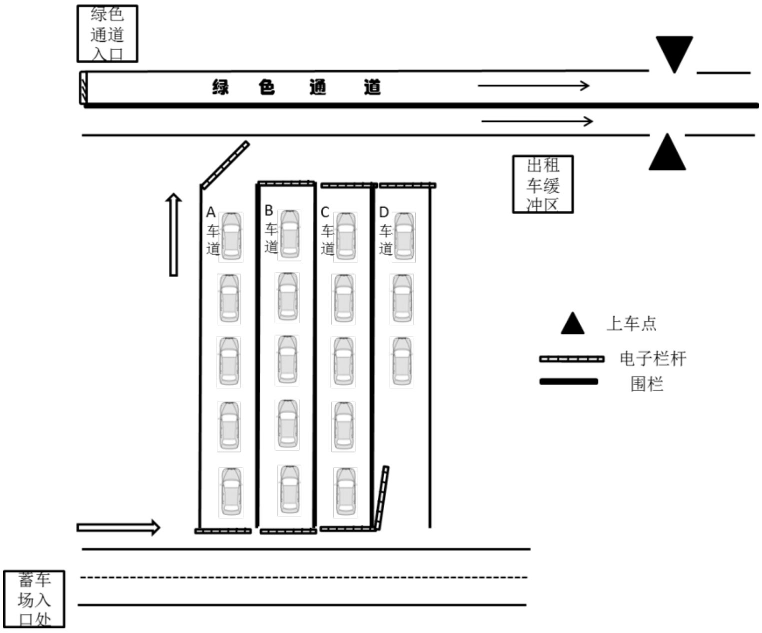

Figure 5. Schematic diagram of the green channel

According to the second question, Jinan Yaoqiang Airport is d for*54*Km, its revenue G is*133*, The starting taxi fare a for*11*Yuan, charge per kilometer for more than 3 kilometers b for*2. 4yuan.weThe* revenue of taxis from Jinan Yaoqiang Airport to Zhangqiu City is regarded as the standard of remote revenue, and the total passenger revenue of the driver shall not exceed the standard of remote revenue.*10*yuan.

Assume that the short-distance mileage carried by the taxi driver is d_i , The revenue of taxi drivers carrying short-distance passengers is $h_i(i=1,2,3\cdots)$, The total revenue of taxis continuously carrying short-distance passengers is H .

Establish a total revenue model for taxis continuously carrying short-distance passengers:

$$\begin{cases} H=\sum_{i=1}^{n} h_i \\ h_i=(d_i-3)\ b+a \end{cases} \tag{7}$$

when $H>G-10$ When $d_i>50$, The taxi cannot enter the green channel when returning.

when $H<G-10$ When $d_i<50$, When the taxi returns, it can enter the green channel to carry short-distance passengers again, without entering the parking lot and queuing again.

3. Model evaluation and promotion

3.1 Evaluation of the model:

3.1.1 Advantages of the model:

The established simulation model can cleverly use the Poisson distribution law in queuing theory and probability to assign a discrete and random passenger queuing and waiting event to a mathematical derivation, thereby deriving a set of feasible solutions. This can provide a certain reference basis for the research and solution of practical problems.

Established decision making the model can be closely integrated with the actual situation, Make the model is more realistic, and it is more versatile and popular.

3.1.2 Disadvantages of the model:

When solving a strategy problem through a model, more conditions are involved, and more factors are affected, and the model has certain limitations.

Due to the many influencing factors involved in the queuing simulation system model, the function of the model is more complicated, and it is difficult to program the model.

3.2 Model promotion

Due to time constraints, this model has some shortcomings, but the results obtained are quite reasonable. This model can not only be used in airport taxi problems, but also can be used to solve problems in real life.

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