Airport Taxi Driver Waiting Decision and Consumption Optimization Plan

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Abstract

The car-free carrier platform is popular with car-free carriers for issuing orders and carrier owners grabbing orders. However, both the car-free carrier and the carrier owner are faced with the issue of how to choose the order pricing and how to increase or decrease the order price. Therefore, we need to establish a mathematical model to solve the problem.

Keywords

Multi-attribute Decision Model; Optimized BP Neural Network Model Simulation; Multi-service Desk Optimized Queuing System.

1. Introduction

Taxi is an important component of urban passenger transportation today. After passengers get off the plane, taxis become one of the main means of transportation. Taxi drivers will face two choices after sending guests to the station: one is to go to the queuing area to wait for the passengers and return to the urban area; the other is to return to the urban area directly with an empty car. Both schemes need to pay a certain cost. The first scheme pays the time cost, and the waiting time becomes the most critical factor in determining the driver's profit; the second scheme the driver will pay the corresponding no-load fee, and the potential benefit may also be damaged. Therefore, in order to study how taxi drivers should make decisions, we need to make the problem specific based on actual conditions and establish a reasonable mathematical model to solve the problem.

With the rapid development of the times, the contacts around the world are getting closer, and the status of the airport is becoming more and more important. Passengers have to go to the city or surrounding destinations after getting off the plane. Therefore, taxis have become one of the main means of transportation for passengers, carrying 30%-70% of the distribution volume.

We consider the mathematical modeling problem of the reasonable arrangement of airport taxis.

After seeing off the passengers to the station, the taxi will have the following two options:
(a) Taxis may queue up at the arrival area to pick up passengers and return to the city. Taxis have to queue up at a designated place. The waiting time is affected by the number of cars in the queue and the number of passengers, and there is a time cost.
(b) Taxis can return directly to the city without picking up passengers at the airport. Correspondingly, the driver will also pay no-load fees and may lose potential passenger revenue.
Drivers know the number of flights arriving at a given time and the number of cars in the pool. Typically, drivers' decisions are related to the time of year, the number of flights arriving at that time of year, the number of possible passengers, and so on. Analyze and study the relevant factors that affect the decision-making of taxi drivers, comprehensively consider the changes in the number of passengers and the income of taxi drivers, select the required decision-making model for taxi drivers, and give their selection strategies.

2. Methods

In order to give the correct decision of whether the taxi driver entering the airport waits, we believe that analyzing and establishing the factors that affect the driver's decision is the basis for establishing the model. Therefore, firstly, the data is dimensionlessly processed through the multi-attribute decision-making model and the matrix calculation weight is established. Then, considering that the driver's decision is highly abstract, a simulation model based on the matrix of the multi-attribute decision-making data is established by optimizing the BP neural network, so as to determine the driver's decision-making plan.

2.1. Airport Overview

We take Shanghai Hongqiao International Airport as an example to study the problem. Before the expansion of Shanghai Hongqiao International Airport, there were about 540 daily take-offs and landings. During the peak period, there were 85 take-offs and landings per hour, and the annual passenger volume exceeded 14.8892 million. The T2 terminal of Hongqiao Airport was opened in 2010 and was constructed according to the design standard of annual passenger throughput of 1 million tons and 300,000 aircraft movements [1]. Currently, Shanghai Hongqiao Hub's road test transportation methods include taxis, airport special lines, railways, rail transit, public transportation and other transportation methods. It is the most complex and largest comprehensive transportation hub area in Asia.

2.2. Travel mode structure of air passenger roadside traffic

Based on the data [1], draw the distribution map of the travel mode selection of passengers on the roadside of Hongqiao Airport. From the figure, taxis are one of the main ways of roadside traffic for air passengers, accounting for 34%. Many passengers choose the subway, accounting for 35%. Secondly, private cars accounted for 15%, while conventional buses only accounted for 8%. As passengers carry luggage with them after landing, taxis have become an important choice for passengers.

2.3. Research and analysis of average peak traffic flow of Hongqiao Airport

Based on the data provided by Shanghai Transportation Network [2], we draw a broken line chart of the traffic flow in and out of the main road sections of the Hongqiao Airport T2 terminal, as shown in Figure 1. It can be seen from the figure that the daily peak period of traffic flow is relatively concentrated, and there are two peaks a day: one is between 11:00 and 12:00 noon. The total traffic volume at this rush hour accounts for 20.6% of the total trip volume throughout the day. The second peak is at 19:00-20:00 in the evening, and the total amount of traffic this time accounted for 18.9% of the total travel volume throughout the day. In order to divide the time into reasonable time periods, and at the same time to make the data of each time period reach the number that can be statistically analyzed, the time is divided into three time periods: peak period, flat peak period, and low peak period. The peak period in the following is the peak period. The time interval between the two peaks in the figure, the flat peak period is the time period that fluctuates up and down in the figure, and the low peak period is the time period when the data in the figure is weak, which is hereby explained.
2.4. Data preprocessing

Data in the real world is chaotic and full of inconsistencies and incompleteness. But at the same time, high-quality decision-making must rely on high-quality data prototypes. For this question, we obtained the GPS data of all taxis of Shanghai Johnson Taxi Company within one day according to the needs of the model, including taxi ID, time, longitude, latitude, angle, taxi speed, taxi The passenger loading status of (where 0 represents the taxi is in an empty status, and 1 represents the taxi is in a passenger status).

2.5. Proposal and analysis of relevant factors affecting the decision-making of airport taxi drivers

As shown in Figure 2, we can see that the factors that affect the decision-making of airport taxis include the average queue time, the number of vehicles in the "car storage pool", the capacity of the pick-up point, the number of flights in a certain period of time, and the service time for passengers to board the bus. Considering the changing law of the number of passengers at the airport and the income of taxi drivers, the following will analyze and evaluate each factor one by one. The sample size is the frequency of occurrence at the designated airport during peak, peak, and low peak periods:

Figure 2. The relationship diagram of factors affecting the decision of taxi drivers
2.6. Delivery demand type
Since the delivery demand type is an independent variable, but its variation factors are few, in order to analyze the correlation between the delivery demand type and the price adjustment ratio, we use MATLAB to establish the scatter diagram between the delivery demand type and the price adjustment ratio for analysis:

2.6.1. Average queue time
The queuing time refers to the length of time from the time the taxi arrives at the storage pool and is at the end of the queue, to the time when the vehicle passengers start boarding. The average queuing time is the most critical factor in determining the decision of taxi drivers. The queuing time depends on the number of taxis and the number of passengers, and the average waiting time determines the revenue of the taxi driver. The longer the average queuing time, the fewer the number of passengers at the airport, and the lower the profit for the taxi driver.

<table>
<thead>
<tr>
<th>Survey site</th>
<th>Survey time</th>
<th>Sample</th>
<th>Mean value</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shanghai Hongqiao</td>
<td>fastigium</td>
<td>2</td>
<td>2h20mins</td>
<td>5.3</td>
</tr>
<tr>
<td>Airport terminal 12</td>
<td>Peak period</td>
<td>3</td>
<td>1h15mins</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td>non-rush hour</td>
<td>2</td>
<td>38min's</td>
<td>1.5</td>
</tr>
</tbody>
</table>

2.6.2. Number of vehicles in the "car storage pool"

The number of vehicles in the "car storage pool" is one of the most intuitive factors that determine taxi drivers' decision-making. The number of vehicles in the “car storage pool” is the definite information that the driver can observe, and the driver usually makes subjective judgments through personal experience. The more vehicles in the “vehicle storage pool”, the greater the time cost paid by the driver, and the smaller the profit for the taxi driver. If the vehicles in the “car storage pool” exceed a certain threshold, the driver's profit will be impaired. By calling the database at different times, the number of taxis in the coordinates (121.3339605, 31.20081)-(121.353138, 31.200195) is drawn as Table 2:

<table>
<thead>
<tr>
<th>Survey site</th>
<th>Survey time</th>
<th>Sample</th>
<th>Mean value</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shanghai Hongqiao</td>
<td>fastigium</td>
<td>2</td>
<td>497</td>
<td>2.3</td>
</tr>
<tr>
<td>Airport terminal 12</td>
<td>Peak period</td>
<td>5</td>
<td>336</td>
<td>4.9</td>
</tr>
<tr>
<td></td>
<td>non-rush hour</td>
<td>4</td>
<td>228</td>
<td>3.6</td>
</tr>
</tbody>
</table>

2.6.3. Capacity of pick-up point
The capacity of the pick-up point refers to the number of vehicles or passengers sent by the pick-up point per unit time. The capacity of the pick-up point is the most important factor affecting the queue time of cars. In order to intuitively describe the relationship between the waiting time in the queue and the capacity, the number of passengers sent in each period can be selected to describe the capacity of the pick-up point. The stronger the passing capacity of the pick-up point and the shorter the average queuing time, the greater the profit for the taxi driver. The data in Table 3 can be obtained through reference [3]:
2.6.4. Number of flights in a certain period

The number of flights in a certain period of time is the definite information that taxi drivers can observe, and it plays an important role in the decision-making of taxi drivers. The number of flights at a certain time directly determines the number of passengers at the airport. During the peak period of arrival flights, the number of passengers will increase greatly, the waiting time of taxi drivers will be greatly shortened, and the income of taxi drivers will increase accordingly. Taxi drivers can make decisions based on the flight schedule at the time of day. Obtain the data in Table 4 through the flight schedule of Shanghai Hongqiao Airport T2 Terminal (see Supporting Material 1 for details):

Table 4. Comparison of the number of flights

<table>
<thead>
<tr>
<th>Survey site</th>
<th>Survey time</th>
<th>Sample</th>
<th>Mean value</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shanghai Hongqiao Airport terminal t2</td>
<td>Fastigium</td>
<td>3</td>
<td>83</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Peak period</td>
<td>4</td>
<td>66</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td>Non-rush hour</td>
<td>3</td>
<td>53</td>
<td>1.2</td>
</tr>
</tbody>
</table>

2.6.5. Passenger boarding service time

The service time for passengers to board the bus mainly depends on the time the vehicle is parked, whether the passengers are carrying large luggage, the number of large luggage, and the number of people on the bus. Therefore, the more passengers carry large luggage, the longer the car parking time, the more people get on the bus, the longer the service time of passengers on the bus, and the lower the profit of the taxi driver. The survey data on the average service time of whether to carry large luggage is shown in Table 5.

Table 5. Comparison table of passenger boarding time

<table>
<thead>
<tr>
<th>Survey site</th>
<th>Variable factor</th>
<th>Sample size</th>
<th>Average hours of service / s</th>
<th>Difference in average service time between the two</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shanghai Hongqiao Airport terminal t2</td>
<td>Not carrying large luggage</td>
<td>18</td>
<td>7.67</td>
<td>4.35</td>
</tr>
<tr>
<td></td>
<td>Carry heavy luggage</td>
<td>29</td>
<td>12.00</td>
<td></td>
</tr>
</tbody>
</table>

2.7. Quantitative analysis of the optimal number of parking points on a single lane in the loading area of Shanghai Hongqiao Airport

Shanghai Hongqiao Airport T2 is an important transportation hub connecting the coast and the inland, the south and the north, and the domestic and foreign countries. Its annual throughput is 40 million passengers and the annual passenger volume exceeds 14.8892 million. While its huge passenger flow brings economic benefits, it also brings huge pressure to airport
operations. Therefore, timely evacuation of passengers has become the top priority of the task, and improving the efficiency of airport taxi passenger pick-up points occupies an important proportion. Increasing the number of parking spaces will increase the capacity, but its marginal effect will decrease. When the number of parking spaces exceeds a certain value, the capacity will decrease.

According to the reference [7], the data in the waiting time questionnaire for passengers who choose to take taxis and the questionnaire on taxi capacity are adopted to determine \( \lambda \) and \( \mu \). Assuming that the ratio of passenger time cost to service desk cost is 1:1000, the above cost decision queuing model is adopted to optimize, as shown in Table 6.

<table>
<thead>
<tr>
<th>Table 6. Cost decision model calculation process</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L_s(1) - L_s(2) )</td>
</tr>
<tr>
<td>( L_s(2) - L_s(3) )</td>
</tr>
<tr>
<td>( L_s(3) - L_s(4) )</td>
</tr>
<tr>
<td>( L_s(4) - L_s(5) )</td>
</tr>
</tbody>
</table>

3. Conclusion

From the above calculation results, it can be seen that when \( C=5 \), it conforms to the formula (7) of question 3, that is, the sum of the cost of the passenger and the service desk is the smallest. That is, when there are 5 pick-up points in the single-lane taxi boarding area, the cost of the queuing system can be relatively minimal.

References

[4] Lv Zhenhua, Wu Jianping, Yao Shenjun, Zhu Li. Analysis of the characteristics of taxi operation based on FCD — Taking Shanghai as an example. 200241.