The Taxi Driver's Decision Model about Picking up Passengers at the Airport

Jifan Li
Department of Computer Science, North China Electric Power University (Baoding), Baoding, Hebei, China
104225339@qq.com

Abstract. The airport taxi plays a very important role in connecting the airport traffic with the city traffic, and its queuing and derivative problems have been paid much attention by drivers, passengers and airport management. In this paper, the factors which influence the taxi driver decision are analyzed, and the time cost driver and profits of contradictory perspective, by calculating the driver "line" and "return to the city" in both cases the net income per unit time, establish a "limitation interests", at the same time, combined with the number of flight arrival at a different time and may choose the number of the car, with the driver received benefit maximization for the principle, the use of recursive thought to establish "recursive model", make the driver arrive at the airport at any point in time, is obtained by the analysis of the model is able to interest the biggest selection strategy.

1. Introduction
Airport taxis play a very important role in connecting airport traffic and urban traffic. When most passengers get off the plane and go downtown, they often choose taxi as one of their main means of transportation. The drop-off and pick-up points at most airports in China are independent of each other, so the taxi driver who takes a passenger to the airport can only judge from his or her personal experience whether he or she "goes to the arrival area to wait for a passenger" or "goes back to the city to pick up a passenger". However, due to the subjectivity and one-sidedness of personal experience, there is often a big deviation between the decision and the expectation, which not only causes the profit of the driver to be unpredictable risk, but also brings great inconvenience to the passengers. Therefore, it is necessary to establish a corresponding model to replace the driver's subjective decision with the objective judgment of the computer, so that the driver and the passenger can get a win-win effect.

2. Conditions for model establishment
2.1. Analysis for the factors influencing taxi driver's decision
The factors that affect taxi drivers' decision-making are complex and changeable, and taxi drivers who send passengers to the airport mainly make decisions by analysing the following four factors:
(1) The number of vehicles queuing in the airport;
(2) The number of flights arriving in a certain time period;
(3) Influence of seasons on load factor;
(4) The influence of different time of day on load factor.

2.2. The idea of establishing the model
First, the purpose of the selection is to pursue higher economic benefits. We make the decision by taking the driver's "time benefit" as the final evaluation standard.

Considering that the number of passengers standing in line and the number of taxis standing in line are time-varying and there is a certain relationship between these two quantities. In the case of "many people and few cars", the driver can pick up passengers to leave in a very short time, so in this case, the driver must choose to stay in line. Since the arrival of flights is discontinuous, the number of people queuing for a bus increases occasionally, so we adopt the idea of hierarchical recursion for analysis.

3. Modeling process

3.1. The basis of the model: Limitation of interests
Considering the unity of process analysis, we put the two schemes under the same conditions and select the same process for analysis [1]. The specific process is as follows:

(1) The driver chooses to wait in line (process A).
(2) The driver chooses to empty out and return to the city to solicit customers (process B).

Assume that in both processes, the driver delivers the passenger to the city, and in process B the driver receives the passenger only after he has entered the outer ring line of the city.

The following definitions are made:

(1) The distance from the airport to the outer ring is \( S_1 \); in process A, the distance between the driver and the destination from the outer ring is \( S_2 \); in process B, the distance of the driver carrying passengers from the outer ring to the destination is \( S'_2 \).

(2) Taxi valuation standard is \( \frac{m \cdot yun}{km} \) on average, the average fuel consumption price of \( \Delta m \) RMB/km, net income per kilometer for \( m \), then \( m = m_0 - \Delta m \).

(3) Considering that in the actual process, the vehicle returning directly may not be able to pick up passengers as soon as it enters the urban area, it is assumed that the possibility of the driver of \( S'_2 \) segment in process B to pick up passengers is \( n\% \).

Based on the above definition:

(1) In scheme A, the total revenue of drivers is \( W_A \), and in scheme B, the total revenue of drivers is \( W_B \). There are:

\[ W_A = m \cdot (S_1 + S_2), W_B = -\Delta m \cdot S_1 + m \cdot n\% \cdot S'_2 \]

(2) The total time that is paid in the plan A driver for \( T_A \), plan B is paying the total time for \( T_B \), and that the average speed of drivers when it was v. There are:

\[ T_A = \frac{S_1 + S_2}{v}, T_B = \frac{S_1 + S'_2}{v} \]

(3) Two options A and B, in the process of their respective A net gain of unit time respectively \( \omega_A \), \( \omega_B \), according to the above the driver of the total income and pay the total time available:

\[ \omega_A = \frac{W_A}{T_A} = \frac{m \cdot (S_1 + S_2)}{T_{waiting} + T_{carrying}} = \frac{m \cdot (S_1 + S_2)}{ct + \sum_{t=1}^{n} \Delta t + \frac{S_1 + S_2}{v}} \]
\[ \omega_B = \frac{W_B}{T_A} = -\Delta m \cdot S_1 + m \cdot n\% \cdot S'_2 \frac{S_1 + S'_2}{v} \]
3.2. The body of the model: Recursive decision model

Assuming that the airport has only one passenger passage and only one boarding point. The taxi located in the waiting area enters the "buffer zone" in order of queuing and picks up passengers at the "boarding point". Based on the above assumptions, the following definitions are made:

1) The arrival time of the driver is the arrival time of the flight, and the number of vehicles queuing currently is \( C \);
2) The timing starting point is when the above car just leaves the boarding point; the timing ending point is when the next car picks up passengers and leaves the boarding point; the time consumed is \( t \);
3) The load factor of aircraft is \( k_1 \);
4) The percentage of passengers choosing the bus is the time-varying coefficient \( k_2 \);
5) The current queue number in the bus area is \( C_1 + C_2 \);
6) If the average number of passengers carried by each vehicle is \( P_{av} \), then the number of people currently carried by all vehicles is \( C \cdot P_{av} \);

By analyzing the passenger throughput of Shanghai Hongqiao airport for 4 years [2, 3], the monthly passenger volume is basically unchanged compared with the total throughput of the current year, that is, the monthly variation trend is consistent for each year. In addition, relevant literature [4] also calculates the daily passenger flow of the airport in a certain period, indicating that when the time is determined as a certain period, \( k_1 \) and \( k_2 \) are determined.

**Step 1:** Judge the relationship between the number of people on the bus \( C_1 + C_2 \) and the number of people currently available on all vehicles \( C \cdot P_{av} \):

The taxi driver will send the passengers to the airport. If \( C_1 + C_2 > C \cdot P_{av} \), it means that the driver does not need to wait for the arrival of the next flight and can pick up the passengers and leave.

**Step 2:** Decide according to the size of "prescription benefit" of drivers in the two schemes:

According to the statistics of flight information and the load factor in different seasons and time periods, the number of people who may take a taxi in the next flight is estimated to be \( k_1 k_2 P_0 \). Meanwhile, the number of passengers required by the vehicles in front of the driver is \( C \cdot P_{av} - k_1 k_2 P_0 \) in total. Therefore, it needs to be considered in two situations:

1) If the number of passengers is larger than the total capacity of the vehicle in front: it means there is no need to wait for the arrival of the next flight and passengers can leave. Accordingly, the prescription benefit \( \omega_B \) of plan B in this period is calculated. Comparing the two sizes, if \( \omega_A > \omega_B \), the driver chose to stay and wait, otherwise, choose to go back to the city to pick up passengers.

2) If the number of passengers is less than the total capacity of the vehicle in front: it means that at least the next flight must arrive before passengers can leave.

**Step 3:** Since the incoming Singapore airlines flight will increase the number of passengers again, resulting in a further update of the number of vehicles in the queue, repeat step 2 to recurse until the driver can make a decision based on his/her "time benefit".

In the recursive process, you only need to make the following substitution:

\[
k_1 k_2 P_i \rightarrow k_1 k_2 P_i (1 < i < n), k_1 k_2 P_0 \rightarrow C \cdot P_{av} - \sum_{i=0}^{n} k_1 k_2 P_i
\]

Where \( i \) represents the flight \( i \) that the driver is waiting for during this period.

4. Model validation

4.1. Problem specification

After searching and screening, we chose Shanghai Pudong international airport for practical simulation. In the simulation, the situations corresponding to 10:30 were taken for decision analysis, and the following explanation was made without affecting the reliability of the analysis:
(1) The delay of passengers from the boarding gate to the "boarding point" after the arrival of the flight is not considered;

(2) To set the taxicabs, as the "new type of Santana 93# gasoline", according to the oil and fuel consumption calculation: fuel consumption for $\Delta m = 0.47$ yuan/km.

By looking for Shanghai Pudong international airport flight information [5], we found that the airport flight number many, every day is difficult to complete individually for each moment arrived in flight accumulation analysis, so we choose to 15 minutes for a unit of time, per hour in 0, 15, 30, 45 points as the statistical moments, each statistical moments before and after the 7.5 minutes of flight are considered in the timing moment arrived.

Since the taxi completes an order completely, the driver's distance and driving time are random, we take $S_2 < S'_2$, $S_2 \ll S'_2$ these two cases and do the calculation. By searching on Baidu map, we get the taxi time, taxi distance and taxi fee corresponding to different routes at the selected time, as shown in Table 1.

| Type          | Starting Point            | Destination                                | Time (min) | Mileage (km) | Amount (Yuan) | Symbol |
|---------------|----------------------------|--------------------------------------------|------------|--------------|---------------|--------|
| $S_2 < S'_2$  | Airport                    | Huaxia west road overpass                 | 21         | 23           | 78            | $S_1$  |
|               | Airport                    | Bund center in Huangpu                    | 46         | 44           | 154           | $S_1 + S_2$ |
|               | Outer ring                 | Fudan university                          | 37         | 25.6         | 86            | $S'_2$ |
| $S_2 \ll S'_2$| Airport                    | Huaxia west road overpass                 | 21         | 23           | 78            | $S_1$  |
|               | Airport                    | Oriental pearl radio and television tower | 52         | 42.9         | 151           | $S_1 + S_2$ |
|               | Outer ring                 | Shanghai Hongqiao airport                 | 40         | 42.5         | 150           | $S'_2$ |
| $S_2 = S'_2$  | Airport                    | Huaxia west road overpass                 | 21         | 23           | 78            | $S_1$  |
|               | Airport                    | Bund center in Huangpu                    | 53         | 43.8         | 154           | $S_1 + S_2$ |
|               | Outer ring                 | Bund center in Huangpu                    | 41         | 22.9         | 76            | $S'_2$ |

5. Problem solving

Take 10:30 for decision judgment. The following is a specific calculation procedure for a case when $S_2 < S'_2$. The calculation procedure is the same for the rest of the time and the driving route.

5.1. Calculate the average speed

As can be seen from the data in the table, different traffic speeds of different routes are caused by different traffic speeds of inner and outer loop lines in the urban area in the same time period. For the two schemes, the corresponding average speed is uniformly adopted to calculate, and the average speed of process A and process B is obtained from the known:

$$v_A = \frac{S_1 + S_2}{T_A} = \frac{44}{46} = 0.9565 \text{ km/min}, \quad v_B = \frac{S_1 + S'_2}{T_B} = \frac{23 + 25.6}{58} = 0.8379 \text{ km/min}$$

The average speed of the two processes is:

$$v = \frac{v_A + v_B}{2} = 0.8972 \text{ km/min}$$

Note: The above calculation method is directly divided by the known distance and time in order to make the average speed more accurate. Since in the actual decision-making judgment, we cannot know the distance to be driven in the next order, so the average speed can be taken as the average speed of Shanghai taxi. According to relevant data selection and calculation, $v=55.68\text{km/h}$.  


5.2. Calculate the average net income \( m \) of taxi
The unit journey fare in process A and B is \( m_A \) and \( m_B \) respectively, and the average unit journey fare \( m_0 \) of the two processes is:

\[
m_0 = \frac{m_A + m_B}{2} = \frac{\frac{M_A}{S_1 + S_2} + \frac{M_B}{S_1 + S_2}}{2} = \frac{154}{44} + \frac{164}{48.6} = 3.4372
\]

By the foregoing, the \( \Delta m = 0.47 \), the net income per unit time:

\[
m = m_0 - \Delta m = 2.9672
\]

Take the number of vehicles queuing at the current moment \( c = 500 \), and the current number of vehicles queuing is:

\[
k_1k_2P_0 = 95\% \times 15\% \times 1699 = 242
\]

Then \( CP_{av} > k_1k_2P_0 \), it belongs to the case of "more people than cars". Then enter the first recursion, when continue to wait for the 10:45 flight to arrive, the number of new taxis:

\[
k_1k_2P_1 = 95\% \times 15\% \times 560 = 80
\]

Then \( CP_{av} - k_1k_2P_0 > k_1k_2P_1 \), it still belongs to the case of "too many passengers and too few passengers", so it enters the second recursion. When the flight arrives at 11:00, the number of new taxi passengers is:

\[
k_1k_2P_2 = 95\% \times 15\% \times 686 = 98
\]

Still in the case of "more people than cars", enter the third recursion. After calculation, the driver was not satisfied until the arrival of the 12:15 flight:

\[
CP_{av} - \sum_{i=0}^{6} k_1k_2P_i > k_1k_2P_7
\]

In the case of "fewer cars and more people", the total waiting time (in minutes) of the driver is:

\[
\sum_{i=1}^{7} \Delta t_i = 7 \times \Delta t = 7 \times 15 = 105
\]

So comparison can then be made by calculating the time benefit.
Substitute \( m, S_1, S_2, S'_2, c, t, \sum_{i=1}^{7} \Delta t_i \), \( v \) into the formula of net income per unit time:

\[
\omega_A = 0.468, \quad \omega_B = 0.502
\]

Because \( \omega_A < \omega_B \), therefore give decision-making for empty return to the city.

6. Conclusion
Process can be seen from the table above, for A total distance of \( S_1 + S_2 \) and process the total distance \( S_1 + S'_2 \), when \( S_2 \) and \( S'_2 \) value is not at the same time corresponding limitation of income \( \omega_A, \omega_B \) is
different also, overall performance for aging earnings are positively related with travel, when \( S_2 < S_2' \) or \( S_2 \ll S_2' \), plan B of greater returns, and the difference, the greater the distance limitation income difference, the greater the; When \( S_2 > S_2' \) or \( S_2 \gg S_2' \), the prescription benefit of scheme A is larger, and the greater the distance difference, the greater the prescription benefit difference. This conclusion is in line with the actual situation, indicating that the driving distance has a major impact on the driver's benefit. In this way, we can not only avoid the unknown carrying distance, but also make the decision results in various carrying distance conditions more consistent with the reality.

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