TEST Engineering & Management

July-August 2020
ISSN: 0193-4120 Page No. 726 - 735

The Quick Choice Model and Empirical Analysis of Airport Taxi Pick-up Strategy—Taking Shanghai Hongqiao Airport as an Example

Wei Zhao*, Yuxian Song, Die Liang, Xinning Huang
Southwest Jiaotong University Hope College, Chengdu, China.
* Corresponding Author: Wei Zhao

Article Info
Volume 83
Page Number: 726 - 735
Publication Issue:
July - August 2020

Article History
Article Received*: 06 June 2020*
Revised*: 29 June 2020*
Accepted*: 14 July 2020*
Publication*: 25 July 2020*

Abstract

After the taxi takes guests to the airport, they will face two choices. One is the taxi returns directly to the urban area with no load in order to carry passengers in the urban area for profit, the other is to wait for new passengers at the airport before returning. This article examines how to quickly make more profitable choices from the perspective of a taxi driver. First, on the basis of considering random factors, the profits of returning with passengers and returning without load are respectively simulated, and a driver selection model based on the profit difference is established. Secondly, a quick selection model was established based on the driver's easy-to-observable data. Finally, according to the relevant data of Hongqiao Airport, through Matlab computer simulation, the calculation results of the driver selection model and the pick-up strategy rapid selection model calculation results in various situations are calculated. After comparison, the accuracy of the rapid selection model is about 79 %.

Keywords: *Rapid selection strategy, computer simulation, income difference, Matlab, accuracy.*

I. INTRODUCTION

Because of the advantages of high speed, high comfort, safety and reliability, airplanes have gradually become an important means of transportation for people to travel. Since airports are often established in areas far away from urban areas, passengers must take other means of transportation to go to the urban area (or surrounding areas) after getting off the plane. Taxi is one of the most convenient means of transportation in the city, so it is the first choice for many passengers to go to the city (or surrounding areas). From the perspective of taxi drivers, the longer the distance traveled, the higher the fare per kilometer. Therefore, some taxi drivers also like to take passengers to and from the airport. As the airport separates the drop-off point and the pick-up point channel. Therefore, the driver will face two choices after sending the guests to the drop-off point. One is go to the pick-up point and wait in line to receive the guests before returning to the city, and the other is directly return to the city without a load. If you choose to take passengers and return, although you can get the return journey, you may need to wait a long time; if you choose to return without a load, there is no return journey, but you can reach the city as soon as possible to generate urban passenger income. Due to the uncertainty of waiting time for passengers at the airport, it is not an easy problem to choose the more profitable option from

July-August 2020
ISSN: 0193-4120 Page No. 726 - 735

the two options. Therefore, how to help the driver quickly determine which option is better based on known conditions is a very important issue. The question of practical significance.

Many scholars have done relevant research on the above-mentioned problem of the optimal selection strategy of airport taxis. Based on the decision-making psychology of taxi drivers, Li Ruiqian and others established a deterministic decision-making model for the driver to choose whether to wait or not, and analyzed the main factors affecting the driver's decision [1]; Yu Handan and Han Zhonggeng established queuing theory under different assumptions The model studies the driver's decision strategy [2] [3]. However, the calculation of the driver's decision-making model established by the above research is relatively cumbersome, and the taxi driver cannot quickly choose a better plan through the above-mentioned model, resulting in low practicability.

Based on the consideration of random factors, this paper simulates the returns of passenger return and empty return, and establishes a driver selection model based on the return difference. Then we analyze the main factors that affect driver selection, establish a taxi driver's quick selection model, and compare it with the results of the driver's selection model based on the profit difference, even calculate the accuracy of the quick selection model.

II. PROBLEM ANALYSIS

Background Analysis

According to the previous article, when the taxi driver arrives at the airport and arrives at the passenger drop-off point, there will be two options A and B to choose from. Among them, Plan A is to wait in line at the designated airport taxi "car pool" and queue in order to enter the ride area to pick up passengers in batches, and Plan B is to go directly to empty and return to the city to solicit passengers. The specific scheme selection process is shown in Figure 1, corresponding to two different options.

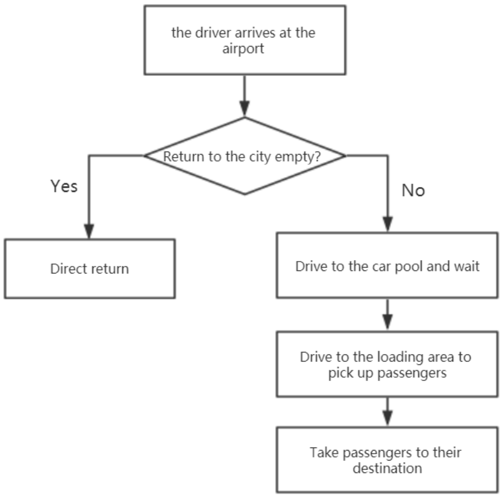

Fig 1: Scheme selection flowchart

Among them, the taxi driver can observe the flight information arriving in a certain period of time and the number of vehicles already in the tank. In order to obtain the maximum benefit, the driver will use these two observable information and make a judgment based on past experience, and finally choose the A or B option.

Analysis of Factors Affecting the Choice of Taxi Drivers

According to the driver's observable information and basic situation, the relevant factors affecting the driver's choice of A or B plan are shown in Figure 2.

TEST Engineering & Management
July-August 2020
ISSN: 0193-4120 Page No. 726 - 735

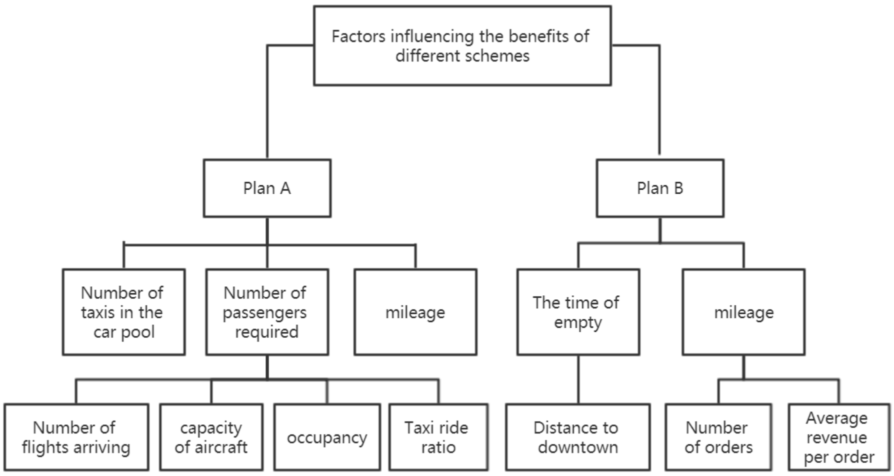

Fig 2: Diagram of the influencing factors of the income of plan A and plan B

As can be seen from the above figure, the benefits of Scheme A are mainly related to the number of existing vehicles in the storage tank and passenger-related information:

The number of vehicles in the storage tank (w): when the driver chooses whether to enter the storage tank and wait in line, the number of existing vehicles in the storage tank at this time is a random variable, assuming that the variable obeys a uniform distribution $w \sim U[a,b]$;

The number of passengers required (Q), mainly depends on y_1, the number of arrival flights at the airport within a certain period of time, y_2 , the number of fully-loaded passengers on the aircraft, y_3, the occupancy rate of the aircraft, and y_4, the proportion of passengers who choose to take taxis among various transportation methods. Among them, y_1, the number of flights arriving at Hong Kong within a certain period of time is a random variable, which obeys a uniform distribution, $y_1 \sim U[a,b]$; due to the different types of aircraft and the number of passengers carried, the average value is used in this article. As the occupancy rate of an airplane is affected by many factors, the occupancy rate of a certain flight at the airport should be close to a certain value, y_3 , which is regarded as a constant; the proportion of passengers choosing different land transportation methods at the airport can be regarded as a constant value, that is, y_4, the proportion of taking taxis is constant;

Order mileage (k_2): When a taxi queues up to pick up passengers in the storage tank, the number of return orders that the passenger wants to bring to the destination depends entirely on the passenger. It will be regarded as a random variable k_2 satisfying a uniform distribution, $k_2 \sim U[a,b]$.

It can be seen from Figure 3 that the benefits of Plan B are related to the empty time of returning to the urban area and the passenger income of the taxi within a certain period of time after returning to the urban area:

No-load driving time for returning to the urban area (t_3): This period of time is the idle driving time for the driver to choose to empty back to the urban area. This period of time is determined by the distance, k_1, from the airport to the urban area;

Income from carrying passengers in the urban area within a certain period of time, (x_i), that is, the passenger income of the driver after returning to the urban area is the total income of Plan B. This factor is determined by the average number of orders received by the unit during this period (n) and the average mileage per order (m), where the number of unit orders and the average mileage per order when the driver returns to the urban area are random variables. That is to say, the number of unit orders and average mileage per order in the urban area within a certain period of time are regarded as uniformly distributed random variable.

After the above analysis, the distribution of relevant influencing factors is shown in Table 1.

Table 1. Distribution of related influencing factors

Influence factor	**Number of cars available(w)**	**Number of passengers required(Q)**	**Order mileage(k_2)**	**Average revenue per unit(n)**	**Average per odd(m)**
data distribution	uniform distribution	uniform distribution	uniform distribution	uniform distribution	uniform distribution
Function form	$w \sim U[a,b]$	$y_1 \sim U[a,b]$	$k_2 \sim U[a,b]$	$n \sim U[a,b]$	$m \sim U[a,b]$

Through the above analysis, when the taxi driver chooses Plan A, he will go through the process of waiting in line and delivering the passengers after receiving them. The only source of revenue in this process is the charges for delivering passengers to passengers at the airport. Similarly, for plan B, it will go through the process of driving the taxi back to the urban area without load and picking up passengers in the urban area within the same time. The source of income in this process is the cost of picking up and dropping passengers in the urban area within a certain period of time. Therefore, the establishment of a model to compare the benefits of programs A and B can provide drivers with relevant choices.

III. DRIVER SELECTION STRATEGY

Calculation of the Duration of Each Stage

To choose plan A or plan B, you must compare the benefits of plan A and plan B. Figure 3 shows the time distribution and revenue of each scheme in the same period of time.

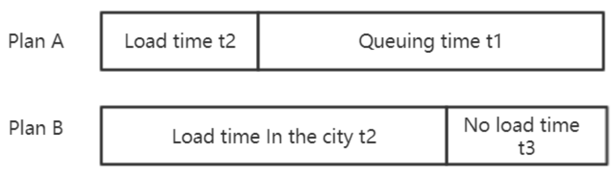

Fig 3: Time distribution diagram of scheme A and B

Q is used to indicate the number of passengers in the airport, w is the number of vehicles in the "car storage pool", p is the number of passengers carried by the taxi each time, B is the average time it takes for a passenger to board the bus, and the period of time Flight interval time is t_5. Considering that there are two situations in which taxis carry passengers at the airport, there are cars and people waiting for cars, and the following t_1 can be obtained:

$$t_1 = \begin{cases} \dfrac{w-1}{p} \times B, & \dfrac{Q}{m} > w \\ t_1 = \dfrac{w-1}{p} \times B + t_5, & \dfrac{Q}{m} < w \end{cases} \tag{1}$$

Use k_2 to represent the distance to send passengers in plan A, k_1 to represent the distance of taxi from the airport back to the city in plan B, and v to represent the average speed of the taxi during driving. Using knowledge of physics, we can know:

$$t_2 = \frac{k_2}{v} \tag{2}$$

$$t_3 = \frac{k_1}{v} \tag{3}$$

July-August 2020
ISSN: 0193-4120 Page No. 726 - 735

According to the principle of the same time for the two plans, the time t_4 when the car in plan B returns to the city without load and then picks up the passengers is as follows:

$$t_4 = t_1 + t_2 - t_3 \tag{4}$$

Driver Selection Model Based on Income Difference

Since neither the waiting time t_1 in the queuing time of plan A nor the dead time t_3 of plan B generates any profit, the profit x_1 of plan A in time t_2 is used to express the profit x_2 of plan B in time t_4. The following profit difference model can be established:

$$C = x_1 - x_2 \tag{5}$$

m represents the average mileage per single taxi after returning to the urban area, n represents the number of orders received per unit time after the taxi returns to the urban area, U represents the unit price of a taxi in a certain city, and k_2 represents the distance to send passengers in plan A ,then:

$$x_1 = U \times k_2 \tag{6}$$

$$x_2 = (m \times n) \times t_4 \tag{7}$$

$$C = \begin{cases} U \times k_2 - [(\frac{w-1}{p} \times B + \frac{k_2}{v} - \frac{k_1}{v}) \times (m \times n)], \frac{Q}{m} > w \\ U \times k_2 - [(\frac{w-1}{p} \times B + t_5 + \frac{k_2}{v} - \frac{k_1}{v}) \times (m \times n)], \frac{Q}{m} < w \end{cases} \tag{8}$$

Then analyze the total return difference C between the plans as follows to obtain the driver's selection strategy:

If $C > 0$, the benefit of plan A is greater than that of plan B, and the driver should choose plan A at this time;

If $C = 0$, then the income of plan A is equal to the income of plan B. At this time, both the driver A and plan B can choose;

If $C < 0$, then the income of plan A is less than that of plan B, and the driver should choose plan B at this time;

Quick Selection Model Based on the Number of Flights and the Number of Vehicles already in the Tank

The result of the profit difference selection model is more accurate, but the calculation process is more complicated, and the driver cannot make a choice through the profit difference model. Since the taxi driver only knows the number of flights arriving in a certain period of time and the number of vehicles already in the tank, the driver can only make a judgment from the number of people who need to ride in the flight information and the number of vehicles in the tank. :

The number of arriving flights is directly proportional to the number of people who need to take a car, and the number of people who need to take a car Q can be used as a substitute for the number of arriving flights. At the same time, it is based on the assumption that every taxi driver is rational, that is, there will not be a situation where there are a small number of passengers and a lot of vehicles in the tank. Therefore, when the number of cars in the storage tank is less than the ideal number of the driver in the mind, and the number of people who need to ride is greater than the ideal number of the driver in the mind of the driver, choose option A; when the number of cars in the storage tank is greater than the ideal number of the driver when the number of cars is less than the ideal number of cars in the mind of the driver, option B is selected. fc means the quick choice made by the driver, and the quick choice model based on the number of flights and the number of vehicles in the tank can be established as follows:

$$FC = \frac{Q}{w} \tag{9}$$

If $FC > FC_0$, we choose plan A; if $FC < FC_0$, we choose plan B; and when $FC = FC_0$, we can choose either Plan A or Plan B.

July-August 2020
ISSN: 0193-4120 Page No. 726 - 735

IV. EMPIRICAL ANALYSIS BASED ON RELEVANT DATA OF SHANGHAI HONGQIAO AIRPORT

Data Collection and Processing

Shanghai Hongqiao Airport is located in the western suburbs of Shanghai, only 13 kilometers away from the city center. With its excellent hardware facilities and high-quality services, it plays a pivotal role in the development of my country's aviation industry. This article takes Hongqiao Airport as an example and uses relevant data about taxis in Shanghai to quantitatively calculate the revenue of A and B plans for taxi drivers.

Parameter Determination

- The Distance between Hongqiao Airport and the Inter-City Area k1

According to the relevant map data, Shanghai Hongqiao Airport is connected with the urban area by a section of Airport Expressway (Airport Expressway), which is about 14.9 in the income difference model.

- The Distance to Send Passengers in Plan A k2

Since the taxi driver will definitely pick up the passenger after waiting for the passenger at the airport, the distance between the destination and the airport that the passenger wants to reach at this time is the distance to send the passenger in plan A, and this distance change value is a random variable. And because the possibility of passengers arriving at any place after departure from the airport is equally possible, k2 is regarded as a uniform distribution $k_2 \sim U[a,b]$, where a is the minimum passenger mileage and the maximum passenger mileage is b.

According to the network map query, the actual distance between Shanghai Hongqiao Airport and the farthest point from Shanghai urban area to Hongqiao Airport is 81.6.

Obtained from the above data, $a=14.9$, $b=81.6$, and $k_2 \sim U[14.9,81.6]$

- Taxi Fare U

According to the "Shanghai General Taxi Pricing Standards" published by Shanghai in 2019, the taxi charging standards in Shanghai are shown in Table 2:

Table 2 Taxi charging standards in Shanghai

Taxi charging standards in Shanghai		
mileage	**Day(5:00-23:00)**	**Night(23:00-5:00)**
0-3km	14 RMB	18 RMB
3-15km	2.5 RMB/km	3.1 RMB/km
Over 15km	3.6 RMB/km	4.7 RMB/km
Additional costs	1.50% increase in distance over 15 km 2.30% increase at night. 3.If the taxi speed is less than 12 km / h or passengers ask to stop and wait, it costs 1 km every 4 minutes	

As can be seen from table 2, the taxi fare in Shanghai is determined by the specific kilometers and time. However, the nearest drop-off point after the taxi leaves the airport is 14.9 km, which is already close to a section of 15 kilometers or more. Considering the maximum profit for the taxi, the freight per kilometer of the taxi is taken as a constant, $U = 4.7RMB/km$.

- The average number of passengers per vehicle p and the boarding time of each batch of passengers in the airport boarding area B

According to [4], the relationship between the distribution of taxi boarding time and the number of passengers is shown in Table 3 and table 4.the distribution of taxi pick-up time and the relationship between pick-up time and number of passengers are obtained. The number of passengers carried by the taxi each time and the time the passengers board the bus should be random variables for easy calculation. Here, they are regarded as two constant values, namely the average number of passengers, $p = 2$, $B = 7.85$.

Table 3. The distribution of boarding time

Survey location	**Number of samples**	**Average(/s)**	**S.D.(/s)**
Hongqiao Airport	63	11.10	4.07

Table 4. Passenger capacity and boarding time

Survey location	**Capacity = 1**		**Capacity = 2**		**Capacity ⩾ 3**	
	Number of samples	Average(/s)	Number of samples	Average(/s)	Number of samples	Average(/s)
Hongqiao Airport	18	7.67	4	7.85	1	8

- The Average Speed of the Taxi while Driving v

According to [4], the speed limit for cars in Shanghai urban area is determined by the type of road. For the convenience of calculation, the average speed of the taxi while driving is regarded as a constant value. That is, $v = 40km/h$.

- Number of Taxis Received Per Unit Time in the Urban Area m

According to [5], the daily order status of taxis in downtown Shanghai is shown in Figure 4 below.

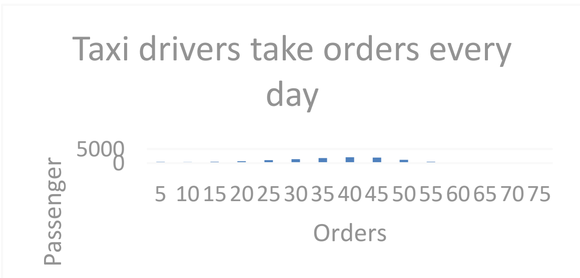

Fig 4: Number of orders received by taxi drivers

It can be obtained that the number of driver orders is a random variable that satisfies a uniform distribution, that is $m \sim U[a,b]$, where a is the minimum and b is the maximum. The maximum and minimum number of orders received in a unit hour are respectively. That is, a, b .The satisfied

TEST Engineering & Management
July-August 2020
ISSN: 0193-4120 Page No. 726 - 735

distribution is $a=\frac{5}{24}\approx 0.20$, $b=\frac{75}{24}\approx 3.1$, $m \sim U[0.20, 3.1]$.

- The Average Revenue Per Order after the Driver Takes the Order in the Urban Area n

It can be seen from the fact that the driver's revenue from receiving orders in the urban area is determined by the distance of each order. According to [6], the daily order status of taxis in downtown Shanghai is shown in Fig 5.

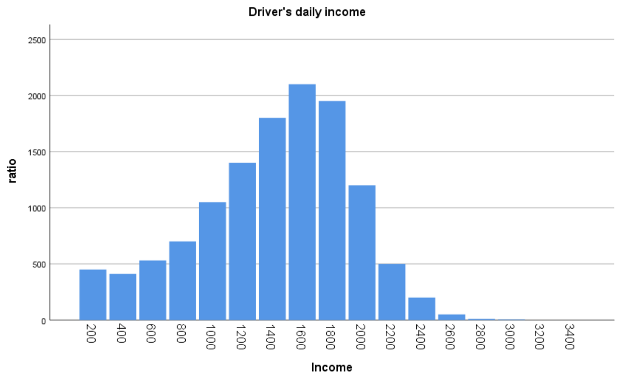

Fig 5: Driver's daily income

As can be seen from the above figure, the driver's return per order is a random variable that satisfies a uniform distribution, that is, $m \sim U[a,b]$, where a is the minimum and the maximum is b. Figure 5 shows that the driver's most likely number of orders per day is 40 per day. Then, $b=\frac{2600}{40}=65$, from Figure 5, a can be obtained as 14, and the satisfied distribution is $n \sim U[14,65]$.

- Number of People Who Need to Ride

From the analysis of problem 1, the number of people who need to take a car Q is determined by the number (y_1) of flights arriving at the airport in a certain period of time at the airport, the average number (y_2) of passengers carried by the aircraft, the occupancy rate (y_3) of the aircraft, and how passengers choose taxis among various transportation modes. The ratio of transportation (y_4) by taxi is determined jointly. And the number (y_1) of flights arriving at the airport in a certain period of time is a random variable and obeys a certain distribution, and, y_2, y_3, y_4 are constant values.

According to [7], the number of flights to Hong Kong in different periods of a day at Hongqiao Airport is shown in Table 5.

Table 5. Number of flights per hour arriving at Hongqiao Airport

time	1	2	3	4	5	6	7	8	9	10	11	12
Number of flights	9	0	2	1	0	10	28	40	27	22	19	25
time	13	14	15	16	17	18	19	20	21	22	23	24
Number of flights	30	33	30	50	21	30	27	31	25	27	13	8

From the above table, the number of daily flights arriving at Hong Kong every hour is a random value, which can be regarded as a uniform distribution, ie, $y_1 \sim U[0,50]$.

The range of passenger types and number of passengers used in Hongqiao Airport can be queried from the China Aviation Portal website, as shown in Table 6 below.

July-August 2020
ISSN: 0193-4120 Page No. 726 - 735

Table 6. Aircraft type & seats

Aircraft type	seats
Airbus 321	180
Boeing 73M	69-79
Boeing 789	250-290
Airbus 32N	180-200
Airbus 320	150 seats A320, 186 seats A321, 124 seats A319, 107 seats A318
Boeing 77W	368-550

From the above table, different aircraft types have different passenger numbers, that is, the average number of passengers carried by the aircraft is taken $y_2=200$.

Aircraft Attendance y_3

Table 7 below is obtained by intercepting some data from Shanghai Hongqiao Airport in the "2017 China Aviation Big Data Yearbook".

Table 7. No-load rate of Hongqiao Airport

Hongqiao Airport	empty-loading ratio
May 1, 2017	0.3%
May 2, 2017	3.4%
May 3, 2017	4.3%
May 4, 2017	12%
May 5, 2017	23%
May 6, 2017	23.4%
May 7, 2017	21.8%
May 8, 2017	22.1%
May 9, 2017	11.3%
May 10, 2017	2.5%
May 11, 2017	21.3%

According to the above table, the daily average empty load factor of Hongqiao Airport is 13.21%, which is the aircraft occupancy rate y_3=1-13.21%=86.79%.

Proportion of Taking Taxi

Due to their special needs, aviation airports are usually built far away from the city. Therefore, airports often have a variety of land-side transportation options to choose from. According to [6], the proportion of taxis is y_4=36%.

- The Number of Cars already in the Storage Tank (w)

According to [6], the taxi storage pool of Shanghai Hongqiao Airport can accommodate about 500 taxis at the same time. In addition, under the ideal condition, there are at least 0 vehicles in the storage pool, and based on the rational assumption of drivers, when the number of vehicles in the pool is large, the driver will not enter the pool, that is, the number of vehicles in the pool meets the uniform distribution.

- The Average Arrival Interval between Two Flights (t_5)

According to the data in the number of Hongqiao Airport's hourly arrival flights in Table 2, the average flight arrival interval in a certain hour is $t_5=5\,\text{min}$.

July-August 2020
ISSN: 0193-4120 Page No. 726 - 735

Summary of Parameter Values

We can get table 8.

Table 8. Factors & its value

factors	k_1	k_2	U	p	B	v
value	$14.9km$	$81.6km$	$4.7RMB/km$	2	7.85	$40km/h$
factors	m	n	Q	w	t_5	
value	$m \sim U[0.20, 3.1]$	$n \sim U[14, 65]$	$62.5 \times y_1 \sim U[0, 50]$	$w \sim U[0, 30]$	5min	

Accuracy Estimation of Fast Selection Model

According to the model table 5, use MATLAB software to generate the corresponding random number, bring it into the model based on the driver selection model based on the profit difference and the quick selection model based on the number of flights and the number of vehicles in the tank, and judge the fast based on the calculation results Choose the accuracy of the model. After 500 simulations, the accuracy rate of the quick selection model is 79%, that is, the choice made by the quick selection model has a 79% probability of being a more profitable choice.

V. CONCLUSION ANALYSIS AND OUTLOOK

After random simulation, it is estimated that the accuracy of the rapid selection model is 79%. It shows that the rapid selection model can basically ensure that the decisions made are better decisions while making decisions quickly.

This article does not consider special conditions such as traffic congestion, and traffic congestion in Shanghai is more common, resulting in a certain deviation between the model results and the actual situation; adding weather and traffic congestion to the model may affect the income of taxi drivers (or taxi orders) Number) or the factors that passengers choose to travel, make the model results more accurate.

REFERENCES

[1] Li Ruiqian, Cao Yufei, Liu Zhipeng (2020) Research on driver decision-making and management optimization of airport taxi.Statistics and Applications, 9(1): 7-18.

[2] Yu Handan, Zhou Luxin, Shi Yuqing, etc. (2019) Research on airport taxi scheduling based on queuing theory. Advances in Applied Mathematics 8 (12):1905-1920.

[3] Han Zhonggeng (2020) The mathematical model of the airport taxi problem. Mathematical Modeling and Its Applications, March 9(1).

[4] Wang Yafei (2018) Feature mining of passenger pick-up points based on taxi trajectory. Henan University of Technology.

[5] Lin Sirui. Research on forecasting technology of airport taxi capacity demand.

[6] Feng Bao (2019) Research on the method for determining the scale of taxi pick-up and drop-off points in a large integrated transportation hub. Urban Roads, Bridges and Flood Control, 2019(7).

[7] Guan Shengfei. (2015) Investigation and analysis of passenger characteristics at Hongqiao Airport. Shanghai Airport (20th Series). Shanghai Century Publishing Co., Ltd. Science and Technology Press, 2015:7.