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An Application of Decision-Making Model of Airport Taxi Drivers

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ABSTRACT: In this paper, taking Beijing Capital International Airport as an example, based on the decision-making model of airport taxi drivers, we study the selection plan of the taxi driver at the airport, and the rationality of the model and the dependence on related factors are analyzed by using the specificity-sensitivity curve and sensitivity analysis.

KEYWORDS: Airport taxi; Decision-making plan; Sensitivity analysis.

I. INTRODUCTION

In [1], a mathematical model of decision-making of airport taxi drivers is established. Combined with the actual situation, a mathematical model will be established to solve the following problems: By analyzing taxi data related to an airport in China and the city where the airport is located, and give the airport taxi drivers' choice and verify the rationality and dependence on related factors of the model.

II. ANALYSIS OF THE PROBLEM

The problem requires that we give the driver's decision-making plan by collecting the data to verify the rationality of the model. This paper takes the Beijing Capital International Airport as the research object, and collects relevant data from the website of the airport official network, the city taxi official network, the GPS positioning taxi and so on. Then, using the model established by the data utilization problem 1 to solve the taxi driver decision-making plan, according to the driver's real decision-making plan and the calculated decision-making plan, this paper draws figure of the total number of each day and the ROC curve of each specific time of the day, compares the matching degree of the two plans to analyze the rationality of the model. Finally, this paper considers the sensitivity analysis of indicator weights to verify the dependence of the model on relevant factors. According to the relationship between the change in the index weight and the change in the evaluation value of the plan, roll out the strength of the model's dependence on indicator.

III. MODELING AND SOLVING OF THE PROBLEM

(I) Data collection

By querying the official website of Beijing Capital International Airport, we can get the flight information that arrived at the airport from September 2 to September 8. Secondly, according to the GPS trajectory of Beijing taxis, we can obtain the data information of some taxis that were delivered to the airport within the seven days and the taxis in the airport storage pool at each time period. Combining the analysis of problem 1, we sort out all data and get the data corresponding to factors studied in this paper. Some of the data in the period from 0 to 2 hours on September 2nd are shown in the following table:

Table 1. 0-2 data table

Serial number	Driver arrival time	Number of storage pools	Number of flights	r_k	Waiting time (h)	Driver selection
1	2019/9/2 0:02	682		10.77	0	leave
2	2019/9/2 0:17	592	64	9.25	3.01	stay
3	2019/9/2 0:40	574		9.64	3.48	stay

…	…	…	…	…	…
498	2019/9/2 1:43	579	9.05	3.19	stay
499	2019/9/2 1:51	577	9.02	3.82	stay
500	2019/9/2 1:57	688	10.75	0	leave

where r_k is a variable that can reflect the relationship between the number of taxis and the number of flights, which is expressed as:

$$r_k = \frac{T_k}{F_i}.$$

where T_k represents the number of taxis in the storage pool at the k-th moment, F_i represents the number of flights arriving during the i-th time period, r_k is understood that the number of taxi corresponding to an aircraft at a certain time.

Based on the collected data, we can get the average number of taxis in the storage pool at various times of the day, the number of inbound flights, and the number of passengers who choose to take a taxi.

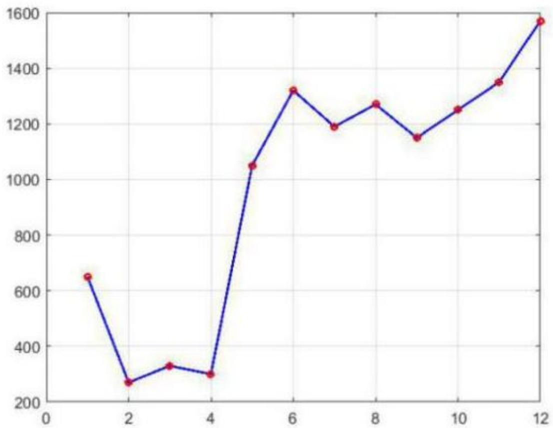

Fig.1. Change in the average number of taxis

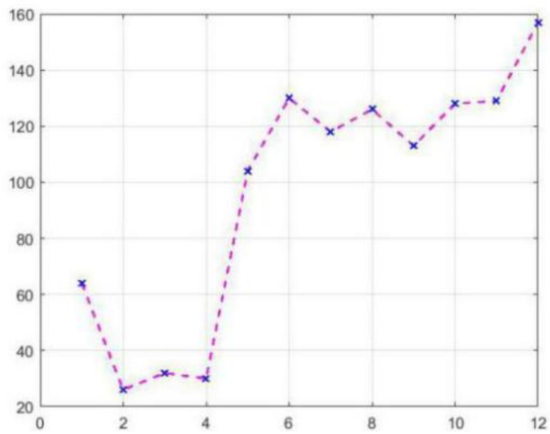

Fig.2. Change in the Number of Flights

Fig.1, Fig.2, the abscissas 1, 2, ..., 12 represent the 12 periods from 0-2 hours, 2-4 hours, ..., 22-24 hours. Looking at the Fig. above, we can conclude that a extremely similar tendency of the number of taxis in the storage pool and the number of incoming flights at a certain time, indicating that when the number of flights arriving at the airport is large, there are also more taxis waiting to carry passengers in the airport storage pool. That is to say, the taxi driver can roughly judge the number of flights entering the port when the airport is in accordance with the experience, and choose the right time period to stay in the storage pool. However, the accurate decisions of drivers at a certain moment stills need to consider a comprehensive analysis of various factors, that is, using the model established by problem 1 to give the driver's choice.

(II) Analysis of driver selection scheme

（1）Determining decision-making plan

According to the idea of building a model in problem 1, we first need to give the decision matrix. In [1], we get a threshold for the impact of the number of flights on the driver's decision-making tendency, that is, the driver tends to stay at the airport when the number of flights is greater than 40 at a certain time, and when the number of flights is less than 40, the driver tends to leave the airport. Since the number of flights is closely related to the number of taxis in the pool, so we defined the relationship between them as r_k , and at that time $r_k \le 10$, the driver tends to stay at the airport; At that time $r_k > 10$, the driver tends to leave the airport.

Below we analyze the change rule of the number of passengers. Using the seven-day data collected, the average number of passengers per period is calculated, as shown in the following table:

Table 2. Rules of change in passenger numbers table

Period of time	Number of passengers	Period of time	Number of passengers	Period of time	Number of passengers
00:00-02:00	7994	08:00-10:00	13741	16:00-18:00	15341
02:00-04:00	2952	10:00-12:00	17097	18:00-20:00	16669
04:00-06:00	3541	12:00-14:00	16148	20:00-22:00	16223
06:00-08:00	4479	14:00-16:00	16251	22:00-24:00	18781

In order to more intuitively observe the change rule of the number of passengers, we made the variation diagram of the two, as shown below:

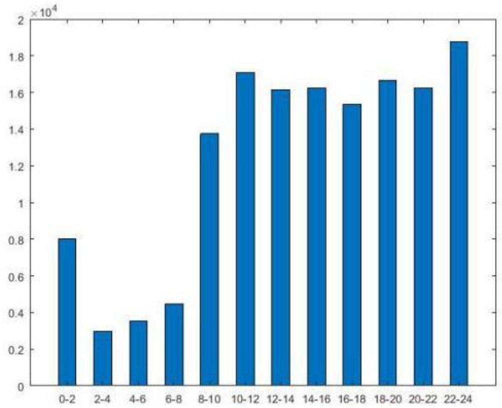

Fig.3. Law of change in passenger numbers

Through Fig.3, we can see that the number of passengers taking taxis after 8 o'clock is more than 13,000. Combining with the change rule of the number of taxis in the storage pool, this paper sets the threshold for the impact of the number of passengers on the driver's decision-making tendency to be 13,000 people. That is, drivers tend to stay at the airport when the number of people willing to take a taxi is greater than 13,000 at a certain time, and drivers tend to leave the airport when the number is less than 13,000.

So far, for the factors one, two, and three, the tendency threshold that can influence the driver's decision-making plan has been given. By comparing the actual observed value with the tendency threshold, this paper defines that when the driver prefers a certain scheme, the eigenvalue of this scheme is 2, otherwise the eigenvalue of the scheme is 1. For example: the number of flights for the corresponding time period when the driver of the 1st arrives at the airport is 65, greater than 40, the driver tends to stay, so characteristic value of plan 1 is 1and characteristic value of plan 2 is 2.

According to Table 5, the waiting time of the driver who delivers passengers to the airport at each moment can be obtained, where 0 represents the driver who did not stay at the airport, and other values are the length of time the driver stayed at the airport from arriving at the airport to leaving the airport. When the driver chooses to stay, the number of taxis that can reach the airport in a unit time, while the airport manager's "release" of the driver is carried out "in batches", that is, the prescribed number of taxis are released at certain intervals. It may be possible to set the number of drivers put into every ten minutes to 100, the average waiting time for taxi drivers can be calculated by formula (2). And when the driver chooses to leave, the driver's waiting time is actually wasted time, which can be calculated by the distance between the computer yard and the city and the driver's speed.

For the driver's benefit, the driver's formula for the benefit of choosing to stop and choose to leave is given in question 1. Here, it is only necessary to analyze the distance between the airport and the passenger's destination. When the distance is 0-3km, the distance is calculated at 2km; When the distance is 3-10km, the distance is calculated at 5km; When the distance is greater than 10km, the distance is calculated at 30km. Combined with the waiting time obtained above, the driver's specific benefits can be calculated.

In summary, combined (5) and based on the indicators of driver 1, we can conclude that the decision matrix for driver 1 is:

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$$X=\begin{pmatrix}1 & 2 & 2 & 0.43 & 14.47\\ 2 & 1 & 1 & 2.01 & 19.27\end{pmatrix},$$

standardizing:

$$X'=\begin{pmatrix}0.5 & 1 & 1 & 1 & 0.7509\\ 1 & 0.5 & 0.5 & 0.2139 & 1\end{pmatrix}.$$

（2）Solution of index weights

Based on the solution weight ingress in problem 1, the weight coefficient sits for each indicator is calculated using the MATLAB software to calculate:

$$W=(0.1287\quad 0.0763\quad 0.2087\quad 0.2034\quad 0.3829).$$

（3）Evaluation value solution

$$V=X'\cdot W'=\begin{pmatrix}0.8402\\ 0.6976\end{pmatrix}.$$

To get $v_1 > v_2$, so the driver chooses plan 1, that is, leave the airport.

With the driver decision-making solution of No. 1 driver, we can get the corresponding decision-making plan based on the observation data of all drivers. Some of the results are as follows:

Table 3. Driver decision-making plan

Driver serial number	Decision-making plan	Driver serial number	Decision-making plan
1	Leave	6	Stay
2	Stay	…	
3	Stay	498	Stay
4	Leave	499	Stay
5	Stay	500	Leave

The comprehensive decision-making plan for all drivers is as follows:

Table 4. Driver integrated decision plan

Date	9.2	9.3	9.4	9.5	9.6	9.7	9.8
Number of stays	371	289	299	321	237	429	357
Number of exits	129	211	201	179	263	71	143

(III) Model rationality analysis

According to the actual observations, we can get the accurate direction of the driver who sent the passenger to the airport. The comprehensive results are as follows:

Table 5. Driver's actual decision-making plan

Date	9.2	9.3	9.4	9.5	9.6	9.7	9.8
Number of stays	358	297	305	305	208	477	354
Number of exits	142	203	195	195	292	23	146

Comparing Table 4 and Table 5 to verify that the model as a whole is reasonable, and making a comparison chart of the number of aircraft actually staying at the airport each day with the number of aircraft staying at the airport by the model, as follows:

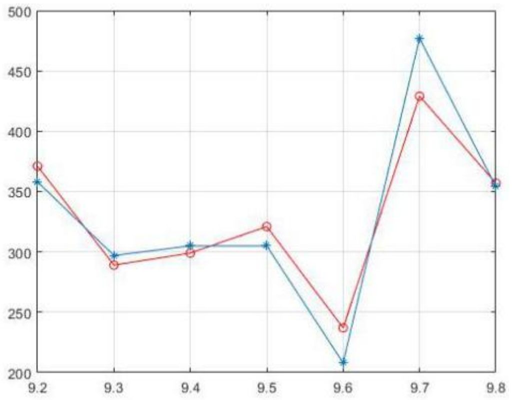

Fig.4. Comparison of actual decision-making plan and calculation decision-making plan

As can be seen from the Fig.4 above, the two straight lines are very close, indicating that the overall driver's stay rate obtained using the model is basically in line with the actual situation, but the actual stay of the driver arriving at the airport at some point in a day and the model's stay needs further discussion. Let's take September 2 as an example, and analyze it. Using the note of problem 1, "0" means the driver leaves, and "1" means the driver stays. Compare the driver's actual decision-making plan with the one we get: some of the results are shown in the table below:

Table 6. Comparison table of actual plan and calculation plan

Serial number	Actual plan	Calculating plan	Serial number	Actual plan	Calculating plan
1	1	0	497	1	1
2	1	1	498	1	1
3	0	0	499	1	1
4	1	1	500	0	0

To more intuitively reflect how close the scenario calculated to the actual scenario, that is, the two levels of matching, we used data from the day of September 2 to draw the ROC curve using MATLAB software, as shown in the following Figure:

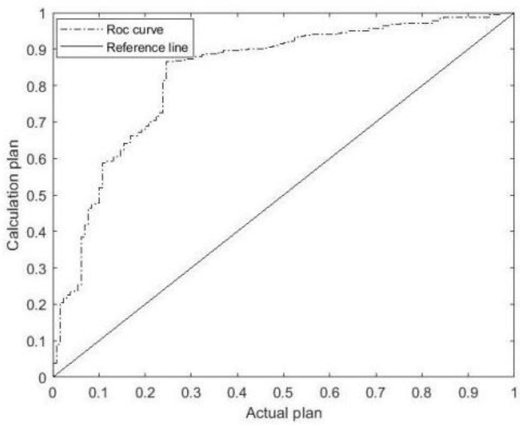

Fig.5. Roc curve

It can be concluded that the lower area of ROC curve is 0.8245, that is, the matching degree of the two schemes is 82.45%. By consulting the literature, we know that when the matching degree is more than 70%, it can better reflect the reality, and 82.45%>70%, so the model established in this paper is more reasonable.

(IV) Sensitivity analysis

To analyze the dependence of the model on related factors is to explain whether the results of the model change when a certain factor changes, that is to say, the sensitivity analysis of the model is carried out. Because the comprehensive evaluation model is established in this paper, the sensitivity analysis of the index weight can be carried out [3], and the dependence of the model on the index can be obtained. We stipulate that the model has a strong, general and weak dependence on the index, and has the following definitions: if the weight value of a certain index is changed, 1) the evaluation value of the scheme changes but the final decision scheme does not change, then the model has a weak dependence on this indicator; 2) the plan evaluation value changes and the final decision-making plan changes, but the maximum change in the plan evaluation value is small (this paper is bounded by 0.05), then the model has a general dependence on this indicator; 3) the plan evaluation value changes, the final decision plan changes, and the minimum change in the evaluation value of the scheme is large, the model has a strong dependence on this indicator.

Since the sum of the weight of each index is 1, when the weight of one index is increased or decreased, then the weight of the other indexes is reduced or increased accordingly. In this paper, the average reduction and the increase method are used

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to calculate the decrease and increase of the weight of other indexes. Weigh the indicators obtained above

$$W = (0.1287 \quad 0.0763 \quad 0.2087 \quad 0.2034 \quad 0.3829)$$

as the initial weight for follow-up analysis.

Firstly, analysis of the impact of indicator 1 (number of flights) on model results. Note that the variable of index weight is σ , then the new weight of indicator one is $0.1287+\sigma$, so the new weights of the other indicators are in turn:

$$0.0763-\sigma/4, 0.2807-\sigma/4, 0.2034-\sigma/4, 0.3829-\sigma/4 \cdot$$

Since the weight coefficient cannot be negative, it can be obtained $\sigma \le 0.3052$. Then by giving σ different values, observe whether the evaluation value of the program changes, which affects the driver's decision-making plan. We still take driver 1 as an example for analysis and set the step size of σ to 0.1

When $\sigma = 0.1$ the new weights for each indicator are

$$W_1 = (0.2287 \ 0.0513 \ 0.1837 \ 0.1784 \ 0.3579) .$$

At this time, the evaluation value of the two schemes is as follows:

$$V_1 = X' \cdot W_1' = \begin{pmatrix} 0.7965 \\ 0.6718 \end{pmatrix}.$$

Compared with V, although the evaluation value of each scheme has changed, the final decision-making plan of the driver has not change. The σ value of the change, when $\sigma = 0.2$ the new weights for each indicator are $W_1 = (0.3287 \quad 0.0263 \quad 0.1587 \quad 0.1534 \quad 0.3329)$, at this time, the evaluation value of the two schemes is as follows:

$$V_2 = X' \cdot W_2' = \begin{pmatrix} 0.7227 \\ 0.7414 \end{pmatrix}.$$

At this time, the evaluation value of scheme 2 is larger than that of scheme 1, that is to say, the driver's decision plan changes, and the minimum change of the two evaluation values is 0.0438, which is close to 0.05, but the maximum is 0.1175, which is greater than 0.05, which indicates that the model has a strong dependence on index 1.

The same reason, analyze the dependence of the model on the other four indicators：

Indicator 2 when $\sigma = 0.2$, the adjusted evaluation value is $V_3 = (0.8711 \quad 0.8857)'$, the driver decision-making plan changes but the scheme evaluation value change variable is small, that is to say, the dependence of the model on indicator 2 is general.

Indicator 3 when $\sigma = 0.3$, the adjusted evaluation value is $V_4 = (0.8146 \quad 0.8751)'$, the driver decision-making plan changes but the change of the evaluation value of the scheme is small, that is to say, the dependence of the model on indicator 3 is general.

Indicator 4 when $\sigma = 0.3$, the adjusted evaluation value is $V_5 = (0.7958 \quad 0.8374)'$, the driver decision scheme has changed and the evaluation value of the scheme has changed greatly, that is to say, the model is more dependent on indicator 4.

Indicator 5 when $\sigma = 0.3$, the adjusted evaluation value is $V_6 = (0.8023 \quad 0.8322)'$, the driver decision-making plan has changed and the evaluation value of the scheme has changed greatly, that is to say, the model has a strong dependence on the indicator 5.

In summary, the model has a strong dependence on indicator 1, indicator 3 and indicator 5 (number of flights, waiting time, driver's income), combined with reality, the first consideration of drivers is income, that is, our analysis results are in good agreement with the actual situation. At the same time, the model has a general dependence on indicator 2 and indicator 3 (the number of taxis in the storage pool, the number of passengers).

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