Airport Taxi Driver Decision and Ride Area Scheme Design Based on Hybrid Strategy

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Abstract. With the development of the civil aviation market, how to improve the operating efficiency of airport taxis while ensuring a balanced income for drivers has become an important task. This paper recommends using a hybrid strategy model for analysis. First, we analyzed the factors influencing the driver's decisions, then obtained the qualitative relationship between the driver's income and costs such as time cost and no-load cost. Second, we simplified the problems that is a game between driver groups whether or not to wait, to establish a hybrid strategy model, to provide references in selection of the two schemes for drivers. Finally, a scheme to give priority to short-distance passenger-carrying drivers is proposed. The two sides of the game are re-determined as short-distance passenger-carrying drivers and long-distance passenger-carrying drivers, and the equation of income equilibrium of both parties is obtained. The result showed that under the new scheme, both parties have equal expectations of income so the new scheme is feasible.

Keywords: Hybrid Strategy, Income Expectation, Income Equilibrium, Queuing System.

1 Introduction

With the development of the air passenger transport market, the capacity of diversified transportation modes at airports is facing more challenges. Among them, the efficient operation of airport taxi pick-up points is a key issue, but scholars are more inclined to study service level in ride area. Few people have paied attention to the driver's decision-making before picking up passengers, and the issue of the income balance of different operating distances. Therefore, the correct establishment of a mathematical model, a selection strategy for drivers, and a reasonable arrangement of planning pick-up points are significant for improving the efficiency of taxi operations and maintaining the benefits of taxi drivers.

In terms of taxi decision and profit maximization, Hairui Zhang established Driver's choice decision model based on time periods and Multi-objective programming model based on queuing theory[1]. Zichao Wang established a judgment formula based on the comprehensive supply and demand relationship and profit relationship, and achieved the long-distance and short-distance taxi driver income balance by dividing the level[2]. Boying Lv established a multi-objective programming model, which was solved using genetic algorithms to obtain a reasonable distribution scheme in airport with the highest riding efficiency[3]. Yansong Zheng established a fitting model by collecting relevant airport data and analysis and calculation methods, and a reasonable scheme is designed for the allocation of taxi resources[4].

The revenue of airport taxis is related to both whether the taxi carrying a long-distance or a short-distance passenger and whether a return taxi carring a long-distance or a short distance passenger. When the airports set the pick-up points, they should consider to give a "priority" to those drivers whose latest trip was short distance, so that the revenue of these taxis is as balanced as possible. Secondly, the existing multi-point side-by-side taxi queuing service system [5] has not maximized the riding efficiency, so taxi boarding points should be set more reasonably and efficiently.

The structure of this paper is as follows.Section 2 introduces the establishment of hybrid strategy model, which simplifies the problems to the game process of waiting or not among driver groups. Section 3 gives the scheme to make short-distance passenger-carrying drivers get priority to make their income equal, and correspondingly gives the scheme of a pick-up point, which has two parallel lanes, to improve the efficiency of the pick-up point, and shows effectiveness of this scheme.

2 Hybrid Strategy Model

2.1 Hybrid Strategy

Traffic psychology[6] research shows that factors such as the driver's driving age, gender, risk perception ability, emotion and decision-making style will have an impact on the driver's driving decision. Combining with the taxi drivers in the target airport of this article, we observed that the changes in the number of passengers at the airport and the driver's expected income will also affect the driver's decision.

To facilitate the following description, the following concepts are introduced here:

- Estimated income (I): Refers to the income that the driver may obtain from entering the waiting area and successfully carrying passengers.
- Time cost (C_1): refers to the revenue lost during the waiting period from when the driver enters the waiting area to successfully carry passengers.
- No-load cost (C_2): Refers to the no-load cost (gas fee) paid by the driver when he chooses an empty vehicle to return to the urban area and the possible loss of passenger income.

- Other cost (C_0): additional costs incurred in other time periods.

For taxi drivers, they have only two decision-making schemes. One is waiting in line for passengers (hereinafter referred to as scheme A), and the other is to empty the taxi and return to the city to carry passengers (hereinafter referred to as scheme B).

Therefore, from the standpoint of the taxi driver (self), maximizing revenue is the key to the decision. The driver's competitors are the biggest distractions affecting the driver's earnings. Thus, the problem can be simplified as a game process of choice between scheme A and scheme B among taxi drivers.

Fig.1 reflects the income calculation principle of different decision-making schemes [7]:

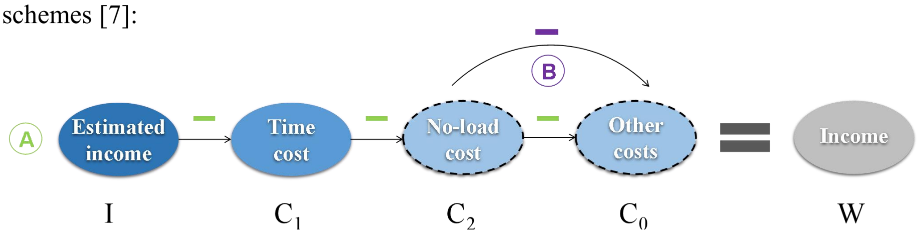

Fig. 1. Principle of income calculation.

The qualitative relationship between income, revenue and cost is as follows:

$$\text{scheme A:}\quad W = I - C_1 - C_2 - C_0 \tag{1}$$

$$\text{scheme B:}\quad W = C_2 - C_0 \tag{2}$$

Also, due to the objective existence of tourist peak-season and tourist off-season, the income and cost of drivers are not fixed, but fluctuate periodically with time.

In this step, we supposed that the probability of "oneself" choosing scheme A is $p\,(0 < p < 1)$, so the probability of choosing scheme B is $1-p$. Similarly, a "competitor" chooses scheme A with probability $q\,(0 < q < 1)$, so the probability of choosing scheme B is $1-q$. Thus the hybrid game matrix of "self" and "competitor" is shown in Table 1(the content of the matrix is represented in brackets):

Table 1. The hybrid game matrix between "self" and "competitor".

probability		q	$1-q$
	Self/Competitor	scheme A	scheme B
p	scheme A	(W_{11}, W_{11}')	(W_{12}, W_{12}')
$1-p$	scheme B	(W_{21}, W_{21}')	(W_{22}, W_{22}')

2.2 Utility analysis

We assumed that the probability of the "competitor" choosing scheme A is q, then the utility function $U(x, y)$ of "self" choosing scheme A and scheme B is respectively

$$U(1, q) = W_{11}q + W_{12}(1-q) \tag{3}$$

$$U(0,q) = W_{21}q + W_{22}(1-q) \tag{4}$$

Let $U(1,q) = U(0,q)$, get the probability

$$q = \frac{W_{22} - W_{12}}{W_{11} - W_{12} - W_{21} + W_{22}} \tag{5}$$

So as to get the income expectation of "self" as

$$E = W_{11}q + W_{12}(1-q) \tag{6}$$

In the same way, we assumed that the probability of "self" choosing scheme A is P. Let $U(p,1) = U(p,0)$, then the probability can be obtained

$$p = \frac{W_{22}' - W_{12}'}{W_{11}' - W_{12}' - W_{21}' + W_{22}'} \tag{7}$$

Decision-making suggestions provided according to the above processes:

- When the probability of the "competitor" choosing scheme A is equal to $W_{22} - W_{12} / W_{11} - W_{12} - W_{21} + W_{22}$, "self" can choose scheme A or B. When the probability of the "competitor" choosing scheme A is greater than $W_{22} - W_{12} / W_{11} - W_{12} - W_{21} + W_{22}$, the "own" scheme A is more dominant. On the contrary, the "self" scheme B is more dominant.
- When the ideal income of "self" is less than the income expectation E, scheme A should be selected, that is, queuing up passengers to obtain greater income. When the ideal income is greater than the income expectation E, scheme B should be selected, that is, empty the car without carrying passengers. When the two are equal, either scheme A or B will work.

3 Income equilibrium

3.1 Principle of income equilibrium

The types of passenger-carrying drivers can be divided into long-distance passenger-carrying and short-distance passenger-carrying. Among them, the curves of the revenue and cost of the two types of drivers over time are shown in Fig.2 and Fig.3:

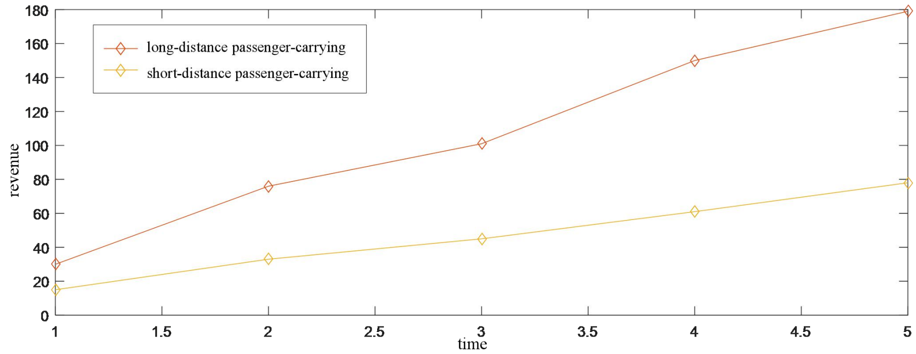

Fig.2. The revenue curve of the two types of drivers change over time

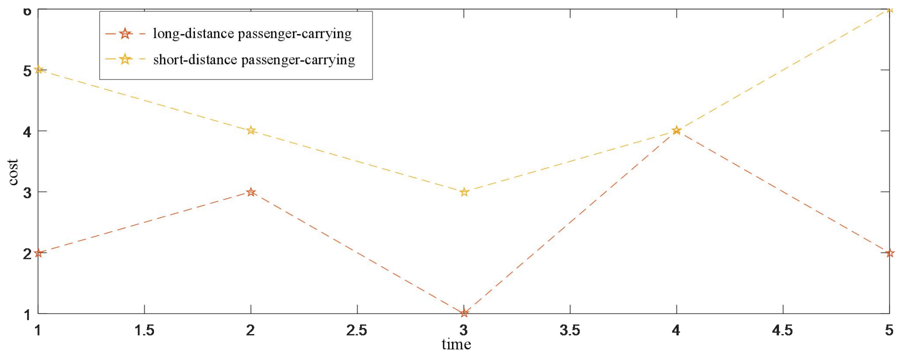

Fig.3. The cost curve of the two types of drivers change over time

It can be seen from the figure that the profit level of long-distance passenger-carrying drivers is much higher than that of short-distance passenger-carrying drivers. In addition, since the no-load cost and time cost of the long-distance passenger-carrying driver is lower than the short-distance passenger-carrying driver, the cost level is also lower than that of the short-distance passenger transportation.

As time goes by, the polar differences between the two sides will become larger and larger, which could disrupt the stability of the taxi economy market. At this time, it is necessary for the airport management department to provide a certain "priority" to the to the drivers whose lastest trip is short distance to ensure that the benefits of both parties are balanced [8], **this is the income equilibrium.**

The two sides of the game in this promble are **the short-distance passenger driver** and **the long-distance passenger driver**. To analyze this promble, the hybrid decision-making model established by section 2 can be obtained. The mathematical expression of the equilibrium of the two parties' income [7] is

$$W_{11}q + W_{12}(1-q) = W_{11}{}'p + W_{21}{}'(1-p) \tag{29}$$

It means that the income expectation of "self" is equal to the income expectation of the "competitor", namely

$$E = E' \tag{30}$$

3.2 "Priority" scheme design

We analyzed a model, which is a double-sided multi-point cross tandem queue service system. In the scenario we set, there are two parallel lanes in the taxi ride area with this model. The model is a double-sided queuing system, and the pick-up points are cross-distributed, providing detour space for the vehicles from the rear. After entering the riding area, taxis could still enter any pick-up point and wait in line. When picking up passengers, they could choose to leave the riding area on the original road or take a detour. Passengers are diverted to the two sides of the two parallel lanes in the ride area through the dedicated passage, forming a line respectively, and the first passenger in the line could choose different pick-up points. The model diagram is shown in Fig.4:

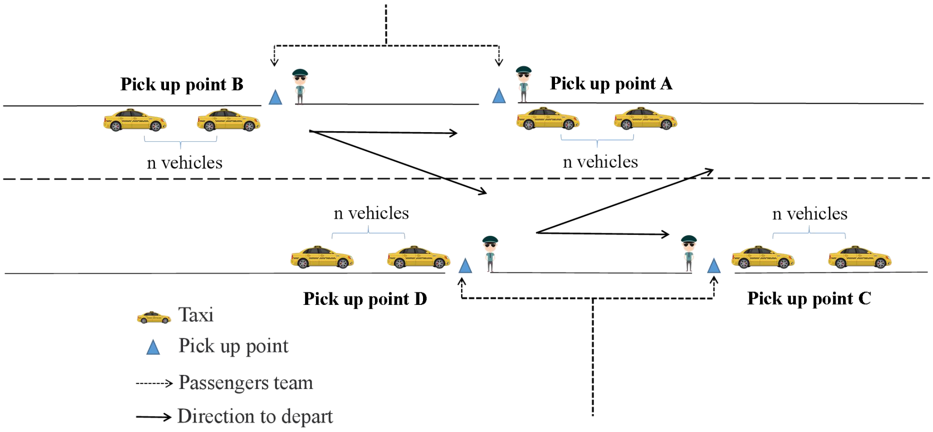

Fig.4. **A** double-sided multi-point cross tandem queue service system

To give a priority for short-distance passanger-carrying drivers, before the vehicles enter the pick-up points, they should be classified into four kinds: oridinary and priority with long and short distance, then be arranged on both sides of the ride area respectively, as shown in Fig.5 and Fig.6.

When a taxi arrived at airport, the driver should select long or short distance to go for next trip. Then, if the lastest trip is short, the driver could enter the priority lane. If not or this is the first trip from airport today, the driver should enter the ordinary lane. Therefore, all vehicles can be divided into four categories: ordinary vehicles A that will carry long-distance passengers, priority vehicles B that will carry long-distance passengers, ordinary vehicles C that will carry short-distance passengers, and priority vehicles D that will carry short-distance passengers.

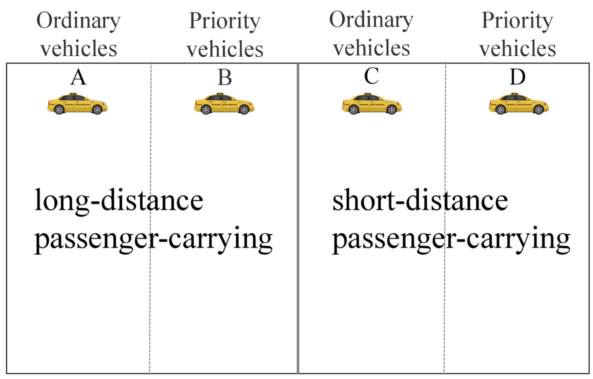

Fig.5. Classification

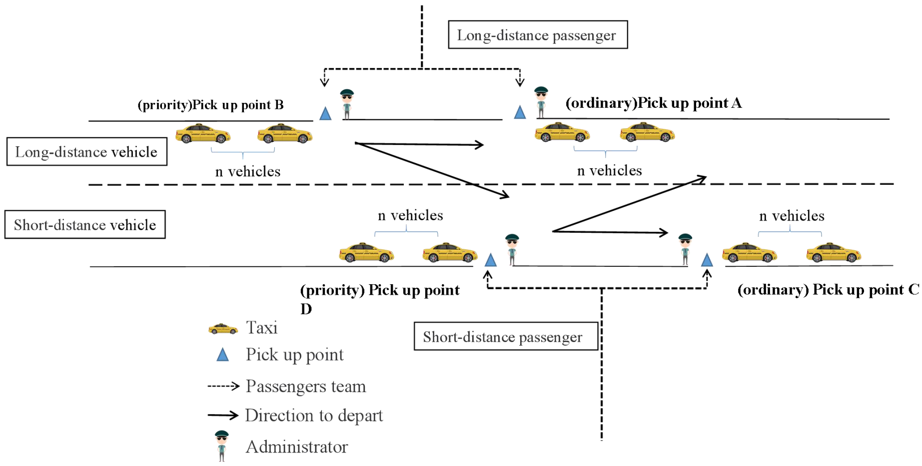

Fig.6. Priority queuing scheme for short-distance passenger transportation-ride area

The priority of short-distance passenger-carrying return vehicles is reflected in the separate queuing channel.

Passengers, before entering the ride area, are divided into two types: long-distance passengers and short-distance passengers. The two types of passengers enter the corresponding ride area in a line, and follow the instructions of the administrator to enter the pick-up point and wait for taxis.

3.3 Effect of hybrid strategy model with "priority"

Based on the priority queuing schemes in Figures 5 and 6, and the Hybrid Strategy Model in the section 2.1, the hybrid game matrix of "self" and "competitor" is re-established [9] as Table.2:

Table 2. hybrid game matrix between yourself and the vehicle in front (with priority).

probability		q	$1-q$
	Self/Competitor	scheme A	scheme B
p	scheme A	$(-3,2)$	$(3,0)$
$1-p$	scheme B	$(0,-1)$	$(2,1)$

Obtaining $E = E' = \frac{7}{3}$ from equation (30) shows that the income expectation of "self" is equal to the income expectation of "competitor", which means the income of short-distance passenger-carrying drivers and long-distance passenger-carrying drivers are balanced. It proves the scheme of priority queuing designed in this paper is effective.

4 CONCLUSIONS

This paper takes airport taxis as the research object, establishes a hybrid strategy model to be used into two problems-first, reducing the problem to a game process of whether or not drivers are waiting; second, calculating the effection of a scheme to balance the income of short-distance and long-distance passenger-carrying dirvers. The results showed that the model has good portability, and the new model can adapt to different conditions by changing the main body of the game.

References

1. H.R. Zhang, Z. Zheng, Y. Cao.: Airport Taxi Management Based on Dynamic Decision and Multi-objective Programming Model. International Journal of Service Science and Management. 2020; 3:7 (2020).
2. Z.C. Wang.: Airport Taxi Decision and Management Model based on Maximum Benefits. SSMI 2019, 375, 412-418 (2019)
3. B.Y. Lv, Y.S. Tian, B.T. Liu.: Airport Taxi Dispatching Based on VISSIM and Multi-objective Programming Model. American Journal of Computer Sciences and Applications, 2020; 3:23 (2020).
4. Y.S. Zheng.: Research on Airport Taxi Resource Allocation Based on Information Asymmetry. Open Journal of Business and Management, 08(02):763-769 (2020).
5. Z.H. Wei, L. Wang, S. Qiu.: Optimization of the service desk of taxi pick-up area in the hub based on queuing theory[J].Journal of Highway and Transport Technology, 13(10): 298-300 (2017).
6. X.C. Chen.: Research on the characteristics and influencing factors of driving decision. Liaoning Normal University (2013).
7. C.J. Zhao.: Optimization and decision-making. China Science and Technology Press, (1988).
8. S.J. Dong.: Analysis of Game Equilibrium in China's Overseas Contracting Projects. Technology and Innovation,2019(16):1-3, (2019).
9. Ewa R., Tom R. Burns.: Fuzzy Bargaining Games: Conditions of Agreement, Satisfaction, and Equilibrium. Group Decision and Negotiation, 19(5):421-440 (2010).