Forecast of Traffic Vehicle Demand Based on AHP Decision Model

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Abstract. The development of high technology has driven the rapid growth of civil aviation passenger demand. However, most current studies ignore the impact of increased passenger traffic on ground vehicle demand. This paper studies the demand forecast of transportation vehicles in a specific environment. Taxis are under huge service pressure when faced with the characteristics of irregular time distribution and high dynamics. After the taxi driver escorts the passenger to the airport, it is a big problem whether to leave without a load or go to the car pool. This paper uses Analytic Hierarchy Process (AHP) to construct a judgment matrix, establishes an airport taxi demand forecast model based on the best interests. Taking the status of taxi operation in Kunming Changshui International Airport as an example, the results show that the model can predict taxi demand more accurately and has practical guidance significance. Compared with traditional schemes, it is more conducive to improving driver’s income.

Keywords: Analytic Hierarchy Process; Forecast of traffic vehicle demand; Target layer-criterion layer; Consistency matrix.

1. Introduction

Today, air transportation is irreplaceable in the global economic and trade system⁹. According to the International Air Transport Association's(IATA) 2018 Air Transport Industry Statistics Report⁹, the 2018 global airlines' scheduled flights carried a total of 4.4 billion passengers, with an attendance rate of 81.9%, an increase of 6.9% over 2017, 284 million new passengers were added. The increasing popularity of airplane travel has greatly increased passenger throughput, and the airport's capacity has also withstood a huge test.

The factors such as the smooth operation of the airport's land-side public transportation system, the reasonable planning, the waiting time for transfers, and the quality of passenger experience all reflect the level of urban public transport operation and management⁹. As a convenient and direct means of transportation, taxis play an irreplaceable role in every airport transportation hub. How to ensure the maximum utilization of taxis is a difficult problem. Therefore, this paper will take Kunming Changshui International Airport as an example to collect all-day flight arrivals and departures and flight model data on September 13, 2019, analyse the impact mechanism of factors related to taxi driver decisions, and comprehensively consider changes in passenger flow and taxi driver revenue.
With the purpose of maximizing the profit of taxi drivers, a driver decision model is established, and finally the driver's choice is given.

2. Related Works
There are many related researches on airport transportation hubs and queues at home and abroad. Sun Jian\cite{4} et al. studied the planning of roadside passenger service resources for aviation hubs from the perspective of operations research, and pointed out two major shortcomings in the construction and management of airport in China. The AnyLogic simulation model was used to analyse the determinants of lane-side traffic capacity, and broke through the classic conclusion of the comparison between the "single queue" and "multiple queue" methods. The multiple simulation models it has created can provide managers with quantitative decision support information from more perspectives. M. Anil Yazici\cite{5} et al. developed a taxi driver pick-up decision model based on an extensive taxi trip GPS data set (which has been merged with weather information), and discussed the determinants affecting taxi drivers and the impact on airport taxi operations. Taking John F.Kennedy Airport as an example, they studied the influence of different variables on a certain factor and finally gave suggestions to alleviate the problem of airport taxi shortage. Wang Xu\cite{6} et al. summarized the situation and characteristics of parking facilities in large airports in China after investigating and analyzing parking facilities in several large airports in China. They designed the layout of the parking facilities and the terminal building, the internal traffic organization of the parking facilities, and the airport ground integrated transportation system. In addition, several large airports listed in this paper also include Kunming Changshui International Airport, and learned that the airport has realized diversified parking facilities. Zhang Ming\cite{7} et al. extended the weather-affected traffic index WITI model to three dimensions, and used regression analysis to study the relationship between the WITI index and flight delay time. It divided the precipitation levels according to the different colors of the radar echo flat scan map and matches the traffic flow information at the corresponding time. Junghoon Lee\cite{8} et al. analyzed the passenger-carrying pattern of taxis based on historical data recorded by taxi companies. They used the K-clustering method to study where passengers boarded, and focused on analyzing the changes in the cluster, and then obtained the impact on the rough car business income. Wai Hong Kan Tsui\cite{9} et al. used ARIMA model and SARIMA model for simulation, and combined with Hong Kong data analysis, they discussed the impact of SARS virus on airport passenger flow model and pointed out the relationship between airport development and surrounding traffic construction. Zichao Wang\cite{10} et al. analyzed the relationship between airport taxi supply and demand and income based on a decision algorithm. They analyzed the effects of weather, temperature and other factors on the decision by the clustering algorithm. They chose Shanghai Pudong Airport as a verification example to obtain the optimal number of berths, and based on the queuing theory, determined the optimal location of the taxi pick-up point.

3. Model
As a strong systematic analysis and decision-making tool with less data and information, Analytic Hierarchy Process (AHP) decomposes complex and fuzzy systems, turns multi-objective, multi-criteria, multi-scheme, and difficult decision-making problems into single-object, multi-level problems, and performs effective qualitative and quantitative analysis\cite{11}. It has simple flexible and practical features.
Assume that the storage pool waits for the number of vehicles, fuel prices, the distance from the airport to the urban area, road conditions, and passenger demand as the five main factors that affect taxi driver decisions. Due to the complexity of this system, it is difficult to make a quantitative analysis of the conditions that need to be considered. We choose an analytic hierarchy model \[12\], as shown in figure 1.

**Table 1. Table of scales.**

| Scaling | Meaning |
|---------|---------|
| 1       | Indicates that two factors have the same effect compared |
| 3       | Indicates that two factors are slightly stronger than the other |
| 5       | Indicates that two factors are more influential than one other |
| 7       | Indicates that two factors are significantly stronger than the other |
| 9       | Indicates that two factors are extremely strong compared to the other |
| 2,4,6,8 | Indicates that two factors influence the level of the two adjacent judgments |
| reciprocal | Comparison of factors $i$ and $j$, satisfy $a_{ij} = 1 / a_{ji}$ |

When determining the weights between factors at various levels, subjective qualitative results are often not accepted. Later, Santy et al. proposed the consistent matrix method, and they compared all factors to improve accuracy\[13\]-\[14\]. We can get the judgment matrix $A$ of the target layer-criterion layer through the scale table of table 1.

$$
A = \begin{bmatrix}
1 & 7 & 4 & 3 & 1 \\
1 & 7 & 1 & 1 & 1 \\
1 & 2 & 5 & 7 \\
1 & 4 & 2 & 1 & 1 \\
1 & 3 & 2 & 1 & 1 \\
1 & 7 & 4 & 3 & 1
\end{bmatrix}
$$

**Figure 2.** Judgment matrix $A$ of goal-criteria layer.

In the same way, the judgment matrix $B1, B2, B3, B4, B5$ of the construction solution layer is shown in table 2.
After finding the maximum feature root $\lambda_{\text{max}} = 5.0637$ of the criterion layer judgment matrix, the feature vector of its maximum feature root can be obtained, normalized and recorded as $\omega_i$. Normalized is the sorting weight of the relative importance of the corresponding element at the same level to the element at the previous level.

A is a n-th order positive reciprocal matrix. Obviously $\lambda_{\text{max}} = n$, then A is a consistent matrix. Check it for consistency:

Step 1: Calculate the n-th root $\bar{\omega}_i$ of the product of each row of the judgment matrix.

$$\bar{\omega}_i = \sqrt[n]{\prod_{j=1}^{n} a_{ij}} \quad (1)$$

Step 2: Normalize $\bar{\omega}_i$ to get $\omega_i$.

$$\omega_i = \frac{\bar{\omega}_i}{\sum_{i=1}^{n} \bar{\omega}_i} \quad (2)$$

Step 3: Calculate the consistency index $CI$.[15]

$$CI = \frac{\lambda_{\text{max}} - n}{n - 1} \quad (3)$$

Calculated $CI = 0.0159$.

Step 4: Query the average random consistency index $RI$, as shown in table 3.

| $n$ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|-----|---|---|---|---|---|---|---|---|---|
| $RI$ | 0 | 0 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 |

Step 5: Calculate the consistency ratio $CR$.

$$CR = \frac{CI}{RI} \quad (4)$$

We get $CR = 0.0142$, and at this time $CR < 0.1$. Therefore, the consistency of the matrix A is considered to be acceptable.

### 4. Experimental Results

The target layer-criteria layer judgment matrix is calculated by MATLAB software. From Equation (2),

$\omega_1 = 0.3594$, $\omega_2 = 0.0432$, $\omega_3 = 0.0844$, $\omega_4 = 0.1536$, $\omega_5 = 0.3594$. The criteria layer ranking weights are shown in figure 3.
For the “Storage Pool” Waiting for Taxi index, normalize it by the formula (2), and obtain the plan order single weights of the two schemes of waiting in line and leaving directly: $\omega_1 = 0.8000$, $\omega_2 = 0.2000$; For fuel price, $\omega_1 = 0.1667$, $\omega_2 = 0.8333$; For the distance from the airport to city, $\omega_1 = 0.2500$, $\omega_2 = 0.7500$; For road condition, $\omega_1 = 0.2000$, $\omega_2 = 0.8000$; For passenger demand, $\omega_1 = 0.8000$, $\omega_2 = 0.2000$. Generally speaking, a $2 \times 2$ matrix always meets the consistency, so no consistency check is performed on the solution layer judgment matrix. Finally, the overall level consistency check and the optimal decision are determined. The weight of the criterion layer is recorded as $1, 2, \ldots, j$, and the weight of the single order of the solution layer is recorded as $ij, j$, where the queued weight of the solution layer is $h_{ij}$, and the weight of the solution layer directly left is $h_{2j}$. Record the total ranking weight of the requested hierarchy as $W_i$. According to formula (5), the total sorting weight of the waiting in line scheme is 0.6340, and the total sorting weight of the leave directly is 0.3660.

$$W_i = \sum_{j=1}^{j} a_i b_{ij}$$  \hspace{1cm} (5)

The single-rank weights of the solution layer and the total weights of the hierarchy are shown in figure 4.
Figure 4. Single-rank weights of the scheme layer and total weights.

Accurately predicting taxi demand will help shorten the waiting time for drivers and passengers and ease traffic congestion. According to analysis, there are three peak time periods of Kunming Changshui International Airport: 6:30~8:30, 11:00~13:00, 16:00~18:30, during these three peak time periods Pool waiting vehicles will definitely increase, and passenger demand will also increase. Then the total weight of the queues waiting in these time periods will also increase, so taxi drivers should choose the scheme $C_1$ to wait for the passengers to return to the city during these three time periods. In other time periods, the taxi driver should choose the plan $C_2$ and return directly to the urban area to solicit passengers.

5. Conclusion
Transportation vehicle capacity management is of great significance to improve operational efficiency and safety, and optimize resource allocation. This paper proposes a prediction model of airport taxi demand based on maximum benefit. Taking Kunming Changshui International Airport as an example to verify the algorithm, it can be seen from the experimental results that the driver should choose different schemes under different time periods, which shows that the model has practical economic value. In summary, the airport taxi demand forecast model based on the best interests will be used to increase the income of airport taxi drivers and improve their work efficiency, reducing the waste of taxi resources. The model can be generalized to the demand analysis of other vehicles, which will help to improve the supervision efficiency of the management department, improve the accuracy of traffic vehicle prediction, and bring better economic benefits.

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