The Impact of VMS on the Choice of Outbound Passengers' Traffic Mode at Airport

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***Abstract*—VMS (Variable Message Signs), as an important part of traffic guidance system, is mainly used in road traffic to guide drivers to choose the optimal path and improve the efficiency of road network operation. This paper establishes a passenger mode selection model with or without information and use the concept of information entropy to quantify the information provided by VMS, which can be used to study the influence of VMS on passenger mode selection in airport integrated transport hub. The heuristic algorithm is used to solve the model. The results shows the relationship between the location of VMS and passenger traffic mode selection and system operation efficiency, which provides theoretical support for the location of VMS in airport integrated transport hub.**

Keywords—integrated transportation hub; travel information; traffic mode choice; VMS location; MNL model

I. INTRODUCTION

As an important part of transportation system, comprehensive transportation hub is a transit center connecting various modes of transportation and radiating certain areas. It can shorten the walking distance and time of passengers and improve the efficiency of the whole system. In order to realize the efficient utilization of multiple modes of transportation within the transport hub, it is necessary to optimize the information guidance system in the hub, and guide passengers to choose the best transfer mode by issuing traffic information. Therefore, the impact of information on people's choice of transportation mode is a problem worthy of our in-depth study.

Variable information boards mainly provide dynamic traffic information to road users in the form of graphics and text. VMS location has attracted many scholars' attention. VMS location directly affects travelers' path selection [1][2]. In order to optimize VMS location, Yuan Shuping[3] and Chen Fang[4], in order to quantify information by using the concept of information entropy, VMS and network traffic are considered. A bi-level programming model of distributed interaction.

Past studies have mainly focused on the influence of VMS on driver's route choice in road traffic, but few studies have focused on the influence of VMS on outbound passenger's traffic choice in hub. This paper mainly studies the influence of information and location provided by VMS on the choice of airport passenger traffic mode. Firstly, the concept of information entropy is introduced to quantify the information of VMS, and a model about VMS information and location is established to calculate passenger's perception parameters. Then, the perception parameters are used in the model of traffic mode selection to obtain the influence of VMS at different locations on passenger traffic mode selection.

II. TRAFFIC MODE SELECTION MODEL FOR MULTI-CLASS AIRPORT OUTBOUND PASSENGERS

The choice of passenger's mode of transportation in airport is influenced by many factors, including travel cost, walking time, waiting time, bus time and comfort degree. The travel information provided in airport will affect passenger's perceived travel time to a certain extent. This paper can compare passenger's mode of transportation choice in the absence of information and information. Whether the current VMS settings will have an impact on passengers' choice of traffic mode.

A. Hypothesis

To simplify the model description, the following assumptions are made:

- All passengers have the same destination, only one OD pair exists.
- There are three traffic.
- Traffic modes for passengers: subway, bus and taxi.
- The routes of buses and taxis are the same.
- The variable information board can display the walking time of passengers to each platform, the waiting time of metro and bus, the current queue number, the queue number of taxi parking stations and the expected waiting time in real time.

B. Symbol definition

k - Traffic modes for passengers, k=1 indicates metro, k=2 indicates bus, k=3 indicates taxi.

w - w=0 means that passengers have not received information, w=1 means that passengers have obtained information provided by the variable information board.

$q_{w,k}$ - Number of passengers of class w who choose mode k.

Q - Total traffic demand.

θ_0 - Perception parameters of passengers without information.

θ - Perception parameters of passengers with information provided by VMS.

x - Distance from VMS location to airport exit.

Δt_k - The departure interval of the metro or bus.

N_k - Maximum capacity of metro or airport buses.

L_k - Number of seats on metro or bus.

μ_k - Number of passengers arriving per unit time.

λ_k - Number of passengers boarding per unit time

C. Traffic mode selection model for outbound passengers without VMS

The actual utility function of class w passengers to mode k is shown in (1), where V_k is the observable utility of passengers, and ε_k is a random term of the utility function.

$$U_{w,k} = V_{w,k} + \varepsilon_{w,k} \tag{1}$$

Passengers without access to information can only rely on their own experience to choose the mode of transportation. Travel cost, walking time, waiting time, invehicle time and comfort are taken as the influencing factors to construct the utility function of each outbound mode. According to the utility maximization theory, a traffic mode selection model of passengers without information is established. According to the MNL model, the utility function of mode k of transportation is shown in (2). According to the queuing theory formula[5], the queuing time of passengers at each platform can be obtained, as shown in (3). In this paper, the comfort coefficient is used to express the effect of comfort on the perceived utility of passengers, as shown in (4). According to BPR function[7], the travel time of airport bus and taxi is calculated as shown in (5).

$$V_k = \beta_{\cos t} C_k + \beta_{walk} T_{k,walk} + \beta_{wait} T_{k,wait} + \alpha_k \beta_{invehicle} T_{k,invehicle} \tag{2}$$

$$T_{k,wait} = \frac{q_k}{\mu_k - \lambda_k} \tag{3}$$

$$\alpha_k = \begin{cases} 1, & \frac{q_k}{N_k} \le 1 \\ \frac{q_k}{N_k}, & \frac{q_k}{N_k} > 1 \end{cases} \tag{4}$$

$$T_{k,invehicle} = t_0 (1 + a(\frac{q_{0,2} + q_{0,3}}{C})^b) \tag{5}$$

According to the utility maximization theory, this paper establishes MNL model of user selection to represent the probability of passenger w choosing mode k without information as shown in (6). It is a perception parameter, which is related to the information obtained by passengers. A larger value means a smaller perception error. The more accurate the passenger gets the information, the larger the value is. From the fixed-point formula, we can get the number of passengers w choose mode k, as shown in (7).

$$P_{0,k} = \frac{\exp(-\theta_0 V_k)}{\sum_k \exp(-\theta_0 V_k)} \tag{6}$$

$$q_{0,k}^* - QP(q_{0,k}^*) = 0 \tag{7}$$

D. Traffic mode selection model for outbound passengers with VMS

Passengers' traffic mode choice in hub is influenced by many factors. Besides passengers' own factors and characteristics of mode of transportation, they may also be affected by information provided by VMS. Different locations of VMS have different amounts of effective information and different benefits. In order to evaluate the different benefits of VMS in different locations, the impact index is used to evaluate the different benefits of VMS in different locations. The degree of influence of VMS on the travelers who choose mode k at different locations can be expressed by the sum of information of all modes of transportation, as shown in (8). It is related to the location of VMS. The farther the VMS is from the place where the passengers get off the plane, the smaller the impact on the passengers' choice of way. So we propose the concept of attenuation factor. We define the attenuation factor as that the attenuation factor is related to the distance from VMS to the place where the passengers get off the plane, as shown in (9).

$$\beta_x = \sum_{k=1}^{3} q_{1,k} e_{k,x} H_k \tag{8}$$

$$e_{x,k} = \sigma x^d \tag{9}$$

Based on the influence of different modes of traffic information in guidance information on passengers' choice of traffic modes, we propose the concept of information entropy to quantify the guidance effect of information in VMS on passengers. By calculating the utility of different modes of transport, we can analyze the influence of different modes of transport information on passenger guidance rate in VMS information, as shown in Table 1.

TABLE I. INDUCTION RATIO AMONG DIFFERENT TRAFFIC MODES

lternative modeOriginal way	**Traffic mode**		
	Metro	***Bus***	***Taxi***
Metro	1	*V2/V1*	*V3/V1*
Bus	V_1/V_2	*1*	*V3/V2*
Taxi	V_1/V_3	*V2/V3*	*1*

The basic definition of entropy is used to express the utility of various traffic modes, the information quantity of each mode of transportation contained in VMS information. A matrix A is listed based on Table 1, as shown in (10). Line *k* vector in matrix A represents the ratio of passengers to other modes under guidance information. The information content of each mode in VMS is obtained from the definition of entropy as shown in (11). Under the information prompt of VMS, the passenger's perception parameters can be expressed by (12).

$$A=\begin{bmatrix} p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ p_{31} & p_{32} & p_{33} \end{bmatrix} \tag{10}$$

$$H_k=-\sum_{i=1}^{3} p_{ki}\log_2 p_{ki} \tag{11}$$

$$\theta=\theta_0+c\beta_x \tag{12}$$

According to the utility maximization theory, this paper establishes the MNL model of user selection to represent the probability of passenger choosing mode *k* under the information condition of VMS. As shown in (13), the number of passengers choosing mode *k* can be calculated by using the fixed-point formula, as shown in (14).

$$P_{1,k}=\frac{\exp(-\theta V_k)}{\sum_k \exp(-\theta V_k)} \tag{13}$$

$$q_{1,k}^{*}-QP(q_{1,k}^{*})=0 \tag{14}$$

III. ALGORITHM

In order to solve the problem of traffic flow assignment, we need to use heuristic algorithm. In this paper, MSA algorithm[8] is used for stochastic equilibrium assignment to obtain the situation of passenger traffic mode selection without information. The specific steps are as follows:

- Step0 Initialization. set the total number of passengers *Q* and parameter values, the time and cost of each traffic mode, Set iteration counter: y=1. Compute the probabilities where the current route is set as above. Compute initial route flows $v_k^{(0)}$.
- Step1 Update travel time and cost.
- Step2 Direction finding. Perform an assignment for q_w based on the current travel time and cost. This yields an auxiliary flow pattern $u_k^{(y)}$.
- Step3 Move. Find the new flow pattern by setting $v_k^{(y+1)}=v_k^{(y)}+(u_k^{(y)}-v_k^{(y)})/(y+1)$.
- Step4 Convergence criterion. If convergence is attained, then stop. Otherwise let y: y=y+1 and go to Step 1.

IV. EXAMPLE

Beijing Capital International Airport is one of the three portal complex hubs in China. It has three terminal buildings, 252 domestic and foreign routes and more than 90 million passengers per year. A large number of passenger flows cause the complexity of the traffic in the hub. The socio-economic characteristics of airport passengers and the characteristics of traffic mode also lead to the uneven choice of passenger traffic mode and the low utilization rate of public transport, resulting in the waste of public resources. In order to improve the operational efficiency and the utilization rate of public transport in the airport hub, this paper proposes to set up VMS in the airport hub, and analyses the function of VMS. We take the airport terminal T2 to Dongzhimen as an example to study the impact of VMS on passenger traffic mode choice. Assuming that the number of passengers departing from the airport exit to Dongzhimen is 200, there are three modes of transportation available: subway, airport bus and taxi. VMS can provide accurate time information for passengers. Reference [9] makes reasonable assumptions about passengers' perceived value parameters, as shown in Table 2.

TABLE II. THE PERCEIVED VALUE PARAMETERS OF PASSENGERS

B_{cost}	B_{walk}	B_{wait}	$B_{invehicle}$	***a***	***b***	***c***
1	9.33	9.62	7.13	$1.12*10^{-5}$	2	2

Assuming there is no VMS, the passenger's perception parameter is 0.3. The time of arrival from the airport exit includes the walking time from the exit to the platform, the waiting time at the platform, the queuing time at the platform and the in-car time. After investigation, it can be found that the walking time from the arrival of the aircraft to the airport exit is about 5 minutes, and the bus departure frequency is 30 m. In, the average departure frequency of subway is 10 minutes, and the time for passengers to take the subway, bus or taxi to Dongzhimen is 30 minutes. The cost is 25 yuan, 25 yuan and 66 yuan, respectively. Considering the average passenger capacity of a taxi is about 1.5 people, the cost for passengers to take a taxi is set at 44 yuan.

In the absence of information, the iteration results of passenger traffic mode selection can be obtained. As shown in Figure 1, the number of passengers selecting subway is 85, the number of passengers choosing bus is 12, and the number of passengers choosing taxi is 103. According to the results of iteration, the total travel time of the system without information is 8918 minutes and the total travel cost is 6962 yuan.

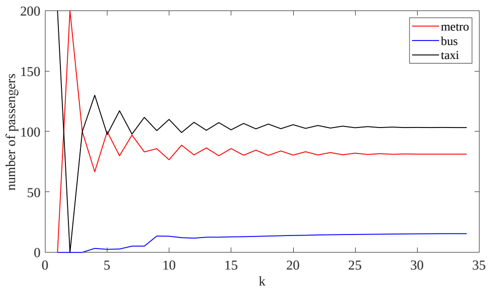

FIGURE I. PASSENGER'S TRAFFIC MODE SELECTION UNDER NO INFORMATION CONDITION

Figure 2 shows the change of passenger's traffic mode choice with *x*. *x* indicates the distance between VMS location and airport exit. From the map, the distance between airport exit and airport arrival of T2 terminal is 260 m. From the graph, it can be seen that with the increase of *x*, the number of people choosing taxis increases gradually, but when *x* is 50 m-70 m, the number of people choosing taxis decreases, and the number of people choosing buses follows. It decreases with the increase of *x*, but the number of bus choices increases between 50m and 70m.

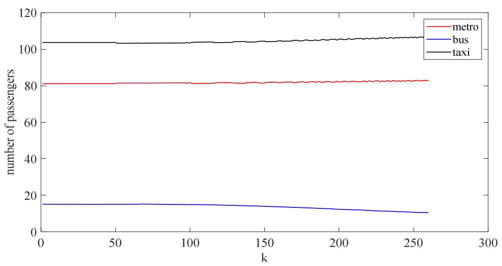

FIGURE II. PASSENGER'S TRAFFIC MODE CHOICE WITH LOCATION OF VMS

Figure 3 shows the change of passenger's total travel cost with *x* in the system. It can be seen from the figure that passenger's travel cost will not increase monotonously with the increase of *x*, but fluctuate with the increase of *x*. When the distance between VMS location and airport exit location is between 50 m and 100 m, passenger's total travel cost is the lowest.

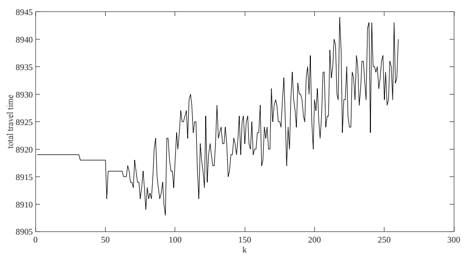

FIGURE III. PASSENGER'S TRAVEL TIME WITH LOCATION OF VMS

Fig. 4 shows the change of passenger's total travel time with *x* in the system. From the figure, it can be seen that the passenger's travel time in the system fluctuates with the increase of *x*, but when *x* is between 50m and 100m, the passenger's total travel time is the shortest.

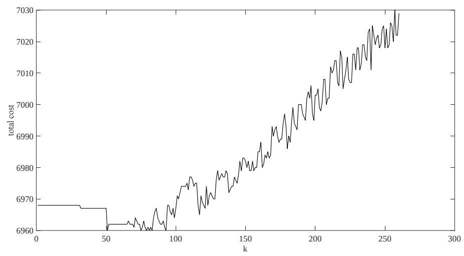

FIGURE IV. PASSENGER'S TRAVEL COST WITH LOCATION OF VMS

V. CONCLUSION

As an important part of traffic guidance system, VMS can not only be used on urban roads, but also try to be used in large-scale integrated transport hub to guide passenger flow and improve the operation efficiency of the hub. This paper draws the following conclusions by studying the influence of information on the choice of passenger transport modes in the hub.

With the change of VMS location, the number of passengers who choose the subway hardly changes. The number of people who choose the taxi increases with the increase of *x*, but the number of people who choose the taxi decreases when *x* is 50m-70m, the number of people who choose the bus decreases with the increase of *x*, but the number of people who choose the bus increases when *x* is 50m-70m. It can be seen that when the distance between VMS and airport exit is 50 m to 70 m, the utilization rate of bus can be improved and the waste of public resources can be reduced.

VMS has an impact on the total travel time and cost of passengers in the system, and its impact on the system varies with the location of VMS. The relationship between the location of VMS and the total travel time and travel cost of passengers in the system is not monotonous. When the distance between the location of VMS and the exit of Airport is 50m-100m, the total travel time and travel cost of passengers in the system is the highest. Small. It can be seen that when the distance between VMS location and airport exit is 50 m to 100 m, the operation efficiency of the airport can be effectively improved.

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