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MODELING AND PREDICTION OF PARKING LOCATION SELECTION OF PASSENGER DROP-OFF AREA AT LARGE INTERMODAL TRANSPORTATION TERMINALS

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Many simulation models are used to simulate the realistic parking choice based on the weight of parking spaces and traffic distribution of passenger drop-off area. However, these methods ignore the impact of vehicle operation, traffic situation, traffic control and other factors. For the purpose of analyzing the influence factors of parking choice behavior and predicting the parking location of vehicles in passenger drop-off area, a structural equation model (SEM) and a multiple regression model were carried out with qualitative and quantitative analysis. The impact indicators of parking choice behavior are extracted from the real-time vehicle running data, including the vehicle speed, acceleration, density of drop-off lane, delays, the distance from the nearest entrance, and traffic police command, etc. The SEM was used to estimate the relationship between these factors, the result shows that spatial constraints, time constraints and the traffic police command has a strong impact on the choice of parking spaces, while the traffic flow has a negative impact. The regression model is established to calculate the parking space of vehicles based on the observed data, the result shows the selected factors are significant to the choice of parking spaces, and it can predict the vehicle parking location well. Finally, some suggestions are put forward to alleviate traffic congestion in the passenger drop-off area.

Keywords: Large intermodal transportation terminals, passenger drop-off area, structural equation modeling, prediction of parking location.

1 Introduction

A reasonable purpose of the vehicle arriving at the terminal is to park and drop passengers off in the passenger drop-off area. Normally, the vehicle is willing to park in a parking space as close as possible to the entrance, so that passengers do not need to drag a heavy baggage to walk a long distance. Webster (1969) completed the first on-street parking simulation, he assumed that the first available parking spaces would be selected by the vehicle which is close to the parking spaces and need to park. Mandle (1982) has observed the uneven distribution of the curb parking, due to the peaking patterns of individual airlines. Wang (1990) simulated the curb parking activity of the airport terminal, waiting time, queue length, jam delay and the utilization rate of the airport terminal parking area were estimated. Parizi and Braaksma (1994) developed a design procedure based on the distribution of vehicle parking demand near the entrance of the

departure curb. Chang (2001) developed and validated a computer simulation model of a micro-stochastic discrete event to simulate traffic of airport terminal and curb parking activity.
The choice behavior of parking spaces has a greatest impact on the service of passenger drop-off area, improper parking behavior has a bad induction for the following vehicles, and it may cause serious local congestion. In order to study the influencing factors of the parking space selection, the impact of pedestrians, vehicles, roads and environment will be taking into account, and a reasonable influencing factor will be selected. The SEM, also known as covariance structures analysis, is widely used in the fields of economics, marketing, psychology and sociology (Khine, 2013; Proitsi, 2011; Wang, 2012). Lee et al. (2008) used the SEM to estimate the effect of road factors, driver factors and environmental factors on the scale of traffic accidents. Hassan and Abdel-Aty (2011) analyzed the effects of visibility conditions, traffic conditions and road types on the response of drivers. The SEM method is an emerging technology in the field of traffic engineering, and many scholars have done a lot of researches (Cheng, 2013; Chu, 2007; Jou, 2011; Karlaftis, 2015; Mariani, 2012; Mokhtarian, 1999; Sasaki, 2010; Van, 2013).
As a data-analytic approach, SEM has a number of appealing features. But it cannot be used to prove that the proposed model is correct, even a well-fitting SEM model can have problematic lower-order components and omit important variables (Breckler, 1990; MacCallum et al., 1993; Tomarken, 2005). The main consideration is the influence factor analysis of the parking space selection of building the SEM, the strong correlation variables were removed, which may lead to the model can't be a good predictor of parking location. For this reason, it is necessary to analyze the effect of observed variables on the choice of parking spaces without consideration of the path, the multivariable linear regression model will be used to predict the parking location of vehicles. All the data in this study are obtained from the video data.

2 Data collection

The Nanjing high-speed railway station was selected as the research site, and the method of extracting the vehicle trajectory was adopted. The commonly-used methods of vehicle trajectory collection are time interval photography, video capture (Wei, 2005) and GPS orientating, etc. According to the actual situation of the site investigation, and efficiency, accuracy and cost are considered, the methods of mouse click on post-processing video will be used to extract the trajectory of vehicle motion.
The following variables were selected for modeling by factor analysis, including: average speed V, Deceleration d, Acceleration a, Inlet Flow Q, Density of Passing Lane K_l, Density of Right Lane K_r, Traffic Delay D, Drop-off Duration T_d, Distance from the entrance L_e, Traffic Police Control C and Parking Spaces L_p. The correlation coefficients of "average speed V" and "average deceleration d" is the highest, and it reaches 0.636. Both "average deceleration d" and "average speed V" has a high positive correlation with "average acceleration a" (0.465, 0.484). For the "parking spaces L_p", the "traffic police control C" has the highest correlation, it indicates that the command of the traffic police has a strong positive correlation with the parking location; the correlation coefficient between the "parking spaces L_p" and the "distance from the entrance L_e" is -0.398, which indicates that the closer the distance from the entrance is, the more rearward the selected parking location is, the two variables have a strong correlation. The "traffic delay D" and "parking spaces L_p" also has a strong positive correlation, it indicates that the more delay, the parking location closer to the downstream of the passenger drop-off area. There is a low correlation between "drop-off duration T_d" (similarly, "average speed V", "average acceleration a" and "average deceleration d") and "parking spaces L_p", but they are positively correlated. The correlation between "inlet flows Q" (similarly, "density of left lane K_l" or "density of right lane K_r") and "parking spaces L_p" is lowest. The most important factors affecting the choice of parking spaces are the traffic police command, the setting of the entrance

location and the traffic delay, especially, the traffic police command and the entrance location play a vital role.

3 SEM methodology

The key factors of this model are determined based on the correlation analysis results of the factors and the factors mentioned in the literature (Mandle, 1982; Wang, 1990; Parizi and Braaksma, 1994; Chang, 2001). The structural equation model (SEM) consists of four latent variables: "Vehicle Characteristics $C_{vehicle}$", "Traffic Characteristics $C_{traffic}$", "Time Constraints C_{time}" and "Spatial Constraints $C_{spatial}$". The "Time Constraints C_{time}" and "Vehicle Characteristics $C_{vehicle}$" are affected by the "Traffic Characteristics $C_{traffic}$", so they are defined as the endogenous latent variables. The "Traffic Characteristics $C_{traffic}$" and "Spatial Constraints $C_{spatial}$" are exogenous latent variables. In addition, the observed variable "Traffic Police Control C" is defined as an exogenous variable, and the observed variable "Parking Spaces L_p" is defined as an endogenous variable. The constructed SEM model is shown in Fig. 1. A good fitting result and analysis conclusion are obtained.

For the path coefficients of the SEM, each path satisfies the 0.05 significance level from the P values, in other words, the paths are reasonable. The impact of the latent variables on the choice of parking spaces is divided into direct effect and indirect effect, direct effect corresponds to the direct impact path in the model, and indirect effect is the sum of the indirect impact path coefficients. The spatial constraints have the strongest influence on the choice of parking spaces, and the effect value (-0.543) indicates that as the spatial constraints enhancing (the more distance from the entrance), the backward effect value of the vehicle parking location increases by 0.543. Time constraints are the second major factor of the choice of parking spaces, the impact is mainly caused by the indicator "Traffic Delay", if the delay increases, and the parking location is closer to the second half of the passenger drop-off area. Traffic police command has a positive impact on the choice of parking spaces, it indicates that the traffic police command prompt vehicles to move forward and reduce the parking in the first half of the drop-off area. Traffic characteristics and vehicle characteristics have a negative impact on the choice of parking spaces, that is, when the traffic flow is large, the vehicle speed is low, and the parking location of the vehicles has the trend of moving upstream, this is a very bad situation for the passenger drop-off area. The vehicle characteristics do not have a direct effect on the choice of parking spaces, but there is an indirect negative effect.

Through analysis of path "Traffic Police Control-> Traffic Characteristics-> Parking Spaces", it is found that traffic police command has a positive impact on traffic flow, which means that the traffic police command may lead traffic flow to increase, but the traffic flow has a negative impact on the choice of parking spaces, so the comprehensive coefficient of the indirect path from "Traffic Police Control" to "Parking Spaces" is negative. It indicates that the traffic police command has a certain negative impact on the choice of parking spaces, the realistic explanation is that traffic police command can only slightly alleviate the congestion of passenger drop-off area (via command and guidance), but it cannot thoroughly solve the problem (the infinite increase of the police cannot get the condign return).

The most important factor influencing the choice of parking spaces is spatial constraints, which is the distance between vehicle and the entrance; next is time constraints, mainly is traffic delay. Overall, the traffic police have a positive impact on the choice of parking spaces, but their command will inevitably lead the density and flow to increase, which has a slight negative impact on the choice of parking spaces, it also shows that the congestion of the passenger drop-

off area can't simply rely on strengthening police powers to solve. While the influence of traffic flow on the choice of parking spaces is weak, but there is a slight negative impact.

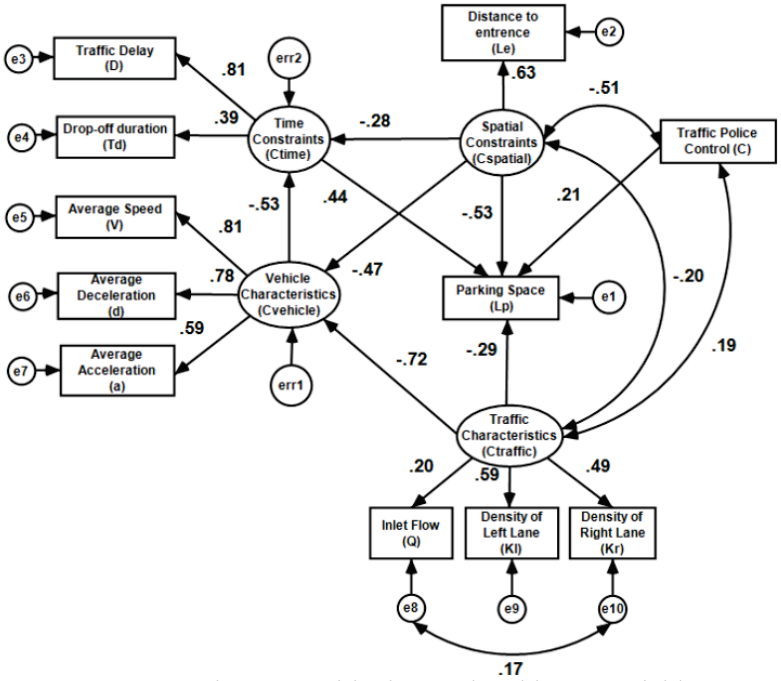

Figure 1. The SEM with observed and latent variables

For the fitting result of the SEM model, CFI/GFI/NFI/IFI/TLI are all greater than 0.9, only the relative fitting index (RFI) is close to 0.9, and RMSES=0.051, SRMR is also less than 0.05. Overall, the goodness of fit test shows that the model is fit.

4 Prediction of parking location selection

In the structural equation model, the squared multiple correlation coefficient of parking spaces selection variable is 0.602, so the structural equation model explains the 60.2% variance of the parking space selection variable. From the results, it can be seen that the comprehensive effect of traffic police control, spatial constraints, time constraints and traffic characteristics on the choice of parking spaces is about 60%, while the remaining 40% of effect is explained by the residual term of the parking space selection variable. The main consideration is the influence factor analysis of the parking space selection of building the structural equation model, the strong correlation variables were removed, which may lead to the model can't be a good predictor of vehicle parking location. For this reason, it is necessary to analyze the effect of observed variables on the choice of parking spaces without consideration of the path, the multivariable linear regression model will be used to predict the parking location of the vehicles. Through the test and analysis of the variables, the variables "Traffic Police Control", "Traffic Delay", "Distance from the entrance", "Average Speed", "Average Acceleration", and "Density of Right Lane" are selected as independent variables, these variables passed a significance test with a 95% confidence level. The parameters of the variables are estimated, it is shown below:

$$L_p = 12.37 - 4.59 \times L_e - 0.79 \times K_r + 0.033 \times D + 2.69 \times a - 0.85 \times V + 0.91 \times C \quad (5)$$

The Goodness-of-fit R^2 of the training set and the validation set are 0.723 and 0.718, respectively. The R^2 of the training set and the validation set indicated that the model has a fairly good predict ability, 72.3 percent of the data can be explained by the regression model.

Simultaneously, the histogram of the regression normalized residual and the standard p-p plot are shown in Fig. 2. It can be seen that the residual point is in the vicinity of the diagonal line. The results of the normal distribution test are as follows: the mean value is -5.65e-16, and the standard deviation is 0.991, it shows that the residuals obey normal distribution.

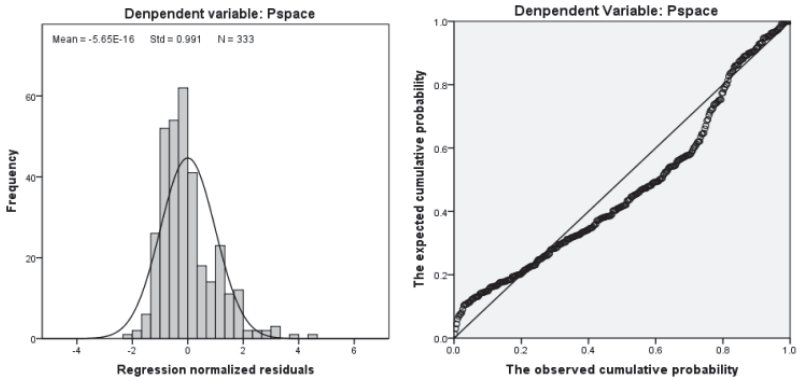

Figure 2. Normal quantile plot of regression residual

5 Conclusions

1) Influencing factor of parking spaces selection. Traffic flows has a negative impact on the choice of parking spaces, the traffic police command has a positive impact on the choice of parking spaces. But the traffic police command has a positive impact on the traffic flow, so the indirect impact of the traffic police command on the choice of parking spaces is negative. It shows that the number of police is limited, and the effect of traffic police command on the alleviation of traffic congestion is also limited, in order to address the traffic congestion of the passenger drop-off area fundamentally, it is necessary to control the inlet flow. The stronger the spatial constraints, the weaker the traffic police command, from a practical standpoint, the region far from the entrance lack the traffic police command. The stronger the intension of traffic police commands, the weaker the spatial constraints, it is indicated that traffic police command makes the vehicles' overall parking location closer to the entrance, it improves the utilization of drop-off lane to some extent.

2) Prediction of parking spaces. The linear regression model can predict the parking location of the vehicle for the passenger drop-off area according to the distance from the entrance, the density of the drop-off lane, the time delay, the average acceleration, the average speed and the traffic police command, and the prediction results are good.

3) Traffic management strategy. ① the location of the crosswalk can be adjusted as appropriate, the crosswalk may be arranged to the downstream area, and then the drop-off locations of the vehicle may concentrate on the downstream area. ②the number of traffic police can be increased as appropriate, especially in the first half of the passenger drop-off area, the traffic police can guide vehicles to move downstream, so as to reduce traffic delays, and supervise the vehicle who completes drop-off as soon as possible to leave the parking space. ③ the law should be strictly enforced. The long-time parking vehicles will be locked, and a penalty for it may be imposed to enhance the law enforcement. ④as the effect of the traffic flow on the choice of parking spaces is negative, it is necessary to control the inlet flow.

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