Shared Parking Behavioral Analysis Based on SEM

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Abstract—Shared parking has become a widely studied topic among researchers due to a rise in urban expansion. Over the past years, several studies have been conducted to investigate the relationship between the choices of shared parking spaces by urban residents and the different factors influencing these choices. This paper analyzes the different factors that can possibly affect parking choice behavior and builds a structural equation model to determine the most influencing attributes.

1. INTRODUCTION

With the high ownership of private cars in big cities, it is a problem to find a parking spot in urban center areas. According to previous studies, more than 30% of traffic congestion is caused by searching for vacant parking spots aimlessly, and over 8 extra minutes are wasted when drivers cruise to park. However, it is impracticable to solve parking problems in large cities simply by construction of new parking facilities. Instead, shared parking has become a hot topic recently.

Shared parking was firstly proposed by Smith [1], it means that parking spaces are shared by more than one user, which allows parking facilities to be used more efficiently. Since, private parking slots are generally under the pattern of ‘go out early and come back at dusk’ [2], which makes it possible for drivers whose destination near residential areas are able to park their cars in the vacant private parking slots.

The current researches about shared parking mainly focus on the feasibility analysis [3-4], implementation strategy [5-8], and the prediction of shared parking space [9-11]. However, research on shared parking behavior is still in its infancy and the existing literature is very limited.

Compared with regular parking tariffs, the individual’s shared parking behavior is more sensitive to the performance of distance between the parking lot and destination. At present, modeling shared parking-related behavior has primarily been done using various forms of discrete choice models such as Binary Logit (BL) Model, Multinomial Logit (MNL) Model. He Peng [12] developed a BL Model to study commute parking and non-commute parking, the distance between parking lot and workplace is the primary influencing factor for commute parking, and non-commute parking is more sensitive to the parking price. Han Xue [13] made a quantitative analysis of the influencing factors of shared
parking choice behavior by building MNL model. Although these studies have assessed the effects of various factors on the choice of shared parking behavior, however, the cross-correlation between the shared parking decisions was ignored.

In this study, a Structural Equation Model is constructed to describe the relationship between influence factors and shared parking choice. Through adopting analysis and results in this study, the government can implement parking policies more accurately and effectively, adjust the contradiction between the supply and demand of parking, balance the choice of parking behaviors, and promote the harmonious development of urban transportation.

2. DATA DESCRIPTION
In this paper we collected individuals’ shared parking intention data in Nanjing, 248 interviewees and 5952 data were investigated through the online and offline survey. We collected interviewees’ traveler characteristics (gender, income, driving years), parking information (travel purpose, parking duration, walking distance after parking, etc.), and shared parking intention (willing to rent parking slot, most concerned about shared parking). The variables in the study and their basic statistics are shown in Table 1.

| Variable Level | Sample size | Percentage | Variable Level | Sample size | Percentage |
|----------------|-------------|------------|----------------|-------------|------------|
| Gender         |             |            | Parking duration (hours) | > 6 | 54 | 21.77% |
| male           | 124         | 50%        |                 | 4-6 | 40 | 16.13% |
| female         | 124         | 50%        |                 | 2-4 | 81 | 32.66% |
| Monthly income (RMB yuan) |             |            |                 | 0.5-2 | 64 | 25.81% |
| > 10000        | 36          | 14.52%     |                 | < 0.5 | 9 | 3.63% |
| 8000-10000     | 59          | 23.79%     |                 | 15-20 | 9 | 3.63% |
| 5000-8000      | 84          | 33.87%     |                 | 10-15 | 44 | 17.74% |
| 2000-5000      | 49          | 19.76%     | Parking fee (yuan/hour) | > 20 | 11 | 4.44% |
| < 2000         | 20          | 8.06%      |                 | < 5-10 | 86 | 34.68% |
| Driving years (years) |             |            |                 | 2-5 | 78 | 31.45% |
| 1-5            | 156         | 62.90%     |                 | < 2 | 31 | 12.50% |
| 5-10           | 69          | 27.82%     | Walking distance after parking (minutes) | 0-5 | 60 | 24.19% |
| more than 10   | 23          | 9.27%      |                 | 5-10 | 142 | 57.26% |
| Travel purpose |             |            |                 | 15-20 | 35 | 14.11% |
| commuting      | 125         | 50.40%     |                  | > 20 | 11 | 4.44% |
| shopping       | 34          | 13.71%     |                  | yes | 201 | 81.05% |
| sight-seeing   | 54          | 21.77%     |                  | no | 29 | 11.69% |
| picking up friends and relatives | 28 | 11.29% |                  | not sure | 18 | 7.26% |
| others         | 7           | 2.82%      |                  |                  |            |
| Most concerned about shared parking |           |            | parking time limit | 51 | 20.56% |                  |
| parking information | 95 | 38.31% |                  |                  |            |
| safety         | 102         | 41.13%     |                  |                  |            |

3. METHODOLOGY
Structural equation modeling (SEM) is a multivariate statistical analysis technique that is used to analyze structural relationships. This technique is the combination of factor analysis and multiple regression analysis, and it is used to analyze the structural relationship between measured variables and latent constructs. SEM is widely used because it estimates the multiple and interrelated dependence in a single analysis.

According to shared parking intention data, two types of variables are used in the SEM. Endogenous variables are the variables to be determined by the model, and exogenous variables are known variables determined by factors other than the model, which are external conditions on which the model is based. The SEM can be described as (1).

\[ \eta = \beta \eta + \Gamma \xi + \zeta \] (1)
Where $\eta$ is endogenous variable, $B$ is the interactions between endogenous variables, $\zeta$ is exogenous variable, and $\Gamma$ is a direct random effect matrix expressing the impact of the exogenous variables on the endogenous variables. $\zeta$ is the residual error.

The construction process of SEM is: firstly, define the construction theoretically. Secondly, develop the overall measurement model by the use of an arrow, draw the arrow from the measured variable to the constructs. The third step is designing a study to minimize the likelihood of an identification problem. Fourthly, compare theoretical measurements against reality models. Then, draw the structural paths between constructs. And finally, examine the structural model validity. A model is considered a good fit if the value of the chi-square test is insignificant, and at least one incremental fit index (like CFI, GFI, TLI, AGFI, etc.) and one bad fit index (like RMR, RMSEA, SRMR, etc.) meet the predetermined criteria.

4. RESULTS & DISCUSSION

4.1 Correlation Analysis of Attributes

We collect 11 attributes of single individual in the shared parking intention survey, which includes: gender, income, driving years, purpose, duration, parking fee, walking distance, willing to rent the slot, parking time limitation, parking information and safety. The Pearson covariance matrix of each two attributes can be shown in Fig.1.

![Fig.1 Pearson covariance matrix heat map](image)

Since the absolute values of all Pearson correlation coefficient are less than 0.4. The correlation between the attributes is not significant.

4.2 Shared parking SEM

Based on the shared parking behavior analysis with the survey data, the variables are defined in Table 1. By calibrating the relationship between endogenous variables and exogenous variables, a shared parking SEM was established. According to the attributes of endogenous variables and exogenous variables, the category and names of these variables are shown in Table 2.

Shared parking behavior SEM model is built with AMOS. The path diagram of the model is created and the set of relationships between exogenous variables and the endogenous variables are defined with the help of the arrows. The path diagram for the model is shown in Fig.2.
After creating the path diagram and assigning the data labels, the analysis is conducted with maximum likelihood method which shows in Table 3. The results show that some of the variables are positive (travel purpose, parking fee, walking distance etc.) correlated with choice whereas others are negatively correlated (gender, income, duration etc.).

### Table 2. Variables in SEM

| Variable        | Category            | Name of variable | Variable        | Category            | Name of variable |
|-----------------|---------------------|------------------|-----------------|---------------------|------------------|
| Gender          | Exogenous variable  | $\xi_1$          | Walking distance after parking | Endogenous variable | $\eta_1$         |
| Monthly income  | Exogenous variable  | $\xi_2$          | Willing to rent parking slot | Endogenous variable | $\eta_4$         |
| Driving years   | Exogenous variable  | $\xi_3$          | Parking time limitation | Endogenous variable | $\eta_5$         |
| Travel purpose  | Exogenous variable  | $\xi_4$          | Parking information | Endogenous variable | $\eta_6$         |
| Parking duration| Endogenous variable | $\eta_1$          | Safety          | Endogenous variable | $\eta_7$         |
| Parking fee     | Endogenous variable | $\eta_2$          |                 |                     |                  |

Table 4 shows the reliability test of the shared parking SEM. RMR is the root mean square of residual error. The smaller RMR is, the better the model fitting is. CFI is the goodness of fit index, and its range is 0-1. AGFI is used to adjust the goodness of fit index, and CFI is adjusted by using the number ratio of degrees of freedom and variables, which should be greater than 0.9. PGFI is the goodness of fit index of simplicity. Based on the absolute estimate values of the variables, the following top 5 variables are selected as the mean factor of individuals’ shared parking behavior, which are ranked in order of their estimate values in Table 5.

### Table 3. Interactions between variables

| Variable         | Estimate | S.E. | C.R. | P    | Variable         | Estimate | S.E. | C.R. | P    |
|------------------|----------|------|------|------|------------------|----------|------|------|------|
| Gender           | -0.029   | 0.049| -0.599| 0.549| Walking distance | 0.089    | 0.033| 2.739| 0.006|
| Monthly income   | -0.008   | 0.021| -0.372| 0.710| Willing to rent  | 0.017    | 0.042| 0.396| 0.692|
| Driving years    | -0.018   | 0.037| -0.499| 0.618| Parking time    | 0.030    | 0.032| 0.936| 0.349|
| Travel purpose   | 0.015    | 0.020| 0.724 | 0.469| Parking info.   | 0.010    | 0.028| 0.340| 0.734|
| Parking duration | -0.028   | 0.021| 1.343 | 0.179| Safety          | -0.024   | 0.027| -0.916| 0.359|
| Parking fee      | 0.003    | 0.024| 0.114 | 0.909|                  |          |      |      |      |
Table 4. SEM reliability test

|               | RMR | GFI  | AGFI | PGFI |
|---------------|-----|------|------|------|
| Default model | 0.274 | 0.957 | 0.911 | 0.274 |

Table 5. Standardized Regression Weights

| Variable               | Walking distance | Parking duration | Parking time limitation | Safety | Travel purpose |
|------------------------|------------------|------------------|------------------------|--------|---------------|
| Estimate               | 0.017            | -0.083           | 0.058                  | -0.057 | 0.045         |

5. CONCLUSIONS

In this study, a structural equation model was established to analyze the impacts of individuals’ attributes on shared parking behavior. Among the total 11 attributes, walking distance after parking, parking duration, parking time limitation, safety and travel purpose are the most effective factors. These findings can be used to help develop measures to regulate shared parking behavior by controlling relevant factors.

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