Research on Travelers' Travel Behaviour in Urban Central Business Districts Based on Nested Logit Model

Dan Ying¹, Zhida Guo¹, Tianrui Ye²

¹ School of Economics and Management, Dalian Jiaotong University, Dalian 116028, China
² Beijing No.4 Middle School, Beijing 100034, China
zhidaguo@163.com

Abstract. From the perspective of individual travel, this paper studies the behavior of travel mode selection of travelers in downtown business districts. In this regard, this paper uses survey data on Dalian residents' travel to summarize the travel characteristics of travelers and to explore the key factors that influence travelers' choice of travel mode. Using all samples and considering that travelers with different travel purposes may have differences in the choice of travel modes, the travel behavior of travelers in the business center is modeled. Finally, the Nested Logit (NL) model is used to predict the traffic mode split rate of travelers in the central business district. And the variation trend of traffic mode split rate is predicted when the important influencing factor (car ownership) in the model changes. The results show that the sharing rate of cars increases significantly, while that of other modes of transportation decreases, and the fastest decline is in the order of bus and walking. This indicates that car ownership has a certain influence on the sharing rate of buses and cars. Therefore, reducing car ownership can, to a certain extent, discourage the use of cars and increase the proportion of travelers who choose public transportation.

1. Introduction
Travel is an important part of urban residents' daily life. So, in traffic planning and management and traffic demand forecasting, residents' travel behavior should be studied. In traffic demand management, one of the most important theories is the travel choice behavior theory, and the travel mode choice behavior is the most basic choice behavior. The choice of traffic mode will directly affect the traffic structure and traffic condition of the city. As the core area of the city, the urban business center attracts more traffic due to the diversified types of social activities and becomes the most concentrated area of urban traffic flow and people flow. However, due to the tense situation of land use, small land area for traffic construction and limited capacity of transportation facilities in the urban business center, traffic problems such as traffic jam and insufficient supply of parking facilities are common in this area. Many scholars have summarized the application of the NL model in the traffic choice behavior analysis, transportation policy evaluation and traffic demand prediction[1-4]. In the aspect of transportation mode selection, some scholars have seldom studied the travel behavior of travelers in urban CBD (central business district), and relevant researches are mainly focused on the choice of travel behavior of commuters[5-7]. From the existing research results, From the existing research results, scholars' research on the travel behavior of urban commercial center is also very limited.

Hence, based on the travel data on residents in Dalian, this paper, which takes travelers in the central business district of Dalian as the research object, uses NL model analysis to study travelers'
travel mode selection behavior in this region, and considers the influence of travelers' travel purpose on modeling. Finally, the NL model is used to predict and explain the behavior of travelers' choice of travel mode, and the influencing factors of travelers' choice of travel mode are clarified, which provides an important reference for easing the traffic pressure in the urban business center and improving the quality of travelers.

2. Premise Foundation

2.1. Data Sources
Real and effective data are needed to study the travel behavior of travelers in the urban business center. In this paper, the travel data on Dalian's residents' travel survey data, whose destination is the central business district of Dalian (Central Business District of Qingniwa), is selected as the basic data, and the travel mode selection behavior model of travelers is constructed based on this part of the data. The main contents of the travel survey of Dalian residents include the family attributes of travelers (such as the home address, population and bus satisfaction), personal attribute (such as age, gender, occupation and travel times) and all travel information (such as travel time, departure and arrival time, travel mode, departure and destination). The respondents of the survey are permanent residents (including temporary residents) living in the survey area. The survey involved 396 communities in Dalian, and the sampling and recycling forms were evenly distributed among households. The total number of households surveyed in the urban area was 16,802, and the population was 42,327.

As shown in the sample, the travel purposes of travelers in the business center mainly include working, shopping and entertainment, which is shown in Table 1. The proportion of commuting mainly to work is relatively large (71.82%), while the rest is non-commuting mainly to shopping and entertainment (28.18%). It can be seen that non-commuting activities such as shopping and entertainment also account for a significant proportion. The NL model was built using all the valid samples (5,170) according to travel purpose of travelers from the business center. This paper uses R-language programming to calibrate the parameters of the established NL model.

| Travel purpose     | Car owners | No car owners | Totality |
|--------------------|------------|---------------|----------|
|                    | Number of | Ratio (%)     | Number of | Ratio (%) | Number of | Ratio (%) |
|                    | trips      |               | trips     |           | trips      |           |
| Go to work         | 1076       | 77.24%        | 2637      | 69.82%    | 3713       | 71.82%    |
| Shopping and Amuse | 317        | 22.76%        | 1140      | 30.18%    | 1457       | 28.18%    |

2.2. Variable Selection
There are many factors affecting the choice of travel mode, which can be summarized into three categories: family characteristics, personal characteristics and travel characteristics. Family characteristics choose family car ownership. The traveler's personal characteristics mainly choose gender, age and occupation, among which the age is 20–29 years old, 30–39 years old and 40–49 years old. Choice of career is workers, statue of service industry, civil servant, individual worker and managerial and technical staff. Travel characteristics choose travel time as factors of travel mode.

3. Model Construction

3.1. NL Model
Assuming that the NL model has \( m \) layers, the expression of probability for the \( n \)th traveler to choose \( rm \) travel mode is shown in the formula (1).

\[
P_n(rm) = P_n(r|m) \cdot P_n(m)
\]
In the NL model, when the upper selection mode of the lower layer is selected, the selection of the lower layer is conditional probability. Therefore, the utility of the upper scheme can be determined, which is generally composed of the maximum expected utility of the lower scheme and the attribute variables of the factors affecting the scheme, which is shown in the formula (2).

$$U_{mn} = V_{mn} + e_{mn} + \theta \cdot \text{logsum}$$  \hspace{1cm} (2)$$

Formula (3) is the probability that decision maker $n$ selects $m$ from the upper $M$ selection. Formula (4) is the probability of decision maker $N$ choosing $R$ in $m$ nest under the condition of choosing upper $m$.

$$P_n(r|m) = \frac{e^{V_{rmn}}}{\sum_{r'=1}^{R} e^{V_{r'mn}}}$$  \hspace{1cm} (3)$$

$$P_n(m) = \frac{e^{V_{mn} + \theta \cdot \text{logsum}}}{\sum_{m'=1}^{M} e^{V_{mn'} + \theta \cdot \text{logsum}}}$$  \hspace{1cm} (4)$$

### 3.2. Utility Function

In the establishment of NL model, bus and car are considered to be more similar to each other than walking. Therefore, bus and car are put into the nest of motor mode, while walking is taken as a separate branch of choice and a reference branch of choice. According to the variable, the utility function of the lower layer is shown in the formula (5) and (6).

$$V_{bus} = ASC_1 \cdot \text{one} + \lambda_1 \cdot \text{Gender} + \lambda_2 \cdot \text{Age}_1 + \lambda_3 \cdot \text{Age}_2 + \lambda_4 \cdot \text{Age}_3 + \lambda_5 \cdot \text{Manager} + \lambda_6 \cdot \text{Worker} + \lambda_7 \cdot \text{Waiter} + \lambda_{15} \cdot T_{bus}$$  \hspace{1cm} (5)$$

$$V_{car} = ASC_2 \cdot \text{one} + \lambda_8 \cdot \text{Gender} + \lambda_9 \cdot \text{Age}_1 + \lambda_{10} \cdot \text{Age}_2 + \lambda_{11} \cdot \text{Age}_3 + \lambda_{12} \cdot \text{Servant} + \lambda_{13} \cdot \text{In} \_ \text{labour} + \lambda_{14} \cdot \text{Car} \_ \text{own} + \lambda_{15} \cdot T_{car}$$  \hspace{1cm} (6)$$

The upper level of the utility function is shown in the formula (7) and (8).

$$V_{walk} = \lambda_{15} \cdot T_{walk}$$  \hspace{1cm} (7)$$

$$V_{auto} = \theta \cdot \text{logsum}$$  \hspace{1cm} (8)$$

### 3.3. Parameter Calibration

| type | Variable name | Parameter estimates | T test value |
|------|---------------|---------------------|--------------|
| Bus  | Sex           | 0.386               | 3.493        |
|      | Age 20-29 years old | 0.993               | 6.171        |
|      | Age 30-39 years old | 0.871               | 5.967        |
|      | Age 40-49 years old | 0.428               | 3.386        |
3.4. Model Checking

The hit ratio of all sample NL models was 75.28%. The Logsum coefficient of all sample NL models is 0.633, which is between 0 and 1, with a significance of 99%. Therefore, it can be considered that the stratification of NL models exists. The goodness of fit ratio of the model is 0.319, which indicate that the model has a good fitting degree.

4. Contribution Rate Prediction

4.1. Predicting Outcomes

Combined with the selection probability formulas (1), (2), (3) and (4) of the NL model, each attribute value of travelers can be put into the utility function (5), (6), (7) and (8) to predict the travel mode sharing rate of all travelers in the central business district. The predicted result is shown in Table 3.

| Table 3  Travel Mode Sharing Rate Prediction Results |
|-------------------------|----------------|----------------|----------------|
|                         | Bus            | Car            | Walk           | Total          |
| Prediction Results      | 56.31%         | 20.15%         | 23.55%         | 100%           |

The car ownership was changed in the model, and the predicted result is shown in Table 4.
Table 4 The prediction results after changing the vehicle ownership

| Variation | Bus   | Variation | Car   | Variation | Walk  | Variation |
|-----------|-------|-----------|-------|-----------|-------|-----------|
| Reduce by 50% | 60.53% | +4.22% | 14.26% | -5.89% | 25.21% | +1.66% |
| Reduce by 40% | 59.72% | +3.41% | 15.38% | -4.77% | 24.90% | +1.35% |
| Reduce by 30% | 58.88% | +2.57% | 16.55% | -3.60% | 24.57% | +1.02% |
| Reduce by 20% | 58.02% | +1.71% | 17.74% | -2.41% | 24.23% | +0.68% |
| Reduce by 10% | 57.16% | +0.85% | 18.95% | -1.20% | 23.89% | +0.34% |
| Original results | 56.31% | 0 | 20.15% | 0 | 23.55% | 0 |
| Increase by 10% | 55.47% | -0.84% | 21.32% | +1.17% | 23.21% | -0.34% |
| Increase by 20% | 54.66% | -1.65% | 22.46% | +2.31% | 22.88% | -0.67% |
| Increase by 30% | 53.89% | -2.42% | 23.56% | +3.41% | 22.55% | -1.00% |
| Increase by 40% | 53.16% | -3.15% | 24.60% | +4.45% | 22.25% | -1.30% |
| Increase by 50% | 52.47% | -3.84% | 23.62% | +3.47% | 21.96% | -1.59% |

4.2. Interpretation of Results
As can be seen from the forecast results of sharing rate, with the increase of family car ownership, the proportion of car travel gradually increases, the proportion of bus travel gradually decreases, and the proportion of walking travel also presents a downward trend, but not obvious. For example, when car ownership decreases by 10%, car sharing rate decreases by 1.2%, bus sharing rate increases by 0.85%, and walking sharing rate increases by 0.34%, indicating that the change of car ownership has the greatest impact on car sharing rate, followed by bus, which has a relatively small impact on walking. Therefore, the reduction of family car ownership can reduce the proportion of travelers who choose to travel by car and increase the proportion of travelers who choose to travel by bus.

5. Conclusion
On the basis of reviewing the previous research results, this paper, from the perspective of individual travel, studies the travel mode selection behavior of urban business district travelers. Based on the travel survey data on Dalian residents, the travel characteristics and travel rules of the travelers in the business center of Dalian city are modeled and analyzed. The NL model is used to explain and predict the behavior of travelers' travel mode selection, and the influencing factors of travelers' travel mode selection are clarified. This paper provides an important reference for formulating corresponding travel demand management measures, easing the traffic pressure in the urban business center, and improving the travel quality of travelers.

Acknowledgments
This work was financially supported by the Social Science Planning Fund of Liaoning Province of China (No. L19BJY045).

References
[1] Koppelman F S, Wen C H, Mannering F . Alternative nested logit models: structure, properties and estimation[J]. Transportation Research Part B Methodological, 1998, 32B(5):289-298.
[2] Heiss F. Structural choice analysis with nested logit models[J]. Stata Journal, 2002, 2(3):227-252.
[3] Wen C H, Wang W C, Fu C. Latent class nested logit model for analyzing high-speed rail
access mode choice[J]. Transportation Research Part E, 2012, 48(2):549-554.

[4]  Qin H, Gao J, Zhang G, et al. Nested logit model formation to analyze airport parking behavior based on stated preference survey studies[J]. Journal of Air Transport Management, 2017, 58:164-175.

[5]  Asensio J. Transport mode choice by commuters to Barcelona's CBD[J]. Urban Studies, 2002, 39(10): 1881-1895.

[6]  Pan C. Incorporating Social Interaction Effects into a Travel Mode Choice Behavior Model[C]. Fifth International Conference on Transportation Engineering Southwest Jiaotong University Dalian Jiaotong University American Society of Civil Engineers. 2015.

[7]  Vander Waerden P, Timmermans H, da Silva A N R. The influence of personal and trip characteristics on habitual parking behavior[J]. Case Studies on Transport Policy, 2015, 3(1): 33-36.