

Article

The Psychological Decision-Making Process Model of Giving up Driving under Parking Constraints from the Perspective of Sustainable Traffic

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Received: 2 August 2020; Accepted: 29 August 2020; Published: 2 September 2020



Abstract: Parking restrictions can affect the use of cars and become an effective means to promote the sustainable development of urban traffic. To understand the influencing factors of car owners giving up driving due to parking constraints, the research constructs a theoretical model of psychological decision process about giving up driving under parking constraints, based on the Theory of Planned Behavior (TPB), and taking the public transit perception as a mediating variable, considering psychological factors. The empirical data were used to verify and modify the model by the Structural Equation Model (SEM) method, and finally the model was determined. The result shows that the choice of travel mode under the constraint of parking berth is not only affected by individual social and economic attributes and travel mode characteristics, but also by psychological latent variables such as behavioral attitude, subjective norms, perceived behavior control, public transportation perception and behavior intention. The subjective norms of car owners about giving up driving have a positive effect on perceived behavioral control and behavioral attitude; perceived behavior control also has an effect on behavior attitude; the behavior attitudes, subjective norms and perceived behavior control all have positive effects on the behavior intention of giving up driving due to parking constraints, among which public transit perception plays a positive adjustable intermediary role. The Integration of Choice and Latent Variable (ICLV) model considering psychological latent variables has a higher fitting degree to empirical data than the traditional Multinomial Logit (MNL) model. Based on the analysis results, some suggestions for auxiliary measures to implement the optimization strategy of parking supply are put forward.

Keywords: give up driving; parking constraints; psychological factors; theory of planned behavior; structural equation model

1. Introduction

The rapid development of urban traffic motorization has brought about a series of social problems such as urban traffic congestion, excessive energy consumption and ecological environment damage. The large number of car trips is one of the direct causes of the problems. In the United States, on-road vehicles accounted for an estimated 40% of nitrogen oxide (NO_x) emissions in 2014, with the remaining sources being power plants, other types of fuel combustion, industrial processes such as manufacturing plants, and off-road engines such as farm equipment [1]. Therefore, guiding some car owners to reduce

the use of cars and turn to public transit or other green transportation modes is the key means to promote the sustainable development of urban traffic.

Under the guidance of transportation demand management theory, more and more people realize the influence of static traffic on dynamic traffic. For instance, too many parking spaces in the city center area will cause traffic congestion by inducing more vehicles to enter the area; when the parking space supply is insufficient, some residents will choose to give up driving because of the inconvenience of parking, so as to alleviate the road traffic congestion. Morrall and Bolger [2] specifically analyzed the relationship between parking supply and public transit in downtown Canada, and the results showed, basically, that the smaller the parking space per employee, the larger the percentage of commuters who use public transit during rush hour. It showed that the parking supply in the central area of the city limited car using, and reasonable parking berth supply could lead car owners to change their way of travel to a certain extent. In recent years, many scholars further analyzed the relationship between parking berth supply and travel mode choice. For example, Gardner and Abraham [3] analyzed the reasons for commuters to drive by themselves and found that sufficient parking space supply was one of the important reasons. In the opposite direction, Eriksson et al. [4] analyzed the reasons for commuters to reduce self-driving travel, including the convenience of parking. Kroesen [5] believed that the availability of parking spaces was an important factor affecting self-driving travel. Xiao et al. [6] suggested giving up driving to reduce travel cost when parking supply was insufficient. However, these studies mainly described the influence of parking berth supply on whether car owners drive, in general, and seldom specifically analyzed the decision-making intention of different car owners facing parking constraints and influencing factors, which is not conducive to improving the effectiveness of the parking supply strategy formulation. Therefore, this research intends to discuss the main factors that lead car owners to give up driving due to parking constraints, drawing lessons from the existing theories and methods of travel behavior.

In existing studies of travel behavior, individual characteristics of travelers (gender, age, occupation, etc.), travel characteristics (travel distance, travel time, travel cost, etc.) and characteristics of vehicles were the most considered factors [7,8]. The main feature of these factors is that they can be observed directly. However, with the in-depth study of travel behavior, it was found that people's decisions were not necessarily completely rational, and some factors that cannot be directly observed, such as travelers' perceptions, will also have impact on the behavior decision to some extent—for example, some people think that public transportation is not safe, others think that carpooling is infeasible because the motorist might need to go home in an emergency. Distance, time and cost have been found to explain part of the variance in mode choice (the proportions vary according to the study), with the remainder attributed to factors that cannot be directly observed. For example, Jing Peng et al. [9] found that psychological latent variables, such as behavioral attitude and habit, had a significant impact on commuting mode selection behavior, that the model with increased latent variables had a higher degree of fitting for empirical data than the model without latent variables and that its predictive value was also more robust. In addition, Ben-Akiva et al. [10] added subjective psychological factors to the discrete choice model of travel mode. Jahansson et al. [11] analyzed the impact of flexibility, comfort and environmental protection on travel behavior. Zeid [12] analyzed its impact on travel mode choice from the perspective of travelers' subjective well-being. Habib and Zaman [13] incorporated habitual dependent psychological factors into travel behavior model. These studies showed that considering both observable and unobservable psychological latent variables is helpful to better reveal the general law of travel behavior decision-making. However, in the study of travel mode selection under parking constraints, no such research has been found so far. On the basis of considering the individual attributes and travel characteristics of the traveler, this paper intends to integrate the latent psychological variables that have an impact on the choice of travel mode, focusing on the psychological factors that lead the car owners to give up driving due to parking constraints, to better understand the factors that influence travel behavior.

Commuting is the most important travel purpose of urban residents. Although commute trips account for only 15% of all household trips [14], they accounted for between 30% and 34%, depending on how the data are tabulated, of household vehicle miles traveled [15]. Taking commuting behavior as an example, this study analyzes the psychological factors that lead car owners to give up driving due to parking constraints. By establishing the psychological decision-making process model of giving up driving under parking constraints, it discusses the relationship and mechanism among various psychological factors, to increase awareness of the behavior of giving up driving due to parking constraints, so as to provide a decision-making reference for giving full play to the role of parking supply in regulating traffic demand.

2. Method

2.1. Theoretical Framework and Hypothesis

In order to quantitatively study the influence of psychological factors on travel behavior decision-making, many researches tried to start with psychological theories and analyze the decision-making process through psychological theoretical models and psychological measurement methods. According to the conclusion of Bamberg [16] and Lanzini [17], psychological models with different complexity and prediction abilities have been applied in the study of travel behavior decision-making. Among them, the Theory of Planned Behavior (TPB) is the most widely applied. Evolving from the Theory of Rational Behavior, TPB, firstly introduced by the famous social psychologist Ajzen, is a kind of social psychology theoretical model which can precisely predict and explain the relationship between attitude and behavior. TPB claims that behavior attitude, subjective norms and perceived behavior control are the main factors controlling and predicting individual behavior intention; behavior intention is the most direct factor affecting behavior; and perceived behavioral control may also directly influence behavior. Among these factors, behavior attitude is the individual's overall evaluation of behavior, reflecting support or opposition; subjective norms are the social pressure that an individual feels when performing an action, which reflect the influence of important organizations or persons; perceived behavior control is the individual's perceive ability to perform behavior, and reflects both the personal cognition in promoting or preventing a given behavior and the personal understanding of behavioral realization. In view of the advantages of TPB in analyzing psychological factors, this study based on TPB to discuss the psychological decision-making process of car owners giving up driving due to parking constraints.

Driving and using public transit (including regular bus, subway, rapid transit bus, etc.) are the two most common modes of commuting. After car owners give up driving due to parking constraints, public transit is the most likely alternative, especially for medium- and long-distance travel [18,19]. It is inevitable that the public transit situation will be taken into account when they make decisions. Different travelers have different demands for public transit services—for example, some pay special attention to the waiting time and transfer time, and some have higher requirements on the punctuality of the operation. At the same time, different people have different degrees of willingness to choose public transit due to the satisfaction of public transit conditions. If the willingness to choose public transit is high because of the satisfaction of public transit conditions and the realistic level can meet their requirements, car owners are more likely to give up driving due to parking constraints. From a psychological point of view, car owners' perception of public transit (the willingness to choose public transit due to the satisfaction of public transit conditions) will have an impact on their behavior intention (whether to give up driving due to parking constraints).

From another perspective, car owners' choice of public transit is also a kind of behavior intention to give up driving. Therefore, the attitude, subjective norms and perceived behavior control of car owners about giving up driving should also influence them. Based on the above considerations, this study expands on the Theory of Planned Behavior and constructs a theoretical model of psychological decision-making process for giving up driving under parking constraints, as shown in Figure 1.

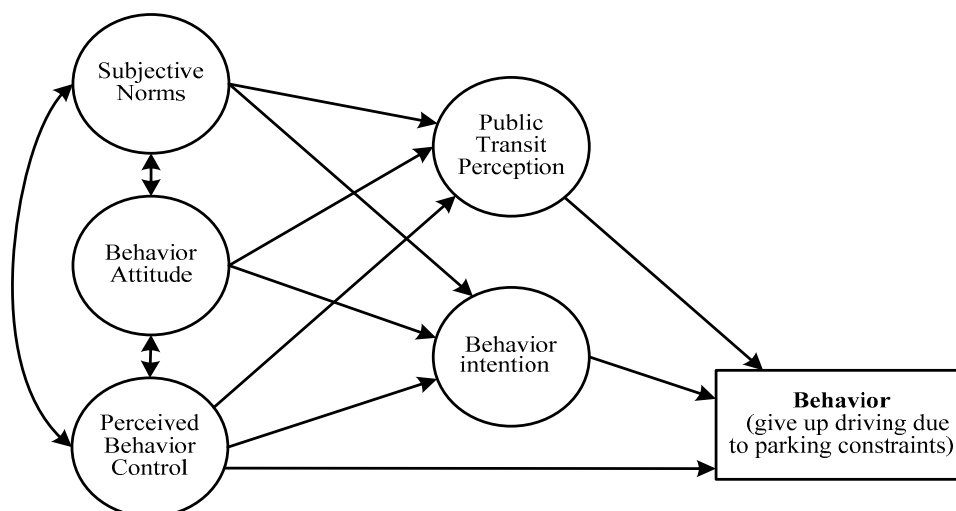


Figure 1. The theoretical framework. Source: author.

Five latent variables of psychological factors and an explicit variable (behavior) are involved in the model framework, and the following assumptions are made: there is an interaction between the behavior attitude, subjective norms and perceived behavior control of car owners about giving up driving; behavior attitude, subjective norms and perceived behavior control have significant positive effects on car owners' perception of public transit and behavior intention (giving up driving due to parking constraints); public transit perception has significant positive influence on behavior intention; perceived behavior control, public transit perception and behavior intention have influence on behavior.

2.2. Variable Settings

In this study, the observation indexes of the latent variables of psychological factors, "behavior intention" and "public transit perception", mainly refer to the existing achievements in parking demand management and travel mode research, and measure the convenience, speediness, reliability, service and so on that travelers pay attention to. The indexes of the Theory of Planned Behavior are set according to the basic principles and methods of constructing a TPB questionnaire and the research purpose. Five-point Likert scales were used to measure the observation indexes of each latent variable. "1" means strongly disagree, "2" means relatively disagree, "3" means average, "4" means relatively agree, and "5" means strongly agree. The variable settings are shown in Table 1.

The travel behavior examined in this study is to give up driving in the final analysis. Therefore, part of the theory of planned behavior mainly measures the attitude and perception of car owners toward giving up driving. Regarding behavior attitude, the individuals' evaluation of travel behavior is measured from the perspective of economic value (ba1) and social value (ba2, ba3). Since there are many components of travel cost, the travel cost of self-driving includes fuel fee, parking fee and time cost, etc. The travel cost of public transport includes the ticket costs and the time cost. From the view of direct payment, bus travel can greatly reduce costs. However, some travelers attach great importance to the time cost and think that the cost savings brought by the cost reduction are not enough to offset the loss caused by the time waste. Therefore, they have different ideas about whether giving up driving will reduce the travel cost. According to the model hypothesis, the more car owners agree that giving up driving will reduce travel costs, the more likely they are to give up driving due to parking constraints. Similarly, the more car owners believe that giving up self-driving travel is a behavior conducive to protecting the environment and easing traffic congestion, the more obvious their intention to give up self-driving travel will be. According to the TPB, travelers will be affected by the surrounding environment when making decisions. Like the policies and public opinion guidance of government departments, as well as the comments and demonstration behaviors of family members, friends or colleagues may influence people's behavioral decisions to some extent. Therefore, regarding

subjective norms, sn1 is used to reflect the impact of the macro environment on travelers, while sn2–sn4 are used to reflect the influence of important surrounding groups felt by travelers. Regarding perceived behavior control, pbc1 measures how difficult it is for travelers to perceive executive behavior, while pbc2 and pbc3 refer to the behavior enforcement conditions perceived by the travelers. According to the hypothesis, the intention of car owners was more obvious when they believed that they could make their own behavioral choices based on the criteria and that it was not difficult to carry out the behavior.

Table 1. Setting of latent variables.

Variable Code	Variable Name	Index Code	Measurement Index
BA	Behavior attitude	ba1	Giving up driving helps to reduce travel costs.
		ba2	Giving up driving is beneficial to environmental protection.
		ba3	Giving up driving is conducive to easing traffic congestion.
SN	Subjective norms	sn1	The government often encourages public transit.
		sn2	Family, friends and colleagues often complain about the difficulty of parking.
		sn3	If one of your family, friends or colleagues takes the public transit instead, you will also give up driving.
		sn4	If your family, friends or colleagues persuade you to take the public transit, you will give up driving.
PBC	Perceived behavior control	pbc1	It is not difficult for you to give up driving.
		pbc2	You will decide whether to give up driving according to the parking conditions.
		pbc3	You will decide whether to give up driving according to the public transit service level.
PTP	Public transit perception	ptp1	Prefer to travel by public transit due to short waiting time and transfer time.
		ptp2	Prefer to travel by public transit due to short journey time.
		ptp3	Prefer to travel by public transit due to high information transparency of vehicle status.
		ptp4	Prefer to travel by public transit due to the stable running time and good punctuality.
		ptp5	Prefer to travel by public transit due to the cleanliness and comfort of the vehicle.
BI	Behavior intention	bi1	Give up driving because it takes too long to search for a parking space.
		bi2	Give up driving because walking distance is too long after parking.
		bi3	Give up driving because the whole parking process takes too long.

Public transit perception refers to the willingness of car owners to choose public transit when the conditions are met, and its measurement index mainly refers to the evaluation index of public transit travel satisfaction. Many scholars have studied the factors that affect public transit satisfaction. For example, Dell’Olio [20] found that waiting time, hygiene and comfort were the most important factors for public transit passengers, while for potential public transit passengers, waiting time, journey time and departure frequency were more important. In the study of Tyrinopoulos and Antoniou [21], the service frequency, interior hygiene, waiting conditions, transfer distance and line coverage were considered as the main factors affecting public transit passenger satisfaction. Del Castillo

and Benitez [22] showed that the reliability of operating lines, the location of stations, the lighting conditions, the on-time rate and the convenience of transfers were important factors affecting the overall satisfaction of public transit passengers. In general, the rapidity, convenience, reliability and service of public transit are the most important satisfaction evaluation indexes. Referring to existing studies, this research selects five representative indicators as the measurement indicators of public transit perception. Among them, ptp1–ptp2 are measured from the perspective of rapidity, while ptp3, ptp4 and ptp5 are measured from the perspective of convenience, reliability and service. According to the model hypothesis, if the traveler's bus travel intention is enhanced due to the requirements of bus travel time (including waiting time, transfer time, driving time) and vehicle operation information acquisition, the traveler is more likely to give up self-driving travel due to parking constraints.

Behavior intention refers to the willingness of car owners to give up driving under parking constraints. Parking charges, changing parking berth supply, parking transfer and parking law enforcement management are the main methods for parking demand management [23]. This paper mainly discusses the impact of parking berth supply on the choice of travel mode. From the perspective of car owners, the dominant influence of parking supply on their travel quality is the convenience of parking. If there are fewer parking spaces in the area, it will take a long time for the traveler to find a suitable parking space near the destination (search for parking space), or it will take a long distance for the traveler to reach the destination on foot after parking. Because the time to find a parking space will affect the whole travel time, and, at the same time, because the process of finding a parking space easily makes people become restless and affect their mood, some people are more concerned about the length of time to find a parking space. However, some people may care more about the walking distance after parking. In addition to the influence of walking distance on the overall travel time, some travelers may reject this factor from a physiological perspective, such as people in weak health, women wearing high heels to their destinations, and even some travelers who do not like walking. If the environment is not good after parking, and if you need to walk outside, the impact of walking distance after parking will be more obvious. Nonetheless, the time for seeking a parking space and the walking time after parking (the corresponding length of distance) are only part of the total time required by the parking process. Sometimes, the time for seeking a parking space is long but the walking time is short, or the time for seeking a parking space is short but the walking time is long. When the two are considered comprehensively, people's intentions may be different. Therefore, in this study, the willingness to give up self-driving travel under the constraints of parking is transformed into the willingness to give up self-driving travel when seeking a parking space and walking after parking and the willingness to give up self-driving travel when the total parking time is too long. Three indicators, bi1, bi2 and bi3, are respectively used for measurement.

"Behavior" is an explicit variable, which reflects the specific choice of behavior. According to the previous analysis, three behavioral decision variables are set in this paper: maximum tolerance in the time for seeking a parking space, walking distance after parking and total parking time. Three scenarios were set, respectively: (1) If a self-driving car goes from the place of residence to the workplace and arrives near the destination, how long could the car take to find a suitable parking space before you would give it up? (B1); (2) If you drive from your place of residence to your work place, how far from your destination would the nearest available parking have to be for you to give up driving? (B2); (3) If you drive from your place of residence to your place of work and arrive near your destination, how long would the total time to look for a parking space and walk to your place of work have to be for you to give up driving? (B3). For travelers, the parking time should not be too long, or it will greatly reduce the convenience and travel experience of self-driving travel, especially commuting, and it is not appropriate to spend too much time in parking. In general, the acceptable parking time is not too long. Therefore, for the measurement of time values B1 and B3, this paper sets the selection limb at an interval of 5 min. The selection limb of B1 is: 10 min, 15 min, 20 min; and the choice of B3 limb is: 15 min, 20 min, 25 min. The selection limb of B2 is set at an interval of 200 m, including 200 m, 400 m and 600 m.

This is reflected in the length of search time and walk distance after parking, or the length of total parking time (sometimes the search time is long and the walk distance is short or the search time is short and the walk distance is long). In view of this, behavior intention was set up with five measurement indicators. Among them, bi1–bi3 represent convenience, and correspond to behavior intention under the restriction of parking berth; bi4 stands for safety, which corresponds to behavior intention under the parking safety constraints; bi5 represents economy and corresponds behavior intention under the restriction of parking fee.

2.3. Data Sources

In this study, data were collected by a random sampling questionnaire to verify the research hypothesis. The respondents were people who work in central areas of China's big cities (mainly provincial capitals) and drive to work. The survey was conducted online and offline in 2019. The offline survey was conducted by inviting people who drive to work in the central district to fill out questionnaires on the spot. The advantage of this method is that it allows us to communicate with respondents face to face and guide them to complete the survey completely and efficiently, but it is harder to find suitable respondents, and a large number of people refuse to participate because they had something to do. Therefore, an online survey was also used to collect data. The advantage of the method is that it can collect sample information from different groups, and the respondents can patiently complete the questionnaire in their spare time, but the data quality is harder to control. In order to ensure the effectiveness of the survey, some items with logical relationships were set in the questionnaire and used to screen whether the respondents participated seriously in the survey, according to their answers. Meanwhile, the conditions suitable for the respondents were clearly defined in the questionnaire description and survey invitation, which noted, in particular, that the respondents reluctant to participate in the survey were not forced.

After the questionnaire was collected, strict data screening was conducted, and the main processing methods were as follows: (1) removing samples with short response time; (2) removing illogical samples, such as unreasonable choices among travel distance, bus travel time and driving travel time; (3) removing samples with consistent choices of consecutive items in the psychometric variables, for this kind of sample can indicate that the respondents did not read or think about the questions carefully. A total of 800 questionnaires were recovered from the survey. After sorting out, 670 valid questionnaires were retained, with an effective rate of 83.7%.

The proportion of men and women in this questionnaire was basically the same, the age group was mainly under 40 years old, corporate employees and public institution staff took up a large proportion, people with junior college or bachelor's degree accounted for 71.5%, the annual household income was mainly 50,000 to 200,000 yuan, most families had only one car (68.5% of the total) and the driving age distribution was more uniform. In terms of work travel characteristics, the short, medium and long travel distances accounted for about 1/3 each, the main mode of travel was going to work directly (83.1%), the bus travel time was basically within 1.5 h, the self-driving travel time was within 1 h, parking charges in the vicinity of the workplace were generally less than 10 yuan per hour and the majority of respondents felt that the parking supply near the workplace was relatively tight. The personal attributes and travel characteristics of the interviewees are shown in Table 2.

Table 2. Descriptive statistics of personal attributes and travel characteristics.

Variables	Sorts	Assignment	Percentage (%)	Variables	Sorts	Assignment	Percentage (%)
Gender	Female	1	47.5	Distance (km)	<5	1	32.9
	Male	2	52.5		5–10	2	30.4
Age	<30	1	38.8		10–20	3	24.2
	31–40	2	40.1		>20	4	13.4
	41–50	3	17.5	Trip model	Go straight to work	1	83.1
	>50	4	3.6		other activities on the way	2	16.9
Job	civil servants	1	14.5	Bus time	<15 min	1	14.6
	Public Institution personnel	2	19.7		15–30 min	2	25.1
	Enterprise staff	3	34.5		0.5–1 h	3	35.4
	Private owner	4	13.7		1–1.5 h	4	16.1
	Others	5	17.6		>1.5 h	5	8.8
Education	Junior and below	1	1.8	Driving time	<15 min	1	32.8
	High school or Vocational School	2	7.6		15–30 min	2	37.9
	Junior or Undergraduate	3	71.5		0.5–1 h	3	22.8
	Master and above	4	19.1		1–1.5 h	4	5.1
Income (unit: thousand Chinese Yuan)	<50	1	9.0		>1.5 h	5	1.3
	50–100	2	29.0	Parking fee (unit: Chinese Yuan)	free	1	44.6
	100–200	3	28.7		<5	2	18.8
	200–300	4	16.3		5–10	3	24.0
	>300	5	17.2		10–15	4	6.6
Cars	1	1	68.5		>15	5	6.0
	2	2	28.5				
	>3	3	3.0				
Driving year	<3	1	27.8				
	3–5	2	23.4				
	5–10	3	28.1				
	>10	4	20.7				

2.4. Analysis Methods

Since there are many factors involved in behavior intention analysis, the structural Equation model is adopted in this paper to analyze the internal relations between different variables and describe the influence direction and degree of each factor. Structural Equation Model (SEM) is one of the important tools of multivariate statistics which can handle multiple dependent variables at the same time. It consists of two parts: the measurement model and the structural model. The measurement model describes how latent variables are measured or conceptualized by the corresponding explicit index; the structural model describes the relationship between latent variables and the unexplained variation parts which cannot be explained by other variables.

Measurement Equation

$$x = \Lambda_x \xi + \delta \quad (1)$$

$$y = \Lambda_y \eta + \varepsilon \quad (2)$$

Structural Equation

$$\eta = B\eta + \Gamma\xi + \zeta \quad (3)$$

where: x is a vector composed of exogenous explicit variables; ξ is the exogenous latent variable; Λ_x is the factor loading matrix of x on ξ , which reflects the relationship between exogenous explicit variables and the exogenous latent variable; δ is the error term of exogenous explicit variables; y is a vector composed of endogenous explicit variables. η is an endogenous latent variable; Λ_y is the factor load matrix of y on η , which reflects the relationship between endogenous explicit variables and endogenous latent variables; ε is the error term of endogenous explicit variables; B is the coefficient matrix, describing the interaction between endogenous latent variables; Γ is the coefficient matrix, describing the effect of exogenous latent variables on endogenous latent variables; ζ is the residual term of structural Equation, reflecting the unexplainable part of the Equation.

Partial least Squares (PLS) is one of the parameter estimation methods of the structural Equation model. The iterative algorithm is used to calculate the estimation value of latent variables, and the model parameter value is calculated accordingly. Compared with other parameter estimation methods, PLS has the advantages of low requirements on sample size and data distribution, as well as two functions of model exploration and validation. The sample data in this study shows a certain skewed distribution, and the theoretical model introduces “public transit perception” to analyze on the basis of TPB, which is not sufficient and belongs to exploratory research, so it is more appropriate to adopt PLS-SEM. In this research, SmartPLS 3.0 software was used to verify the model hypothesis and obtain the path coefficient.

3. Results and Analysis

3.1. Behavioral Preference

As for the parking conditions under which to give up driving, the respondents' overall choice tendency is shown in Table 3. It can be seen that when the time for seeking a parking space is more than 15 min, or the walking distance after parking is more than 400 m, or the whole parking time is more than 20 min, about 80% of the population will choose to give up driving. Comparing the distribution of the tolerance extreme value of time for seeking a parking space and the tolerance extreme value of walking distance after parking, the former chooses a larger time value with a smaller proportion, while the latter chooses a larger distance with a higher proportion. This shows that some people cannot bear too long a time to seek parking, but the requirements for walking distance after parking are not so high, as the respondents are willing accept a longer walking distance.

Table 3. Behavior selection distribution.

Behavior	Situation	Option	Assignment	Percentage (%)
B1	How long must it take to find a suitable parking space before you give up driving?	10 min.	1	51.0
		15 min.	2	34.1
		20 min.	3	14.9
B2	How far must the walking distance after parking be for you to give up driving?	200 m	1	39.4
		400 m	2	39.4
		600 m	3	21.2
B3	How long must the total parking time be for you to give up driving?	15 min.	1	41.9
		20 min.	2	37.6
		25 min.	3	20.4

3.2. The Measurement Model

In the process of model analysis, it was found that there was collinearity between ptp4 and other measurement variables (variance inflation factor <5 was taken as the evaluation criterion), so it was deleted. Table 4 shows the reliability and convergent validity indexes of the constructs in the final model. It can be seen that the Cronbach's α of all constructs are higher than 0.8 (>0.7 is generally required) and that the Composite Reliability (CR) of all constructs is higher than 0.9 (exceeding the critical value of 0.7), which indicates that the constructs in this study have good reliability. At the same time, the Average Variance Extracted (AVE) of all constructs is higher than 0.5, and the Factor Loadings of all constructs are higher than 0.8, indicating that the research scale used has a good convergent validity.

Table 4. Test results of reliability and convergent validity.

Psychological Latent Variables	Measurement Index	Mean	Factor Loadings	Cronbach's Alpha	CR	AVE
BA	ba1	3.46	0.917	0.931	0.956	0.880
	ba2	3.78	0.947			
	ba3	3.73	0.950			
SN	sn1	3.64	0.868	0.880	0.917	0.734
	sn2	3.62	0.839			
	sn3	3.14	0.857			
	sn4	3.23	0.863			
PBC	pbc1	3.36	0.850	0.870	0.920	0.794
	pbc2	3.73	0.921			
	pbc3	3.53	0.901			
PTP	ptp1	3.90	0.918	0.929	0.949	0.824
	ptp2	3.72	0.898			
	ptp3	3.78	0.910			
	ptp5	3.77	0.904			
BI	bi1	3.82	0.933	0.924	0.952	0.868
	bi2	3.65	0.924			
	bi3	3.71	0.938			

A discriminant validity index was used to measure whether there was sufficient discriminant validity among various latent variables. The common detection method is to compare the correlation coefficient between AVE square root and latent variables. In order to ensure a good discriminant validity, the square root of AVE should be greater than the correlation coefficient between latent variables. The comparison in Table 5 shows that the discriminant validity of the measurement model is also acceptable.

Table 5. Test results of discriminant validity.

	BA	BI	PBC	PTP	SN
BA	0.938				
BI	0.813	0.931			
PBC	0.847	0.818	0.891		
PTP	0.835	0.853	0.820	0.908	
SN	0.847	0.826	0.869	0.821	0.857

Note: The diagonal shows the square root of average variance extracted (AVE), and the rest are the correlation coefficients between latent variables.

As can be seen from the mean distribution of all measurement indicators (as shown in Table 2), the scores of all indicators are higher than 3, indicating that most respondents hold a positive attitude toward giving up driving. Specifically, in terms of behavior attitude, the score of “giving up driving helps to reduce travel costs” is relatively low, indicating that more people do not agree with this view, but hold a more unified view that giving up driving is beneficial to environmental protection and easing traffic congestion. In terms of subjective norms, the demonstration effect of important surrounding groups and their persuasion behaviors are slightly smaller. In terms of perceived behavior control, more people think that they will choose whether to give up driving based on parking conditions. In terms of public transit perception, the score of “prefer to travel by public transit due to short waiting time and transfer time” is relatively high, which indicates that waiting time and transfer time are important factors affecting the decision of travel mode. In terms of behavior intention, “give up driving because it takes too long to search for a parking space” gets the highest score, showing that the time to search for a parking space is an important constraint which has a great influence on the decision of car owners’ travel mode.

As can be seen from the factor loading of each measurement index (as shown in Table 2), the cognition of car owners regarding the social value (ba2, ba3) of giving up driving has a great influence on the behavior attitude (factor loadings are 0.947 and 0.950). In the subjective norms, “the government often encourages public transport” (sn1) has a slightly more important influence, and the factor load is 0.868. The behavior enforcement conditions perceived by car owners (pbc2 and pbc3) had a greater effect on perceived behavior control (factor loadings are 0.921 and 0.901). The measurement indexes with the greatest influence on public transit perception were rapidity and convenience (ptp1 and ptp3). In terms of behavioral intention, bi3 and bi1 had a relatively large influence.

3.3. The Structural Model

The structural model was tested mainly by the estimated path coefficient and R^2 value. Path coefficient reflects the direction and degree of influence between latent variables. R^2 reflects the degree to which the endogenous potential variables in the model can be explained by exogenous potential variables, as well as the predictive power of the model. In this paper, the bootstrapping method was used to test the significance level of the path coefficient in the model, and the results showed that all the path coefficients were significant at the level of 0.01. The model analysis results for behavior B3 are shown in Figure 2.

The R^2 of the PLS-SEM model is also called the coefficient of determination, indicating the percentage of the variance of the dependent variable that can be explained by the independent variable. The value of R^2 is between 0 and 1, and there is no consensus on the criteria for its determination. Some scholars believe that an R^2 greater than 0.2 indicates higher prediction validity [24]. The number in the circle in Figure 2 represents the R^2 value of the corresponding variable. It can be seen that the theoretical model constructed in this study can explain a 56.2% variation of behavior B3, indicating that unobserved psychological latent variables such as behavior attitude can play a role in the analysis of travel behavior under parking constraints. In addition, R^2 values of BI, PTP, BA and PBC are also higher, reaching 0.789, 0.755, 0.767 and 0.755 respectively. A modeling analysis of behavior B1 and B2

in the same way showed that the R^2 of B1 is 0.545, and the path coefficients of BI and PBC to B1 are -0.515 and -0.254 , respectively; and that the R^2 of B2 is 0.383, and the path coefficients of BI and PBC to B2 are -0.451 and -0.193 , respectively.

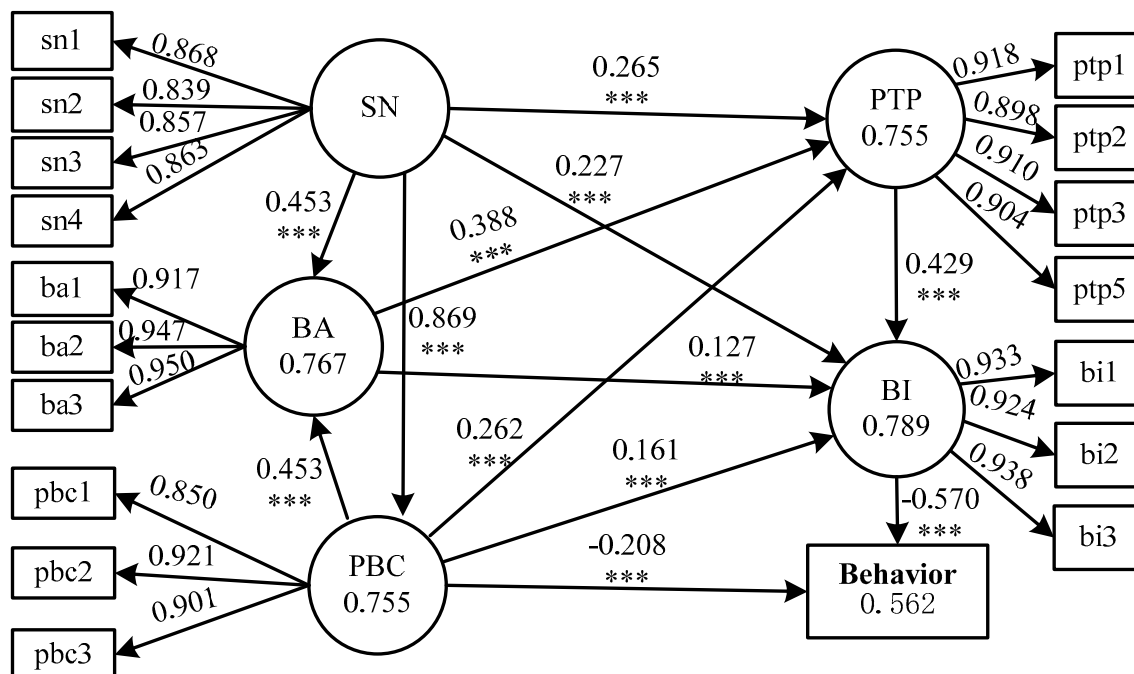


Figure 2. Analysis results of the model. Note: *** denotes $p \leq 0.01$. Source: author.

It can be seen from Figure 2 that the hypotheses in the original theoretical model are basically valid except that PTP has no significant effect on behavior. The relationship among behavior attitude, subjective norms and perceived behavior control is as follows: subjective norms have a positive effect on perceived behavior control; subjective norms and perceived behavior control have a positive effect on behavior attitude, which can influence the public transit perception and behavior intention through behavior attitude. The behavior attitude, subjective norms and perceived behavior control of car owners on giving up driving not only have direct impact on the behavior intention, but also an obvious positive effect on the public transit perception (the behavior attitude has the greatest impact, with a path coefficient of 0.388). They can have an indirect influence on behavior intention through public transit perception. That is, public transit perception plays an intermediary role in the psychological decision-making process. To further prove this point, the “public transit perception” variable was removed from the model, and the results showed that the R^2 of behavior intention (BI) was reduced to 0.743, which reduced the interpretation and prediction ability of the variable. This indicates that it is significant to introduce the “public transit perception” variable to analyze on the basis of the Theory of Planned Behavior. The direct positive influence factors of behavior intention (give up driving due to parking constraints) are, in descending order, public transit perception, subjective norms, perceived behavior control and behavior attitude (path coefficients are 0.429, 0.227, 0.161 and 0.127, respectively). In addition, perceived behavior control and behavior intention can have a direct positive effect on behavior, and the path coefficients between them are -0.570 and -0.208 . On the whole, the model results are consistent with the relationship described in the TPB, and the mediator variable “Public Transit Perception” added is significant.

4. Further Discussion

In order to understand whether the analyzed psychological latent variables can indeed play a certain role in the analysis of travel behavior under parking constraints, based on other travel

behavior analysis methods, this paper establishes a travel behavior model with psychological latent variables, and compares it with the model without latent variables, so as to analyze the differences with empirical data.

4.1. Establishment of Travel Behavior Model Considering Psychological Latent Variables

Due to the awareness that psychological factors may also have a significant influence on travel behavior, Ben-Akiva et.al. [10] proposed the Integration of Choice and Latent Variable Models (ICLV), also called Hybrid Choice Model (HCM). In recent years, many scholars have applied the ICLV model to the study of travel behavior [11,13]. ICLV is an extension of the traditional discrete choice model. Its essence is to combine the psychological attributes that affect individual decision-making behavior with external observable variables (basic individual attributes, travel attributes, etc.) to more truly depict individual decision-making behavior preference. According to ICLV's modeling idea, this paper establishes a model framework for travel behavior under parking and berth constraints, as shown in Figure 3.

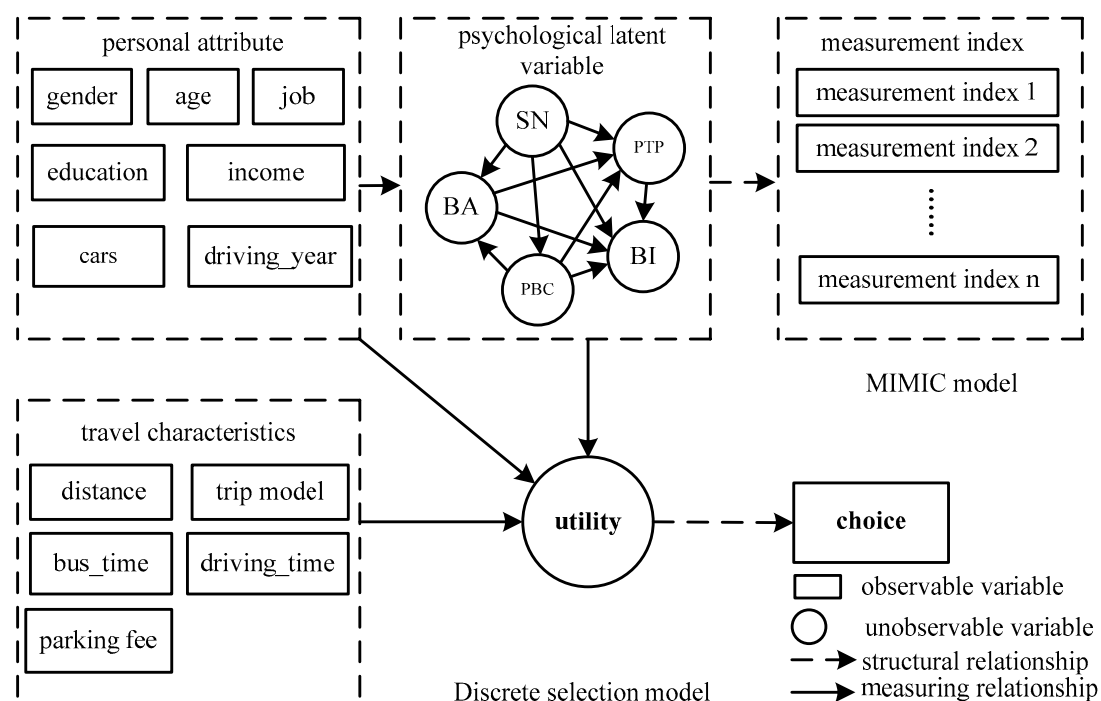


Figure 3. The integration of choice and latent variable (ICLV) model's framework for travel behavior under parking constraints. Source: author.

The model is composed of individual attributes, travel mode attributes, decision-making process psychological attributes and their measurement index, among which individual attributes are not only the explanatory variable of mode utility, but also the explanatory variable of each latent variable in the decision-making process. The structural relationship between individual attributes and latent variables constitutes a multi-indicator and multi-cause model (MIMIC model).

4.2. Data Analysis

For the estimation of model parameters, the continuous two-stage estimation method is usually used. Firstly, the parameters of the MIMIC model were estimated; then, the adaptation values of latent variables were calculated and substituted into the discrete selection model as exogenous variables for parameter calibration [11]. Since the relationship between latent variables and measurement indicators and between latent variables and latent variables has been specifically estimated and analyzed in

Section 3, this section will focus on the structural relationship between observable explanatory variables and latent variables and the final discrete selection model.

(1) Estimation of the adaptation value of potential variables

Since the latent variables such as behavior attitude and subjective norms cannot be directly measured, they need to be expressed through their measurement indicators and exogenous observable variables. The multi-indicator parts of the MIMIC model are represented by the previously mentioned Formula (2), and the multi-cause parts can be expressed as:

$$\eta = \Gamma s + \zeta \quad (4)$$

In the formula, s is the vector of exogenous observable variables affecting latent variables η , namely personal attribute information; Γ is the estimated parameter matrix; ζ is the measurement error.

The collected data were used to estimate the parameters of the MIMIC model, and the results are shown in Table 6. The adaptation value of each latent variable can be calculated according to the parameters.

Table 6. Estimate parameters of the multi-indicator and multi-cause (MIMIC) model.

	η_{BA}	η_{SN}	η_{PBC}	η_{PTP}	η_{BI}
S_{gender}	−0.202 ***	−0.130 ***	−0.157 ***	−0.118 ***	−0.156 ***
S_{age}	0.107 **	−	0.161 ***	0.119 ***	0.137 ***
S_{job}	−0.113 ***	−0.111 ***	−0.106 ***	−0.159 ***	−0.143 ***
S_{cars}	−0.268 ***	−0.294 ***	−0.290 ***	−0.254 ***	−0.253 ***
$S_{driving-year}$	−	−	−0.146 ***	−0.104 **	−0.191 ***

Note: *** $p < 0.01$, ** $p < 0.05$, “−” means insignificant.

It can be seen from Table 6 that, except for education and income, other personal attributes have a significant influence on each latent variable, among which age has a positive influence, while other factors are all negative. The older people show a more obvious intention to give up driving; and men and people who own more cars or have been driving for longer have a weaker intention to give up driving; institution or government workers may find it easier to give up driving.

(2) Parameter calibration of discrete selection model

Current research about ICLV is mostly based on the Multinomial Logit model (MNL). The utility formula of MNL is:

$$u_i = a_i s + b_i z + c_i \eta + \varepsilon_i \quad (5)$$

In the formula, s is the vector of observable traveler's individual attributes; z is the travel mode attribute vector; η is the vector of unobservable latent variables; a_i , b_i , c_i are unknown parameter vectors to be estimated; ε is a random item.

Taking the third behavior (B3) as an example, this paper uses SPSS22.0 software to substitute the fitness value of each latent variable into the MNL model and calibrate the model parameters. Moreover, the MNL model without latent variable is also established. The final results of both are shown in Table 7. It shows that the pseudo R square of the two models is 0.269 and 0.318, respectively. Generally, if the value of the pseudo R square reaches more than 0.2, it can be considered that the model has a good fitting effect and certain explanatory ability. Therefore, both models are acceptable, but from the perspective of fitting indexes, the ICLV model with latent variables is better.

Table 7. Estimation results of the multinomial logit model (MNL) model and the ICLV model (25 min is the reference).

	MNL Model without Latent Variables		ICLV Model with Latent Variables	
	15 min	20 min	15 min	20 min
Constant	-	-	4.651 **	-
$S_{cars} = 1$	1.657 **	3.311 ***	-	-
$S_{cars} = 2$	-	2.502 **	-	-
$S_{job} = 1$	1.608 ***	1.399 **	-	-
$S_{driving_year} = 1$	1.535 ***	0.971 *	-	-
$S_{driving_year} = 2$	1.177 **	-	-	-
$S_{age} = 1$	-	-	-1.285 *	-
$S_{bus_time} = 1$	4.697 ***	3.465 ***	3.912 ***	2.907 ***
$S_{bus_time} = 2$	4.274 ***	3.685 ***	3.733 ***	3.260 ***
$S_{bus_time} = 3$	2.985 ***	2.506 ***	2.669 ***	2.204 ***
$S_{bus_time} = 4$	1.263 *	1.38 **	1.134 **	1.254 **
$S_{driving_time} = 1$	-4.127 ***	-4.474 ***	-3.982 ***	-4.230 ***
$S_{driving_time} = 2$	-3.5477 **	-3.667 ***	-3.041 **	-3.209 *
$S_{driving_time} = 3$	-	-2.863 *	-	-2.263 *
η_{BI}	-	-	6.057 ***	2.962 *
η_{SN}	-	-	-4.728 **	-2.037 *
Pseudo R-squared	0.269		0.318	

Note: The independent variables refer to the last option. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. “-” means insignificant.

In the MNL model without latent variables, groups such as those whose members have fewer cars or less driving experience and civil servants are more inclined to choose a small time value, which make it relatively easy to give up driving. People with short bus-time are obviously more likely to give up self-driving travel, while people with short self-driving travel time are more reluctant to give up self-driving travel. In fact, it might be that the time ratio between the two has an impact on people's travel decisions. We tried to convert the two time indicators into the time ratio of the two and incorporated them into the model for analysis, and found that they did have a significant impact. In general, travel time is an important factor affecting behavioral decisions.

In the ICLV model, in addition to bus-time and driving-time, age also plays a certain role, in that young people's willingness to give up driving is relatively small. In addition, the latent variables BI and SN also have a significant influence on behavior. In practice, active intervention measures can be taken to guide the car owners to change their travel mode according to the measurement indexes of the latent variables affecting the traveler's behavior and the relationship among them.

5. Suggestions

As regards the model's construction and verification results, this study is a beneficial theoretical exploration. The model clearly describes the psychological influence factors of car owners' behavior to give up driving under parking constraints and their correlation. The behavior of car owners to give up driving due to parking constraints is affected in different degrees by behavior attitude, subjective norms, perceived behavior control, public transit perception and behavior intention. According to the basic characteristics revealed by the model, in order to better motivate some urban residents to give up driving by limiting the available parking space and promoting the sustainable development of urban traffic, we can actively work on the following aspects:

1. Enhance public awareness of parking supply. In reality, many residents who drive by themselves often complain about the lack of parking spaces, which results in negative psychology, and one of the main reasons is that residents do not have enough understanding of parking problems. Most ordinary citizens only pay attention to the convenience of parking and seldom analyze parking problems from the perspective of traffic and urban development. Therefore, it is necessary

to make the following clear to the majority of car owners, through publicity and other means: As regards parking in the central area of the city, more spaces is not always a good thing, for too many parking spaces will induce more vehicles to enter the area and cause traffic congestion. Meanwhile, less parking spaces in the central area of the city may also be problematic, for too few parking spaces will cause a large number of vehicles to cruise on the road in search of parking spaces, which will also cause traffic jams. When city residents come to understand the problems concerning the supply of parking spaces, the negative emotions caused by parking will be reduced, and the change of travel mode due to parking restrictions will be changed from a completely passive behavior to an active choice. In this way, the effect of adjusting traffic demand through parking supply will be more obvious.

2. Improve the level of public transit services in a targeted way. Car owners pay more attention to the rapidity and convenience of public transit (ptp1 and ptp3). When these factors meet their demands, they are more likely to give up driving due to insufficient parking supply. Time is the main factor of urban public transit to consider, including waiting time, transfer time and traveling time, etc.. The waiting time is related to the number of public transport and scheduling, transfer time is closely related to the completeness and layout of public transportation, driving time is associated with the performance and running routes of public transport. Then, it is necessary to establish a diversified public transit operation system and optimize the layout and scheduling, so as to reduce the travel time of public transport. At the same time, compared with self-driving travel, bus travel has a lower controllability, and timely access to bus operation information has become an important factor of concern. In an age of more and more advanced information, there are many ways and forms to solve this problem. For example, the public transit operation information can be released through electronic screens set up on platforms, navigation software, specialized applications and other ways to improve the convenience of travel for residents. In addition, compared with the use of public transit, self-driving travel has the obvious advantage of comfort. In order to improve the attraction of public transit, active measures should be taken to beautify the environment.
3. Enhance the residents' understanding of the economic value and social value of "giving up driving". Research shows that the more travelers realize that giving up driving is a low-cost (ba1) behavior conducive to protecting the environment and alleviating traffic congestion (ba2, ba3), the more likely they are to give up driving due to parking constraints. Seen from the average of various measures of "behavior attitude", in comparison, "giving up driving helps to reduce travel costs" has not been accepted by the majority of people. The main reason is that some travelers consider the cost of time, and even the possible cost increase caused by the inconvenience and lack of comfort of public transportation. Therefore, in order to enhance urban residents' recognition of the economic value of "giving up self-driving travel", it is necessary to focus on reducing residents' travel costs from the perspective of time and convenience. Currently, the subway and rapid transit bus systems built in major cities can effectively solve this problem. On the other hand, in order to enhance urban residents' awareness of the relationship between giving up self-driving travel and protecting the environment and easing traffic congestion, environmental protection publicity should be strengthened to guide people to deepen their understanding of giving up driving from the perspective of social value, and encourage people to take the initiative to reduce the use of cars.
4. Creating a good social atmosphere. Whether car owners will give up driving due to parking restrictions is greatly influenced by the guidance of the government and their perceived behavior execution conditions (sn1, pbc2 and pbc3). Therefore, the government needs to take measures such as publicity work and fare concessions to actively encourage public transit. For example, it is necessary to strengthen the publicity when major public transport construction projects are completed, public transport operation conditions have been greatly improved, or there are important favorable public transport policies; or offer better bus fares or transport subsidies

to residents who regularly travel by public transport. Moreover, the government can expand the publicity and guidance function of changing travel mode and green travel through the influence between people, so as to reach a consensus among the public on reducing the use of cars. In addition, relevant departments should also actively take measures to create conditions for car owners to change their travel modes.

5. Carry out guidance work by groups and stages. The influence of individual attributes on latent variables indicates that the travel behavior intention and psychological decision-making process of different groups are different—for example, people with a large number of cars and a long driving age have a relatively weak intention to give up self-driving travel due to limited parking. Therefore, in order to improve the effect of adjusting traffic demand through parking supply, when implementing various auxiliary measures, we first need to group related areas within the scope of the residents. The aim is to give priority to guide the residents who have a positive attitude towards giving up driving to change the mode of travel, in order to achieve the goal of parking demand management. In addition, as various auxiliary measures mainly affect the psychological process of residents, it is not advisable to implement them overnight. In order not to arouse the aversion of residents, different measures should be implemented step by step.

6. Conclusions

In order to reveal the psychological “black box” of car owners giving up driving behaviors under parking restrictions, based on the Theory of Planned Behavior, this study constructs a psychological decision-making process model of giving up driving under parking constraints, which includes the influence of behavior attitude, subjective norms, perceived behavior control, public transit perception and behavior intention. The PLS-SEM and ICLV models were used to analyze and verify the results. The following conclusions were drawn:

1. The choice of travel mode under the constraint of parking space is not only affected by individual social and economic attributes and travel mode characteristics, but also by psychological latent variables such as behavioral attitude, subjective norms, perceived behavior control, public transportation perception and behavior intention. In order to give full play to the positive role of parking supply in regulating traffic demand, appropriate auxiliary measures should be taken to enhance public awareness of parking supply, improve the level of public transport service, heighten residents’ understanding of the social value of “giving up driving” and create a good social atmosphere while optimizing the parking berth scale.
2. The psychological factors influencing the choice of travel behavior under parking constraints are interrelated. The social pressure (subjective norms) experienced by car owners will influence the perceived behavioral ability (perceived behavioral control) and, together with it, impact on the understanding of the economic and social value of giving up driving (behavior attitude). This will then affect car owners’ perception of public transit and their behavior intention of giving up driving due to parking constraints. At the same time, car owners’ perception of public transit (increasing the willingness to travel by public transit due to the satisfaction of demands such as speed, convenience and service) will directly affect their behavior intention of giving up driving due to parking constraints.
3. Through comparison, it is found that the ICLV model considering psychological latent variables has a higher fitting degree to empirical data than the traditional MNL model. In actual forecasting, considering the observable variables and an observation will lead to higher prediction accuracy. It is only necessary to consider the individual characteristics, travel time and so on to forecast the travel mode choice, and the requirement for data is not higher than that of the traditional MNL model, which is highly practical.

This paper studies the psychological factors that influence the travel behavior under the constraint of parking berth and identifies some rules in the decision-making of travel behavior. However, there are still some limitations. Future studies can explore the following aspects:

1. This study mainly applies the theory of planned behavior in the continuous psychological model to discuss the psychological factors of travel behavior under parking constraints. In the future, it may be advisable to integrate other behavioral theories, such as the Normative Activation Theory, or theoretical model of stages to discuss the psychological decision-making process (e.g., self-adjusting behavioral change phase model) and explore more potential factors that may have an impact.
2. This study takes commuting behavior as an example. In urban central areas, there may also be travel demands for official business, medical treatment, shopping, entertainment, etc., and there may be differences in the influence relationship of behavior intentions under different travel purposes. In order to better understand the influence factors of car owners giving up driving under parking constraints, future research can analyze different travel purposes and dig deeper into the universal laws of travel behavior decision-making, so as to provide a decision-making reference for urban parking supply optimization and travel structure optimization, and contribute to the sustainable development of urban traffic.

Author Contributions: Conceptualization, P.S. and C.Q.; methodology, P.S. and C.Q.; validation, C.Q.; investigation, P.S. and Z.G.; data analysis, P.S. and Z.G.; writing—original draft preparation, P.S.; writing—review and editing, P.S., Z.G. and C.Q. All authors have read and agreed to the published version of the manuscript.

Funding: This study was supported by the Philosophy and Social Science Fund Project of Hunan Province, China, grant number 19YBA379.

Conflicts of Interest: The authors declare no conflict of interest.

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