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ABSTRACT
This paper explores car drivers' cruising behaviour and location choice for curb parking in areas with insufficient parking space based on a survey of car drivers in Beijing, China. Preliminary analysis of the data show that car drivers' cruising behaviour is closely related to their parking duration and parking location. A multinomial probit (MNP) model is used to analyse cruising behaviour and the results show that the closer to the destination car drivers are, the more likely they choose to park on the curb. The adjacent locations are the basis of car drivers' sequential parking decisions at different locations. The research results provide a better understanding of cruising behaviour for parking and recommendations for reducing cruising for parking. The provision of parking information can help regulate the parking demand distribution.

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Parking; cruising behaviour; sequential decisions; parking location choice; multinomial probit model; case study

1. Introduction

With the rapid economic growth in cities and the rapid increase in the use of motor vehicles, the parking problem is becoming more and more serious. This is particularly the case in Beijing, China. In May 2016, the number of motor vehicles in Beijing reached 5,650,000. As of the end of the third quarter of 2016, there were only 1,992,822 filed parking spaces in Beijing. The supply could only accommodate less than 40% of potential parking demand. The shortage of parking spaces, especially those on the curb, will result in more illegal parking and traffic congestion caused by car drivers driving around in search of parking spaces. As summarised by Shoup (2006), some researchers conducted analysis of cruising for parking in the central business districts (CBDs) of 11 cities around the world between 1927 and 2001. Results showed that drivers spent about 3.5 to 14 min on cruising for curb parking and between 8% to 74% of vehicles in

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the traffic flow were cruising for parking. Cruising vehicles could lower traffic efficiency and then increase significant time and fuel consumption. Therefore, investigating the potential behavioural mechanism underlying cruising for parking would be helpful for minimising its impact.

Our research focuses on analysing car drivers' cruising behaviour for curb parking around commercial facilities. It is based on parking survey data collected near a commercial centre in Beijing. Parking choice models for the cruising process were established to analyse the factors affecting cruising behaviours and explore the correlations among sequential decisions for parking. The results of our study could provide a reference for the analysis of cruising behaviour and recommendations to reduce the chance of car cruising for parking.

2. Literature review

Cruising for parking is commonly observed on road networks due to the shortage of parking facilities, inappropriate parking-pricing, and so on, resulting in traffic congestion or illegal parking (Barata, Cruz, and Ferreira 2011; Hössinger et al. 2013; Levy, Martens, and Benenson 2013; Thanh and Friedrich 2017). Pierce and Shoup (2013) pointed out that underpriced and overcrowded curb parking causes cruising for parking, bringing up problems such as time and fuel waste, traffic congestion, and air pollution. Gallo, D'Acierno, and Montella (2011) presented a multi-layer assignment model to analyse parking choice behaviour and estimated the impact of cruising for parking on traffic flows. The model was tested on trial and actual networks. The results showed that the model was able to simulate user parking choice behaviour and the impact of cruising on congestion especially when parking saturation exceeded 70%.

Several scholars have explored the factors affecting cruising for parking and the mutual relations among these factors. Liu and Geroliminis (2016) used the Macroscopic Fundamental Diagram (MFD) to find that commuters' cruising distance and time for parking is higher with decreasing curb parking vacancies during the morning peak. Van Ommeren and Russo (2014) found that the average cruising time for parking is about 36 s when the price of curb parking is the same as off-street parking. Meanwhile, the cruising time for parking increases with increasing travel time and parking duration. Thompson and Richardson (1998) proposed a model within a behavioural framework to analyse cruising behaviour for parking. Furthermore, they also found that a long-term searching experience for parking does not always bring about better parking choices.

In addition to behavioural analysis, simulation is also an important method to reproduce the car drivers' cruising process for parking and analyse the effects of many factors on cruising for parking. Several researchers have established parking simulation models based on utility theory, agent theory and other methods used for constructing parking decision behavioural rules (Van der Waerden, Timmermans, and Borgers 2002; Benenson, Martens, and Birfir 2008; Dieussaert et al. 2009; Guo, Huang, and Sadek 2013; Horni et al. 2013; Fulman and Benenson 2017). These researchers modelled the microscopic cruising behaviour for parking using simulation models and estimated the traffic and environmental effects of cruising for parking. They also used real-life cases to conclude that additional parking supply only has a small impact on average cruising time or average walking distance from parking place to destination.

Based on the analysis of external and internal factors affecting cruising for parking, some studies have been conducted to provide some recommendations to reduce cruising for parking. Shoup (2006) developed a model to explore whether a driver cruises to find a vacant curb parking space or pays for off-street parking when all the curb parking spaces are fully occupied. The results showed that an equal market price for curb parking and adjacent off-street parking will reduce cruising. Arnott and Inci (2006) established a parking model and revealed that raising the price of curb parking is an effective method to eliminate cruising. Increasing the number of curb parking spaces is the second-best method. Arnott and Rowse (2009) proposed an integrated model of downtown parking and traffic congestion to conclude that raising the curb parking price will reduce car drivers' cruising time and the number of cars cruising for parking. Qian and Rajagopal (2014) investigated the effects of dynamic parking pricing and information provision on parking choice behaviour. It concluded that optimal parking pricing can make the system perform best with a parking occupancy of around 85-95%.

Overall, the above research focused on cruising for parking based mainly on survey data analysis, behavioural analysis and simulation. Some measures are further proposed to reduce cruising. However, car drivers often make sequential decisions during the cruising process for parking depending on various factors such as parking occupancy, cruising time, walking distance after parking, parking price, parking information, and so on. Currently, little research has been conducted to investigate the sequential decision process of cruising for parking. One related study by Jou et al. (2005) established a multinomial probit (MNP) model to study sequential route switching behaviour of travellers. The model results showed that real-time traffic information has a significant positive effect on route switching behaviour.

In order to explore car drivers' behavioural rules during cruising for parking, this paper conducted a survey in a large commercial district in Beijing. The cruising behavioural characteristics and parking location choice are further discussed under two scenarios with parking vacancy information and images taken in the field. Moreover, we use a multinomial probit (MNP) model to analyse the correlations among sequential parking decisions during the cruising process. Our research conclusions will provide a better understanding of cruising behaviour for parking and be able to make some recommendations for reducing cruising.

3. Parking cruising survey and analysis

3.1. Overview of survey site

Central Business Districts (CBDs) usually attract a large number of people and cars, leading to serious parking problems and traffic congestion. The survey site chosen for this study is Youshige Commercial Center (YCC) adjacent to one of Beijing's CBDs. This centre is located between the Second and Third Ring Expressway and at the south of Guangqumenwai Avenue. The investigation point is along the frontage road of Guangqumenwai Avenue, an east–west primary arterial with 10 lanes divided by a median, five lanes for each direction, as shown in Figure 1. There is an intersection at 200 m east of the commercial centre. Curb parking spaces are available along the bi-directional frontage road of Guangqumenwai Avenue. The number of curb parking spaces is approximately

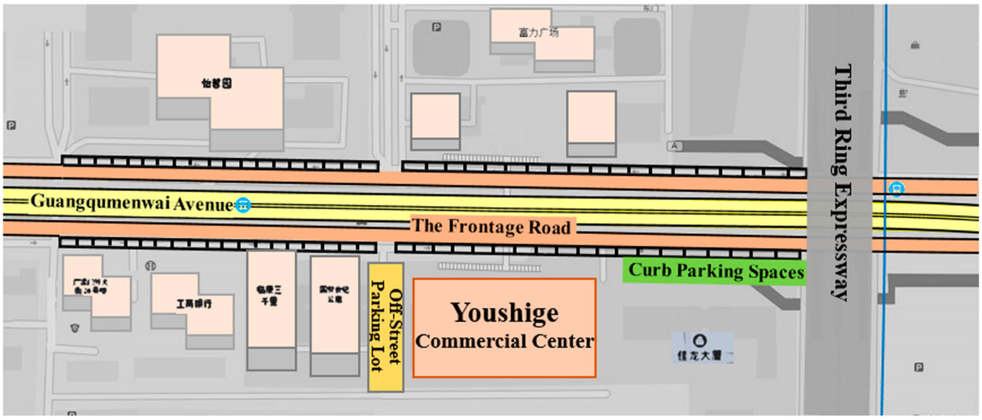

Figure 1. Survey site.

38 along the frontage road in the south and adjacent to YCC. The occupancy rate for curb parking in this section is relatively high and the parking problem is exceptional. There is an off-street parking lot with 40 parking spaces, 50 m west of YCC. During daytime, the occupancy rate of the off-street parking lot is roughly between 80% and 90% based on our field survey. The parking fee around this area is collected by manual toll and each fee collector oversees about 15~20 parking spaces. In this case, the car entering YCC would have two choices of parking: either curb or off-street. If a car passes the commercial centre and still cannot park, the car has to enter the intersection ahead to park somewhere else or circle the block. The parking fees are summarised in Table 1.

3.2. Parking survey

In order to analyse the factors affecting cruising behaviour for parking and the correlation among sequential decisions during the cruising process, a questionnaire was designed to collect the additional data regarding travellers' characteristics, parking behaviours, and parking location choices. [The questionnaire can be found in Appendix A.] In summary, this questionnaire covers: (1) personal information, (2) travel and parking attributes for each trip, (3) parking choice preferences under two different scenarios with assumed unchanged parking purpose and parking duration for this trip.

For the third part, Scenario 1 presents diagrams with different numbers of vacant parking spaces distributed along a section of road. Scenario 2 presents images for the parking situation taken in the field. In this case, respondents were asked to judge the number of empty spaces by themselves. The occupancy situation of parking spaces in

Table 1. Fees for curb parking and off-street parking.

	From 7:00 to 21:00 during the day		
	Within the first hour	After the first hour	From 21:00 to 7:00 during the night
Curb parking	2.5 Yuan (0.38 USD) per 15 min	3.75 Yuan (0.56 USD) per 15 min	1 Yuan (0.15 USD) every 2 h
Off-street parking lot	2 Yuan (0.30 USD) per 15 min		1 Yuan (0.15 USD) every 2 h

the diagrams is basically consistent with that in the actual images. Assuming that YCC is the travel destination, each scenario included four stated questions at four different positions, from far to near the centre. The available parking spaces at 200 m were assumed as 60% and 100% at 0 m, which is directly in front of the centre. The parking occupancy rate at 100 m has two assumed levels, 70% and 40%. Likewise, the parking occupancy rate at 50 m has two levels, 80% and 85%. Therefore, there are four combinations of different occupancy levels for the locations of 100 m and 50 m. Each respondent was required to respond to four stated choice questions for one level-combination of parking occupancy rates at different locations along the road. (The questionnaire in Appendix A only shows an example for one level-combination in Scenario 1 and Scenario 2.)

The sequential parking decision problem facing a driver during the cruising process in each scenario is presented in Figure 2. The available parking options are different at different positions. Two options, including 'Park on Curb' and 'Keep Cruising', are available at 200 and 100 m from the destination. 'Park in the Off-Street Parking Lot' is a supplementary option at 50 m. Four options are available when assuming that the respondent drives to the front gate of the centre and finds no empty parking places to park.

The respondent was asked to give a parking choice according to a map-based scenario marked with the assumed position at which he/she had arrived, the parking situation at this position and other factors. Once the respondent chooses to park at a specific position, he/she will stop answering the subsequent questions.

The questionnaire survey was conducted at different times between 26 April to 5 May 2016. The survey was undertaken in sunny weather. The investigators were mainly distributed along the frontage road adjacent to YCC. They randomly selected the survey objects who visited the centre. The investigator conducted a face-to-face interview as soon as the car driver parked their cars and collected questionnaires on the spot. Because some car drivers were not willing to answer the questionnaire due to a tight schedule or other reason, the response rate was about 70%. It was found that drivers who had a longer parking duration and drove alone were more likely to answer the questionnaire. Finally, a total of 173 valid questionnaires were collected.

3.3. Analysis of cruising behaviour for parking

Among all the respondents, 83% were male, 64% had a monthly household income of 5,000 (747 USD) to 20,000 Yuan (2987 USD), 64% were between the ages of 26 and 45,

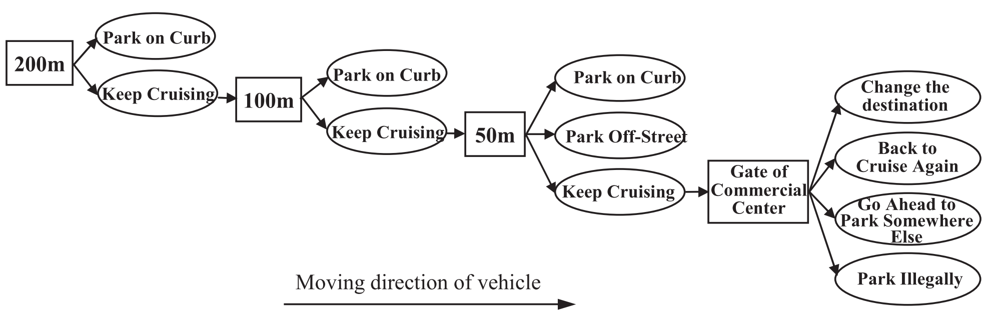

Figure 2. Sequential decision process for parking.

29% worked for the public sector or educational institutes, 23% were self-employed, and 18% held management positions.

The proportion of respondents who were familiar and unfamiliar with this survey area accounted for 21% and 33%, respectively. As for parking purpose, the majority (31%) of respondents were there to pick up people. 29% and 21% of the trip purposes were for shopping and entertainment, respectively. 92% of respondents paid the parking fee themselves without any reimbursement.

Table 2 further summarises the results of the parking behaviour data. Most of respondents (86%) had a parking duration within 2 h, 89% had a walking distance after parking within 100 m. 79% of respondents started to cruise for a vacant parking place from 150 m to the destination, 74% found a parking space within one minute, and 13% took more than two minutes to find one. Overall, these results based on the field observation imply that cruising for parking in this area is moderate.

Figures 3 and 4 further summarise the survey results. Figure 3 shows that the longer the parking duration, the more car drivers would like to spend on finding a vacant parking space. Figure 4 shows that the closer the car drivers park their cars to the destination, the shorter their cruising distance would be. In summary, drivers' cruising behaviour for parking is closely related to parking duration and location.

Table 2. Summary of survey data.

Variables	Content	Proportion (%)	Mean	Standard Deviation	Variables	Content	Proportion (%)	Mean	Standard Deviation
Parking duration	≤30 min	34	63 min	51 min	Cruising distance	≤50 m	21	103 m	55 m
	30–60 min	24				50–100 m	35		
	60–120 min	28				100–150 m	23		
	120–180 min	10				150–200 m	15		
	≥180 min	4				≥200 m	6		
Walking distance after parking	≤50 m	51	60 m	42 m	Cruising time	No cruising	42	1 min	2 min
	50–100 m	38				Within 1 min	32		
	100–150 m	9				1–2 min	13		
	150–300 m	1				2–5 min	9		
	≥300 m	1				≥5 min	4		

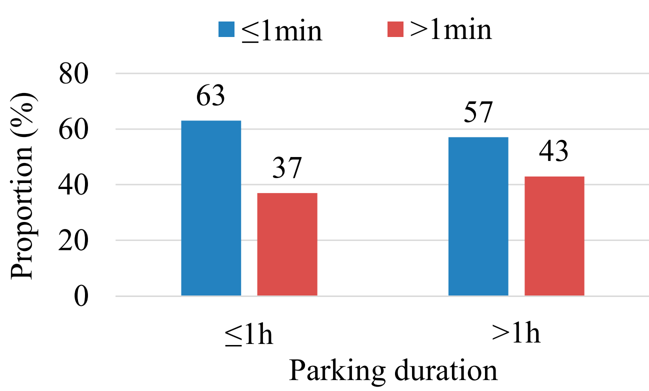

Figure 3. Cruising time distribution under different parking durations.

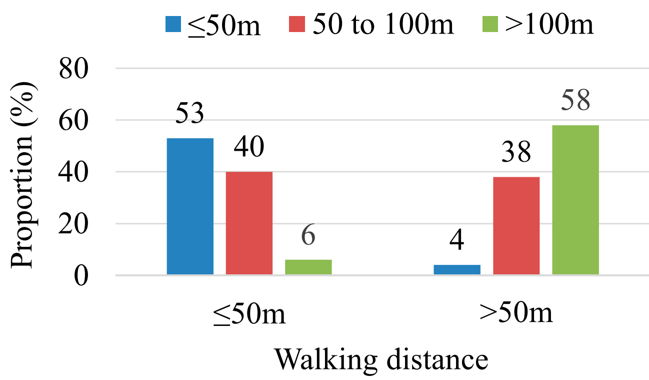

Figure 4. Cruising distance distribution under different walking distances.

Figure 5 shows curb parking choice at different locations under two scenarios. Overall, the proportions of drivers choosing curb parking increase with decreasing distance to the destination and increasing curb parking occupancy. This indicates that most drivers prefer to park close to the destination. Meanwhile, the choice proportions at each location in Scenario 1 are equal to or lower than those in Scenario 2. The choice proportions for curb parking at 50 m are 49% in Scenario 1 and 62% in Scenario 2, which indicates that car drivers are more willing to go ahead to find a parking place when providing parking vacancy information along a road. At the same time, the result also demonstrates that the provision of curb parking information can regulate the distribution of parking demand.

From Figure 6, we can see that when car drivers reach the front of the Commercial Center and find no empty parking place to park, the proportions of choosing cruising again and parking illegally are 5% and 17% in Scenario 1 and 1% and 5% accordingly in Scenario 2. The results suggest that insufficient parking spaces can increase disorderly parking and the chance of cruising for parking.

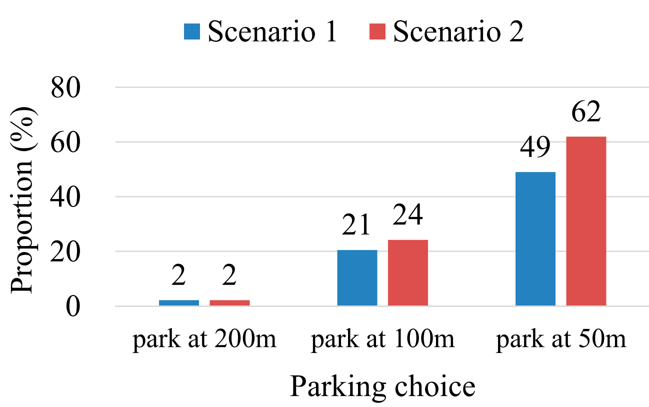

Figure 5. Curb parking choice at different locations.

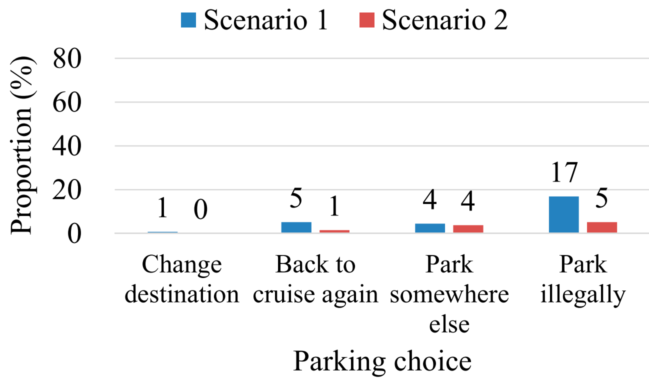

Figure 6. Parking choice in front of the centre.

4. Estimation and analysis of parking choice models

4.1. Methodology

Discrete choice models are generally used to analyse individual's choice behaviour. Among these models, the advantages of the binary logit model and the multinomial logit model are their closed form and convenient estimation of parameters. Meanwhile, these two logit models obey the hypothesis of IIA (Independence from Irrelevant Alternation). However, in fact, there exists a certain correlation or substitution relation between different alternatives. Based on the covariance matrix of the random term, the multinomial probit (MNP) model is not restricted by IIA and more suitable to resolve the decision problems that represent the correlation between alternatives (Hensher and Button 2000; Imai and van Dyk 2005; Jou et al. 2005). Considering that there exist sequential decisions during the cruising process for parking, this paper used a MNP model to analyse car drivers' parking choice behaviour.

In the MNP model, individual n will choose the alternative based on utility maximisation among J alternatives. The utility U_{in} when individual n select option i can be expressed as:

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

where, V_{in} is the deterministic component of utility for option i by individual n; ε_{in} is the random component of utility for option i by individual n. The random terms with utilities for different options are not completely independent.

The deterministic component of the utility can be defined as a linear function with different influencing factors:

$$V_{in} = \sum_{k=1}^{K} \theta_k X_{ink}, \tag{2}$$

where, k is the number of variables; θ_k is the corresponding coefficient; and X_{ink} is the variable k for option i by individual n.

The probability of choosing option i by individual n can be obtained by:

$$P_{in} = \Pr ob(V_{in} + \varepsilon_{in} > V_{jn} + \varepsilon_{jn}, \forall i \neq j) = \int I(V_{in} + \varepsilon_{in} > V_{jn} + \varepsilon_{jn}, \forall i \neq j)\varphi(\varepsilon_n)d\varepsilon_n, \quad (3)$$

where, $I(\cdot)$ is an indicative function, while the term in parentheses is true if it is equal to 1, otherwise 0. $\varphi(\varepsilon_n)$ is the probability density function of ε_n. ε_n is unobservable and represents a normal distribution with the mean value and the covariance matrix. The covariance matrix can explain the correlation or substitution relation between different options.

The integral in Eq. (3) covers all values and is non-closed. Therefore, the choice probability cannot be calculated by integration and only be estimated by simulation methods. These methods include Maximum Likelihood Simulation, Monte Carlo Simulation and so on. Here, we estimate the MNP model using NLOGIT5.0 software.

This model can also be fitted with panel data. In this case, the utility function is modified as follows:

$$U_{int} = V_{int} + \varepsilon_{int} + v_{int}, \quad (4)$$

where, t is the periods or replications. v_{int} is the random component of utility relative to time. There are two formulations for v_{int}:

$$\text{Random effects: } v_{int} = v_{ins}$$

(the same in all periods or replications) and

$$\text{First order autoregressive: } v_{int} = \alpha_i v_{in,t-1} + a_{int}$$

where, α_i is the corresponding coefficient and a_{int} is white noise.

4.2. Parking choice models

In order to conduct an in-depth analysis on behaviour of cruising for parking and the correlation among sequential decisions, we establish parking choice models based on the MNP model.

Some important influencing factors are identified preliminarily by the correlation analysis. The categorical variables are summarised in Table 3. For the variable of gender, male is assigned to 0 and female is 1. The degree of familiarity is classified into three levels: unfamiliar, neutral and familiar, represented by 1, 2, and 3 respectively. For the variable of payment for parking fees, self-payment is assigned to 1 and other payment is 2. Other variables are continuous variables.

Based on the stated preference data for parking choice, we assume that each car driver makes repetitive and sequential decisions during the cruising process. For example, there are two decisions for the parking location if the car driver chooses to keep cruising at 200 m and park at 100 m away from the destination. In the models for the cruising process shown in Table 4, the available parking options for locations of 200, 100 and 50 m are 'Parking on Curb' and 'Keep Cruising' through data processing. The parking choice models can be further estimated based on panel data coming from the car drivers' sequential decisions for parking in the survey. Because the distance to the

Table 3. Settings of dummy variables.

Variables	Classification	Dummy variable	
Parking purpose	Parking purpose 1: leisure and shopping.	1	0
	Parking purpose 2: picking up people	0	1
	Parking purpose 3: work and other	0	0
Occupation	Occupation1: public and scientific institution personnel; technical personnel	1	0
	Occupation 2: management personnel and self-employed	0	1
	Occupation 3: other	0	0

destination has a highly negative correlation with the parking occupancy rate at locations for parking choice, only parking occupancy rate is included in the models.

The McFadden Pseudo *R*-squared is the performance index to determine the overall goodness-of-fit of the models. The index is defined as $1 - L(\hat{\theta})/L(0)$, here $L(\hat{\theta})$ is the log likelihood value for the fitted model and $L(0)$ is the log likelihood for the null model that only contains an intercept as predictor. When the index approaches between 0.2 and 0.4, the model is considered to have very good goodness-of-fit (Hensher and Stopher 1979). Generally, the more the statistically significant covariates, the higher the McFadden Pseudo *R*-squared. Accordingly, the overall goodness-of-fit of the model is considered very good. Table 4 shows that parking choice models in the two scenarios have very good goodness-of-fits and can well be used to describe cruising behaviour for parking.

For model calibration, since all independent variables were placed into the utility for option 'Parking on Curb', the significant positive coefficients mean that the affecting factors have positive effects on the choice for curb parking. Similarly, the significant negative coefficients mean that the factors have negative effects on the choice for curb parking.

The models in the two scenarios show that the parking occupancy rate, cruising distance and walking distance after parking are important factors affecting car drivers' cruising behaviour for parking. The variable of parking occupancy rate has the most important positive influence on drivers' sequential decisions for parking. This suggests that car drivers pay more attention to the parking vacancy during the cruising process when approaching the destination. Meanwhile, with increasing parking occupancy, the

Table 4. Parking choice models for cruising process.

	Scenario 1		Scenario 2	
Variables	Coefficient	T Test	Coefficient	T Test
Constant	−6.326***	−13.22	−5.047***	−12.65
Parking occupancy rate	6.476***	12.72	5.915***	14.09
Cruising distance	0.004***	2.59	0.004**	2.41
Parking duration	–	—	0.004*	1.83
Walking distance after parking	0.008**	2.41	0.005*	1.72
Parking purpose 2	–	–	−0.340*	−1.72
Number of people in car	−0.218**	−2.36	–	–
Gender	–	–	−0.642***	−4.72
Monthly household income	0.052***	4.51	–	–
α_{park}	−0.542	−1.20	−0.415*	−1.72
Sample size	386		369	
Inf. Cr. AIC	375.3		395.2	
McFadden Pseudo *R*-squared	0.325		0.255	

Note: *, **, *** indicates significant at the 90%, 95% and 99% level of confidence, respectively.

probabilities of choosing parking on curb increase accordingly. In addition, the farther car drivers cruise for parking and the longer their walking distance after parking, the more they are likely to park on the curb far away from the destination.

Some variables only have a significant effect in a Scenario. For the model in Scenario 1, the number of people in the car and monthly household income are important factors. Car drivers with more people in their car and lower income prefer to keep cruising and park as close as possible to the destination. In Scenario 2, parking duration, parking purpose 2 and gender have important effects on sequential decisions for parking. The longer the parking duration, the larger the probability of choosing to park far away from the destination is. Compared to work and other purposes, drivers with the parking purpose of picking up people are more likely to park as close as possible to the destination. Female drivers tend to cruise for parking near the destination.

The autoregressive coefficient for α_{park} is negative. The t-test values show that it is more significant in Scenario 2. This result indicates that the accumulation of travel experience or knowledge has an important effect on travellers' sequential decisions for parking location while providing no parking vacancy information.

The above analysis shows that car drivers mostly focus on curb parking vacancy during the cruising process for parking when approaching the destination. Car drivers with longer cruising distance and walking distance are more willing to park on the curb far away from the destination. Compared with Scenario 1, without the provision of parking vacancy information, car drivers make sequential decisions mainly based on travel experience or knowledge accumulated during the decision process in Scenario 2.

In order to further analyse the car drivers' choice behaviour for parking location and the influencing factors, parking location choice models are established based on the MNP model, as shown in Table 5. The three alternative locations for parking choice include 200 and 100, 50 m away from the destination and near the destination. These available locations for parking are assigned 1, 2, 3 respectively in the model calibration. The parking locations for 200 and 100 m are combined into one option because only

Table 5. Parking location choice models.

		Scenario 1		Scenario 2	
Location	Variables	Coefficient	*t*-test	Coefficient	*t*-test
Location 1: 200 and 100 m	Constant	4.198***	3.37	−0.643	−0.37
	Occupancy rate at 200 and 100 m	−6.215**	−2.39	–	–
	Walking distance after parking	0.020**	2.00	0.053***	2.61
	Cruising distance	0.007*	1.71	–	–
Location 2: 50 m	Constant	11.036***	4.83	3.005**	2.28
	Occupancy rate at 50 m	−4.469**	−2.25	–	–
	Occupancy rate at 200 and 100 m	−7.943***	−4.29	−4.651***	−2.62
	Parking purpose 1	−0.408**	−2.37	–	–
	Parking purpose 2	–	–	0.405***	3.29
	Number of people in car	−.46946***	−3.35		
	Gender	–	–	−0.623***	−4.30
	Occupation 1	–	–	−0.500***	−4.37
	Monthly household income	−0.047**	−2.54	−0.063***	−5.13
	Payment of parking fee	–	–	2.083***	3.03
Common Variable	Distance to the destination	−0.021**	−2.43	−0.027***	−4.89
Sample size		173		173	
Inf. Cr. AIC		257.8		255.3	
McFadden Pseudo *R*-squared		0.213		0.201	

Note: *, **, *** indicates significant at the 90%, 95% and 99% level of confidence, respectively.

3% of drivers choose to park on the curb at 200 m. The parking occupancy rate for 200 and 100 m is obtained by averaging the values of these two locations.

Table 5 shows that the McFadden Pseudo *R*-squared for these two models are 0.213 in Scenario 1 and 0.201 in Scenario 2. This illustrates that both models have an acceptable goodness-of-fit and are suitable to analyse the car drivers' choice behaviour for parking locations.

In these models, as a common variable, distance to the destination has a significant negative effect on parking location choice in two scenarios. This result indicates that the closer to the destination the car drivers are, the more likely they are to choose to park their cars.

In Scenario 1 with providing parking vacancy information, parking occupancy rate is also a significant affecting factor for parking location choice. Its coefficient for the location of 200 and 100 m is −6.215, meaning that the probability of choosing curb parking increases with the decreasing parking occupancy at this location when there are more vacant parking spaces along the road far away from the destination. The parking occupancy rate at 50 m also has a negative influence on parking choice for this location. Meanwhile, the effect of parking occupancy rate on the parking choice at 200 and 100 m is more significant than that at 50 m. This result means that car drivers make a parking location choice mainly based on the parking situation along the road they pass along. The less vacant parking spaces on a curb far from the destination, the larger the probability of choosing to park close to the destination. In addition, walking distance after parking and cruising distance are significant factors for car drivers to make a parking choice at 200 and 100 m. Parking purpose 1, the number of people in car and monthly household income have a certain impact on the parking decision at 50 m.

In Scenario 2 without providing parking vacancy information, the parking occupancy rate at 200 and 100 m is not a significant factor for parking choice at this location. However, it has a significant negative influence on parking choice at 50 m. This result suggests that car drivers' travel experience, habit or the accumulation of knowledge during the cruising process plays a certain role in parking choice behaviour. In addition, walking distance after parking has a positive effect on parking choice at 200 and 100 m. Gender, occupation 1, and monthly household income have a negative effect on parking choice at 50 m. This means that female drivers who work in the public sector and scientific institutions, technical departments and have higher incomes are less likely to park their cars at 50 m.

Through comparative analysis of the differences between the two scenarios, it is clear that the provision of parking vacancy information can affect car drivers' parking location choice and then regulate the parking demand distribution. Otherwise, the car drivers would make parking location choices based mainly on travel experience, habit or the accumulation of knowledge during the cruising process.

It can be found from Tables 6 and 7 that the standard deviations and the correlations are positive under these two scenarios. This result indicates that there exist certain

Table 6. Standard deviations and correlations matrix for Scenario 1.

Decision points	Location 1: at 200 and 100 m	Location 2: at 50 m	Location 3: near the destination
Location 1	0.679(0.65)	0.299(1.46)	0.119(0.07)
Location 2	0.299(1.46)	0.999(5.14)	0.763(3.63)
Location 3	0.119(0.70)	0.763(3.63)	1.000(1.00)

Note: (*t*-values in parentheses).

Table 7. Standard deviations and correlations matrix for Scenario 2.

Decision points	Location 1: at 200 and 100 m	Location 2: at 50 m	Location 3: near the destination
Location 1	2.536(2.12)	0.426(1.61)	0.064(0.02)
Location 2	0.426(1.61)	1.349(5.49)	0.247(0.55)
Location 3	0.064(0.02)	0.247(0.55)	1.001(1.00)

Note: (*t*-values in parentheses).

inherent relations among the sequential parking decisions for different locations. Car drivers focus not only on the trip destination, but also the position at which they have arrived and the corresponding parking situation during the cruising process for parking. The relationship between adjacent parking locations is larger than those between non-adjacent parking locations, indicating that adjacent locations are the basis of car drivers' parking choice.

In addition, for Scenario 1, the correlation between location 2 at 50 m and location 3 near the destination is relatively large. But in Scenario 2, the correlation between location 1 at 200 m and 100 m and location 2 at 50 m is relatively large. This means that the provision of parking vacancy information can make car drivers pay more attention to the parking decisions near the destination.

5. Conclusions

This paper has mainly analysed car drivers' cruising behaviour and location choices for curb parking based on a survey of visitors conducted at a commercial centre in Beijing.

Multinomial probit models were considered suitable for in-depth analyses of the cruising behaviour of car drivers and the correlations among sequential decisions for parking during cruising process. The following conclusions can be drawn.

Preliminary analysis of the survey data shows that parking cruising around the commercial centre was moderate. The average cruising time for finding a vacant parking space on the curb was about one minute, while the average cruising distance was about 103 m. The longer the parking duration, the more car drivers would like to spend on finding a vacant parking space. Thus, curb parking time limits may be a good way to reduce the cruising for parking. When car drivers approach close to the destination but find no empty parking place to park, between 5% and 17% will choose to park illegally. In this case, city managers should strengthen law enforcement in this area.

The parking choice models for the cruising process show that parking occupancy rate, cruising distance and walking distance after parking are significant factors which affect cruising behaviour. The probability of choosing curb parking increases with the increasing parking occupancy when car drivers are approaching their destination. The further car drivers cruise for parking and the longer their acceptable walking distance after parking, the more they are likely to choose parking on the curb far away from the destination.

The estimated models for parking location choice showed that the closer to the destination car drivers are, the more they choose to park on the curb. There are certain relations among all sequential parking decisions at different locations. The adjacent locations are the basis of car drivers' parking choice. This indicates that the provision of parking vacancy information should guarantee its continuity and validity based on the decision behaviour of car drivers.

Meanwhile, the analysis of our models reveals that the provision of parking information can affect car drivers' parking behaviour and then regulate the parking demand distribution. In this case, car drivers mostly focus on curb parking vacancy during the cruising process and the parking occupancy rate of the current location has an important effect on parking choice. Without the provision of parking vacancy information, car drivers make a sequential decision based mainly on travel experience or knowledge accumulated during the cruising process. These conclusions imply that if parking vacancy information could be provided, the cruising time would be shortened and the use of parking resources could be more balanced, resulting into a reduced number of parking problems.

Even though this study provides a better understanding of cruising behaviour for parking, further research could focus on examining the impact of parking fees on cruising for parking and fee adjustment depending on regional parking demand distribution.

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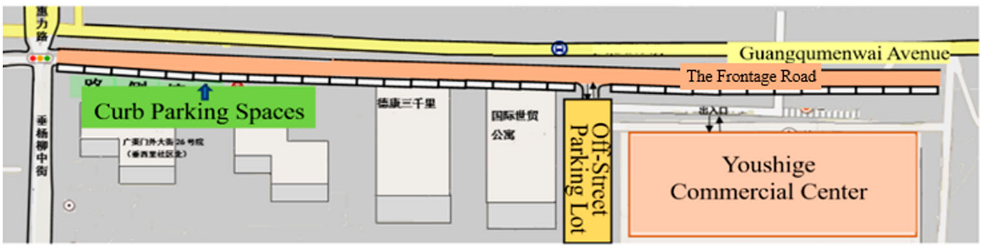
Appendix A

Questionnaire on cruising behavior for parking

Investigator: ______________ Parking location: □ on curb □ in off-street parking lot
Survey time: ______________ Plate number of parked car: ______________

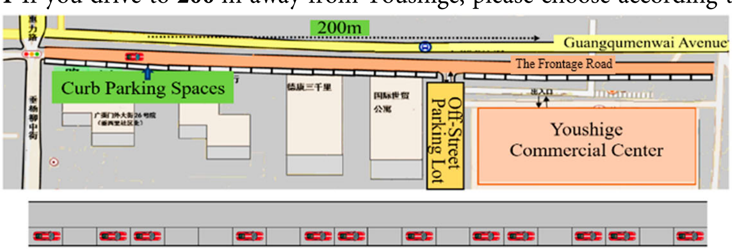
1 What's your gender? A. Male B. Female
2 What's your age? A. 18-25 B. 26-45 C. 46-60 D. Over 60
3 What's your monthly household income? A. Less than ¥5000 B. ¥5000-10000 C. ¥10000-20000 D. Over ¥20000
4 What's your occupation? A. Public and scientific institution personnel B. Technical personnel C. Self-employed D. Management personnel E. Other
5 How many people come with you in your car? A. 1 B. 2 C. 3 or more
6 Are you familiar with this area? A. Familiar B. Neutral C. Unfamiliar
7 What's your parking purpose? A. Shopping B. Work C. Entertainment D. Picking up people E. Other
8 What's your expected parking duration? A. Less than 0.5 h B. 0.5–1 h C. 1–2 h D. 2–3 h E. Over 3 h
9 What's your walking distance after parking? A. Less than 50 m B. 50–100 m C. 100–150 m D. 150–300 m E. over 300 m
10 How long did you spend finding a parking space? A. No cruising time B. Less than 1 min C. 1–2 min D. 2–5 min E. Over 5 min
11 How do you pay for this parking? A. Self-payment B. Reimbursement C. Others
12 Please use ○ to mark the location where you started cruising for a vacant parking space in the figure below.



If your parking purpose and parking duration are unchanged and your destination is Youshige, please make a decision based on the following assumptions included in the following **two Scenarios**.

Scenario 1

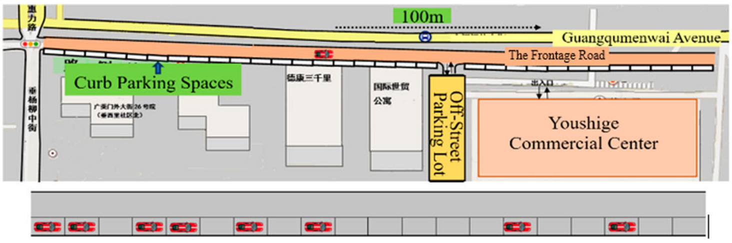
1 If you drive to **200** m away from Youshige, please choose according to the parking situation:



A. Park on Curb
B. Keep Cruising

If you choose B, continue to answer the next question.

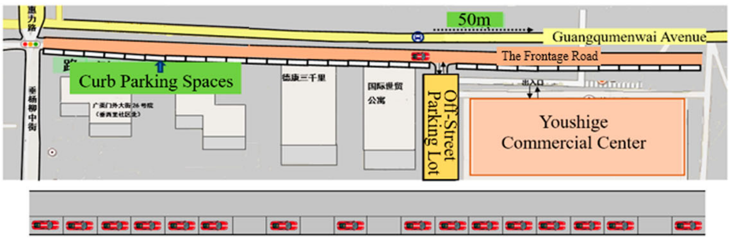
2 If you drive to **100** m away from Youshige, please choose according to the parking situation:



A. Park on Curb
B. Keep Cruising

If you choose B, continue to answer the next question.

3 If you drive to **50** m away from Youshige, please choose according to the parking situation:



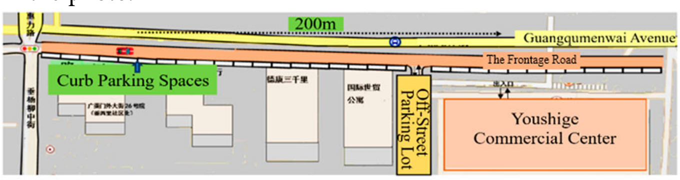
A. Park on Curb
B. Off-Street Parking Lot
C. Keep Cruising

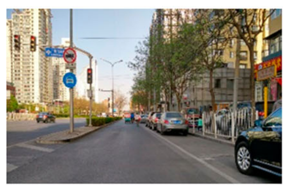
If you choose C, continue to answer the next question.

4 If you **arrive at** Youshige and find no vacant parking space to park, please make a decision:
A. Change the Destination B. Back to Cruise Again
C. Go Ahead to Park Somewhere Else D. Park Illegally

Scenario 2

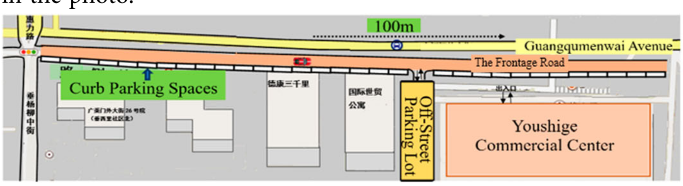
1 If you drive to **200** m away from Youshige, please choose according to the parking situation ahead in the photo:

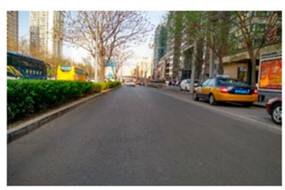




A. Park on Curb B. Keep Cruising
If you choose B, please continue to answer the next question.

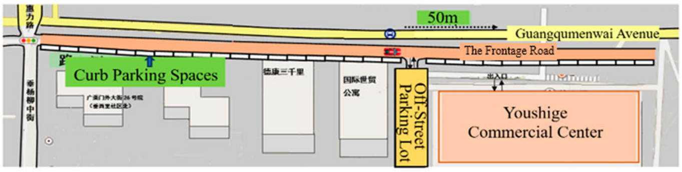
2 If you drive to **100** m away from Youshige, please choose according to the parking situation ahead in the photo:





A. Park on Curb B. Keep Cruising
If you choose B, please continue to answer the next question.

3 If you drive to **50** m away from Youshige, please choose according to the parking situation ahead in the photo:



A. Park on Curb B. Off-Street Parking Lot C. Keep Cruising
If you choose C, please continue to answer the next question.

4 If you **arrive at** Youshige and find no vacant parking space to park, please make a decision:
A. Change the Destination B. Back to Cruise Again
C. Go Ahead to Park Somewhere Else D. Park Illegally