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Parking behavior and the possible impacts on travel alternatives in motorcycle-dominated cities

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Abstract

The objectives of this study are to investigate parking behavior and possible impacts of parking management measure on travel alternatives, then giving the recommendation for transport authorities to achieve the sustainable development of urban transport. To achieve these objectives, the following tasks are addressed. The study firstly gives a basic understanding of factors influencing mode choice, parking location selection, and destination choice. It also highlights the significant role of parking pricing on transport demand management based on international experience. Secondly, parking behavior is investigated in terms of parking location preference, illegal parking phenomenon, and parking duration. Finally, multinomial logit models are developed to estimate the probabilities that transport users who currently drive their private vehicles might choose to use their current mode, change to use the bus, or change to walk for work trips under two scenarios of parking fee increase and bus accessibility improvement. The results of the study might be useful for developing effective parking policies in motorcycle-dominated cities.

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Keywords: Parking Behaviour, Parking Management, Parking Pricing, Travel Alternatives, Regression Model

1. Introduction

Rapid motorization with high motorcycle volume is a unique traffic situation in Asian developing countries. The travel behavior in these countries is dominated by motorcycle-traffic-culture in which the convenience of this transport mode is exploited. With the ability to enter small alleys and to serve door-to-door mobility, motorcycles are excellent in accessibility. They are also relatively small in size, offering maneuvering flexibility and freedom to park practically nearly anywhere.

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Such a motorcycle-dominated culture has resulted in a number of parking issues in Asian developing countries. Transport users are having a unique parking behavior regarding parking duration, parking searching time and walking distance. The number of private vehicles has been increased while the available space on the roads has remained unchanged, leaving a huge gap between parking supply and demand. Illegal parking occurs frequently in many urban areas, especially central business districts.

In Vietnam, motorcycles are by far the dominant mode which covered 62.7% of travel needs while the modal share of public transport (only buses available) was quite small at 8.4% (ALMEC, 2015). In Hanoi urban area (covering 12 districts) the daily trips include 0.5 million bicycle trips, 8.5 million motorcycle trips, and 1.1 million car trips, require for 260,000 bicycle parking spaces, 4.5million motorcycle parking spaces, and 212,000 car parking spaces. Those parking spaces required a total of 1,700ha of the parking area. However, the parking supply currently serves only 38ha making up only 2% of total demand (My Thanh & Friedrich, 2017).

Parking supply-demand gap represents a challenge, but also an opportunity for controlling private vehicle traffic and increasing public transport use. Appropriate parking management measures might reduce traffic demand and control travel mode choice. For instance, parking pricing can help manage travel demand on the one hand, it can attract the private sector to invest in parking facilities on the other hand. However, little information has been collected and analyzed on parking management policies and practices in motorcycle-dominated cities in Asian countries. Therefore, this study aims to answer the two following questions:

(1) What are the characteristics of parking behavior in such typical motorcycle-dominated city as Hanoi?

(2) How parking management policies might influence travel alternatives?

Adequately answering the two questions could help us in examining the possibilities to apply parking management scheme in motorcycle-dominated cities. In the remainder of this paper, we firstly provide an overview of significant factors influencing travel alternatives from international studies. Then, a detailed examination of parking characteristics in Hanoi, a metropolis with the fastest urbanization and growth of motorcycle ownership in Vietnam, is provided. Using stated preference survey, the study attempts to reveal and confirm the impacts of such important transport demand management measures as parking pricing and bus accessibility on travel demand.

2. Literature review

There are many factors influencing travel alternatives (mode choice, parking location selection, and destination choice). The impact aspects relate to socio-economic characteristics of travelers, including gender (White, 1977), occupation (Brown, 1986; DeSalvo & Huq, 2005), income (Brown, 1986; Sasaki, 1990), trip cost (DeSalvo & Huq, 2005; Zhang, 2004), travel distance (Böcker, Prillwitz, & Dijst, 2012), travel mode and departure time (Zou et al., 2016), the quality of walkway (Park, 2008), and car ownership rate (Ding, Wang, Liu, Zhang, & Yang, 2017; He & Thøgersen, 2017).

The influences might come from the spatial configuration of land use (Anas & Moses, 1979; Li, Shao, Yang, Hoz, & Monzón, 2009; Limtanakool, Dijst, & Schwanen, 2006; Wan, Chen, & Zheng, 2009; Zhang, 2004), urban structure (Sasaki, 1990), and transport structures (Anas & Moses, 1979).

Other influences relate to public transport service, for instance, the accessibility to the bus station (walking distance and the quality of the walkway) (Park, 2008), provision of transit system (Zahabi, Miranda-Moreno, Patterson, & Barla, 2012), bus fare (Torres-montoya, 2014), and the quality of bus service (Chee & Fernandez, 2013).

Many impact factors directly relate to parking characteristics, for instance, walking time and walking distance from parking location to the destination (Park, 2008), provision of free parking (Hess, 2010), parking requirements (Rowe, Bae, & Shen, 2012), strategies for parking (Zahabi et al., 2012), parking pricing (Torres-montoya, 2014), and parking fee scheme (Chang, Chung, Sheu, Zhuang, & Chen, 2014).

Among those influences, parking pricing has been used as an effective instrument for traffic management (Glazer and Niskanen, 1992; Kelly and Clinch, 2009; Caicedo, 2012).

Economists were among the first to suggest that parking is not independent of the rest of the transport system and that optimal parking policy often depends on how road usage is priced. Glazer & Niskanen (1992) questions the intuitive idea that congestion would be reduced by increasing the price of parking – if road usage is sub-optimally priced, then a lump-sum parking fee can increase welfare, but a parking fee per unit time does not. This is because, under a marginal parking cost scheme, an increase in the price of parking incentivizes each person to park for a shorter period, allows more people to use parking spaces each day, and subsequently increases traffic. For this reason, consumers may not prefer free parking.

Verhoef et al. (1995) suggest the possibility of using spatially differentiated parking fees to regulate traffic in the absence of road pricing. By simulating alternative policy scenarios in an urban transport market, Calthrop et al. (2000) further suggest that the second-best pricing of all parking spaces produces higher welfare gains than the use of a single-ring cordon scheme, though marginally lower than the combination of a cordon charge with the resource-cost pricing of parking spots.

Through evaluating alternative parking policies, economists generally believe that parking fees prove superior to restrictions on parking space supply for information, temporal efficiency, and inter-temporal efficiency arguments (Verhoef et al., 1995). A prominent planning scholar against free parking, Shoup emphasizes several aspects of distortions in parking cost. Using case studies of eight firms that have complied with California's employer parking cash-out requirement, Shoup (1997) shows that by eliminating the free parking to employees, the benefits to commuters, employers, taxpayers, and the environment exceed program costs by at least three times. Addressing the popular minimum parking requirements, Shoup (1999) and Shoup & H.Pickrel (1978) argues that a forced supply of parking spaces reduces the price of parking, but the cost translates into the price increases of the goods and services sold. By modeling the curb parking behavior, Shoup (2006) suggests that below-optimal curb parking prices induce inefficient cruise searching for cheap curb parking, leading to traffic congestion, air pollution, and additional energy and safety costs. Shoup's work has convinced countless practitioners that efficiency can be restored by pricing on-street parking and abandoning required off-street parking.

Appropriate management measures, for instance, parking pricing and bus accessibility improvement, can manage traffic demand. Parking pricing scheme can also attract the private sector to invest in parking facilities. However, little information on parking management policies and practices in motorcycle-dominated cities has been collected and analyzed. The study, therefore, focus on these two important attributes. A stated preference method and multinomial logit model technique were utilized to test the impact of parking fee and bus accessibility on travel alternatives. The data collection and analysis results are presented in the following sections.

3. Data collection

For this study, two types of surveys have been conducted in Hanoi including parking demand survey and parking user interview survey.

Hanoi is the capital of Vietnam and the country's second largest city by population with 7.7 million people, area of 3,345 km² and the population density of 2,279 person/km² (General Statistics Office of Vietnam, 2016). Hanoi after being expanded in 2008 includes 12 districts, one town and 17 suburban districts (peri-urban area). The peri-urban areas are characterized with a high percentage of free land and low density of population and vehicles. Therefore, parking here currently is not a big problem. Therefore, the study focuses on the urban area with twelve districts as shown in Fig.1.

Based on the development of economics and housing and population density, twelve districts in urban area of Hanoi are divided into three major zones. Old Quarter Area is characterized by ancient buildings. It is the location of the busiest shopping streets and tourist attractions. Developed Area locates inside the Ring Road II and having the highest population density. There is mixed land use area, with the combination of Government authorities, office buildings and shopping streets. New Development Area places inside the area of Ring Road II and Ring Road III with modern condominiums, office buildings and universities. The characteristics of three major areas is shown in Table 1.

Table 1. The characteristics of three major areas in Hanoi

Old Quarter Area	Developed Area (Dong Da District)	New Development Area (Cau Giay District)
• Area: about 0,81km²; • Very high density, about 84.000 people/km² (2009) • Total 76 streets; • City central of on-street shopping and commercial activities.	• Area 9,96 km²; • High density, with 39.156 people/km² (2011); • Total 74 streets; • Mix land use of on-street shopping, commercial area, hospital, universities.	• Area: 12,04 km²; • High density, with 19.682 people/ km² (2010); • Total 60 streets; • Mix land use of new residence areas, new office buildings, hospitals and universities.

Source: Decision No.70 BXD/KT-QH dated 30/3/1995 of the Ministry of Construction
Note: The average density of Hanoi is 1.926 people/ km² (General Statistics Office, 2009)

Fig.1. The map of research area in Hanoi

3.1. Parking demand survey

The on-street parking survey was conducted in thirty street sections, representing major road network and distributed equally in three districts including Hoan Kiem (Old Quarter Area), Dong Da (Developed Area), Cau Giay (New Development Area).

To determine on-street parking demand, parking counting surveys were conducted to count the number of vehicles (car, motorcycle, bicycles) parking on the roadsides and on the sidewalks. The counting survey included both legal and illegal parking vehicles. Parking duration was measured by vehicle license plate.

The off-street parking survey was conducted at three different land-use types, including a shopping mall, commercial buildings, and office buildings. Parking duration was also measured by vehicle license plate survey. Five parking stalls (total 100 parking spaces) were monitored at a continuous interval of 15 minutes and every license plate number was noted down. The survey was conducted from 5:00 AM to 24:00 PM on a Wednesday and a Sunday. The results of parking demand are presented in the following part.

3.2. Parking user interview survey

A survey on parking user's behavior was conducted in June 2016. A total of 311 people was randomly selected at the buildings of different land use types. They were directly interviewed to analyze parking behavior changes under the impacts of parking fees, covering five different office buildings with different type of parking users (bicycle, motorcycle, and car). To test the influence of parking charge and public transport accessibility on travel alternatives, two scenarios were set up.

In the first scenario, travel alternatives were tested under the impact of increased parking fee. Parking fee was set at three levels: (1) pay at the current rate (100%), two times higher (200%), and three times higher (300%). Many people in Hanoi have not to pay for their parking vehicles. For instance, shoppers have free parking whenever they buy something in the shops. With the same story, many commuters did not need to pay for their parking since their companies already did.

The respondents were given five options in each impact level: (1) still use current mode, (2) change to use bus, (3) change to walk, (4) change to use a taxi, and (5) change to other destination. Only three participants, who currently used cars, reported that they might use a taxi for their working trips. These observations are excluded from further analysis. Finally, only 308 respondents were selected for the analysis with four options: (1) still use current mode, (2) change to use bus, (3) change to walk, and (4) change to other location.

In the second scenario, travel alternatives were tested under the impact of two indicators, including increased parking fee increasing and improved bus accessibility. Parking fee was also set at three levels: pay at the current rate (100%), two times higher (200%), and three times higher (300%). Bus accessibility was measured by the walking time to the bus station, set at three levels: 5 minutes walking, 10 minutes walking and 15 minutes walking.

A multinomial logit model was employed to estimate the influence of parking fee on the decision to choose a certain travel alternative of parking users. This study defines four dependent variables: P1 (the probability that a respondent chooses to drive his/her current transport mode), P2 (the probability that a respondent chooses to shift to the bus), P3 (the probability that a respondent chooses to walk), and P4 (the probability that a respondent chooses to change to other destination).

Four probabilities sum to unity:

P1 + P2 + P3 + P4 = 1

The fitted regression model for the first scenario is given by three equations:

$$\log\left(\frac{P2}{P1}\right) = \alpha_a + \beta_a x \quad \text{(Equation A)}$$

$$\log\left(\frac{P3}{P1}\right) = \alpha_b + \beta_b x \quad \text{(Equation B)}$$

$$\log\left(\frac{P4}{P1}\right) = \alpha_c + \beta_c x \quad \text{(Equation C)}$$

The fitted regression model for the second scenario is given by three equations:

$$\log\left(\frac{P2}{P1}\right) = \alpha_a + \beta_{a1} x_1 + \beta_{a2} x_2 \quad \text{(Equation D)}$$

$$\log\left(\frac{P3}{P1}\right) = \alpha_b + \beta_{b1} x_1 + \beta_{b2} x_2 \quad \text{(Equation E)}$$

$$\log\left(\frac{P4}{P1}\right) = \alpha_c + \beta_{c1} x_1 + \beta_{c2} x_2 \quad \text{(Equation F)}$$

In these equations, x and x1 and x2 denote the attributes of alternative (i) that are relevant to the choice being considered; αa and αb and αc are the intercepts, and ßa and ßb and ßc are the coefficients of equations a and b and c that are determined using SPSS software. The dependent variables were mode choice and destination selection.

The model was estimated for two demand groups. In the first case, parking charge impact was tested with three groups and at three cases of parking fee: (1) A pool of all parking users (308 respondents * 3 cases per respondent); (2) Commuters only (182 * 3); and (3) shoppers only (103 * 3). In the second case, parking charge impact was tested with other three groups: (1) Car users (24 respondents * 3 cases per respondent); (2) Motorcycle users (242 * 3); and (3) Bicycle users (27 * 3).

4. Results

4.1. Behavior of parking demand

4.1.1. The preference of on-street parking

It is observed that on-street parking is much preferred in Hanoi. Sidewalks fully occupied by motorcycles are observed in many areas. In Old Quarter Area, the streets with over 100% parking utilization (including illegally parked vehicles) accounted for 70%. In those streets, on-street parking is banned in the roadsides and sidewalks but vehicles still parking illegally. The mapping of parking utilization is illustrated in Fig.2.

Fig.2. Mapping of on-street parking utilization in Old Quarter Area – Car

In Developed Area, the utilization of motorcycle parking was higher than that of car parking. The streets with over 100% utilization of motorcycle parking accounted for 40%, whereas it was about 20% for car. The mapping of parking utilization is shown in Fig.3.

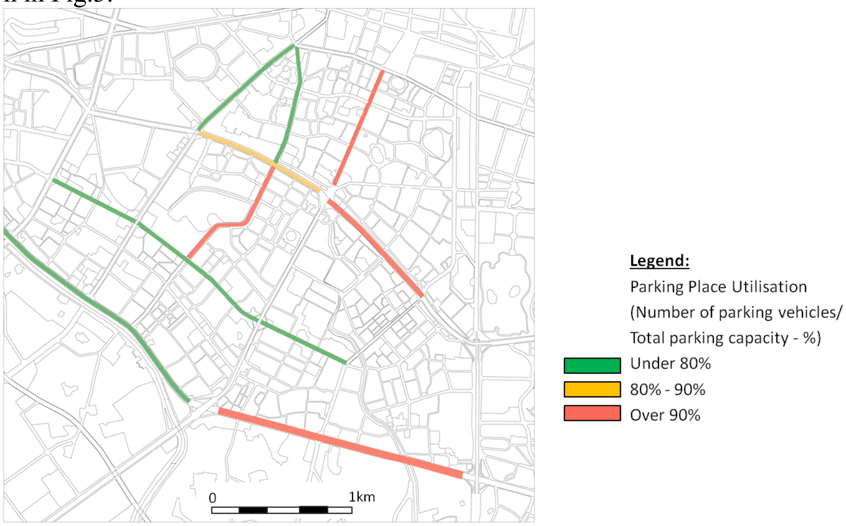

Fig.3. Mapping of on-street parking utilization in Developed Area - Motorcycle

In New Development Area, parking utilization for car and motorcycle with over 100% were similar (accounted for about 30%). In those streets, on-street parking is not banned but the number of parked vehicles exceeded the parking capacity (parking expands to the pedestrian walkways). The mapping of on-street parking utilization is shown in Fig.4.

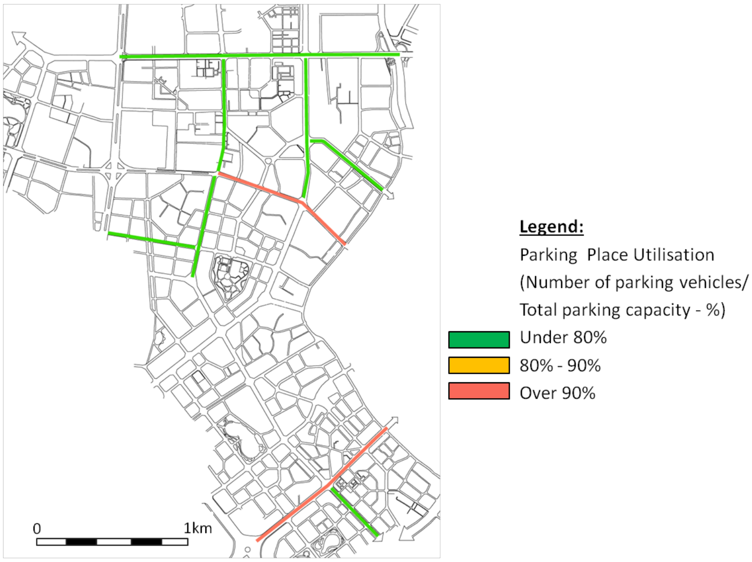

Fig.4. Mapping of parking utilization in New Development Area - Car

4.1.2. Illegal parking phenomenon

Illegal parking activity is the act of drivers parking vehicles in an illegal or restricted area, where signs are posted, in crosswalks, on sidewalks, or blocking traffic lanes as dictated by area traffic laws. The illegal parking acts are cited by a warning from local law enforcement and may result in a punishment, for instance, vehicle towing or fine.

In Vietnamese cities and other motorcycle-dominated cities in Asia, the extremely high volume of motorcycle, increasing number of private cars, inefficient parking supply, inadequate public transport system, and immature driver's behavior are contributing to the problem of illegal parking.

Illegal parking was regular at all survey areas in Hanoi, especially on-street parking in the core city center. There was more motorcycle illegally parked in the core city center than in other areas (Fig.5). Meanwhile, there was more illegal car parking in New Development Area (Fig.6).

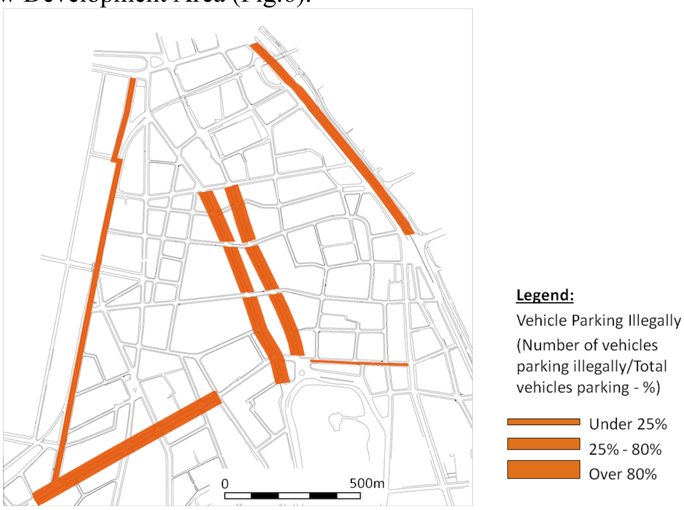

Fig.5. Mapping of motorcycle illegal parking in Old Quarter Area

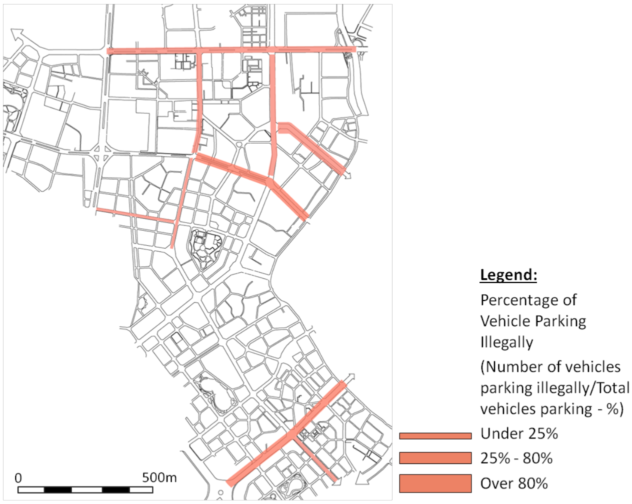

Fig.6. Mapping of car illegal parking in New Development Area

Among the car use respondents, people who used car for business and private purposes area likely to involve in parking violations than who used car for shopping and working purposes. Actually, more than half of the formsers park their cars at unregulated parking spaces while 60% of the latters park their cars at regulated spaces. People using car for shopping and workind trips are willing to walk further to find cheaper parking spaces. Oppositely, more than 60% of the motorcycle use respondents involve in parking violations regardless of trip purposes.

4.1.3. Parking duration

It is observed that on-street parking duration mostly in short-term, especially in the shopping streets in the Old Square Area. About 70-80% of the respondents actually park their vehicles for less than 2 hours. Many motorcycle users park their vehicles only in 20-30 minutes to enter the shop, buying some goods and going out. This fact may explain for their parking violation in shopping center, where police patrol is less.

Off-street parking reveals different characteristics. Parking duration at different parking areas are given in Fig.7. Parking duration was dissimilar at different land-use types and the results also complied with trip purposes. At the office buildings, many vehicles had long parking duration (over 8 hours) with 60%. Parking duration between 4-8 hours took 26%. Only 3% of vehicles parked less than one hour. Results gained at commercial buildings (utilized for both offices and shopping malls) were quite different: 20% of vehicle parked longer than 8 hours; 14% of vehicles had long parking (between 4h-8h); 35% of vehicles had medium parking duration (2h-4h). Parking at the shopping mall was dominated by short duration (between 1h-4h) with 76%; 12% of vehicles had long parking duration (between 4h-8h); and a similar number of vehicles parked less than one hour.

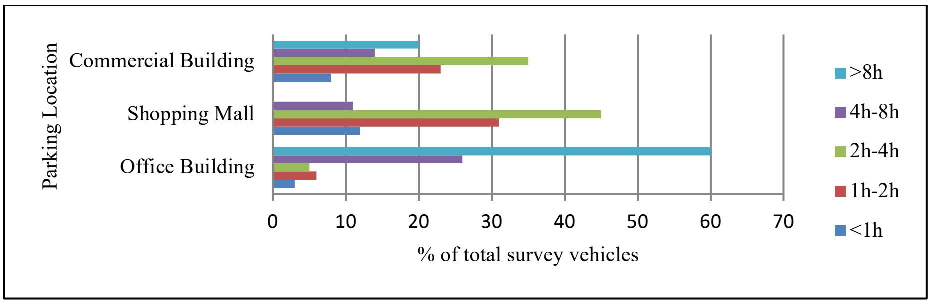

Fig.7. Parking duration of the surveyed vehicles at different land-use

4.2. Impacts of parking fees and bus accessibility on travel alternatives

4.2.1. Characteristics of the samples

There were totally 311 people who using off-street parking interviewed, including 24 car users, 242 motorcycle users, 27 bicycle users and 18 users of others mode. Their socioeconomic characteristics are presented in Fig.8. The survey revealed that among 311 interviewees, most of the car users used their vehicles for working purposes with 75% and for shopping purpose with 21%. Meanwhile, 65% of the motorcyclists used their vehicle for work and 29% used it for shopping trips. As for bicycle users, 70% used their vehicle for shopping, 15% for going to school and 11% for going to work.

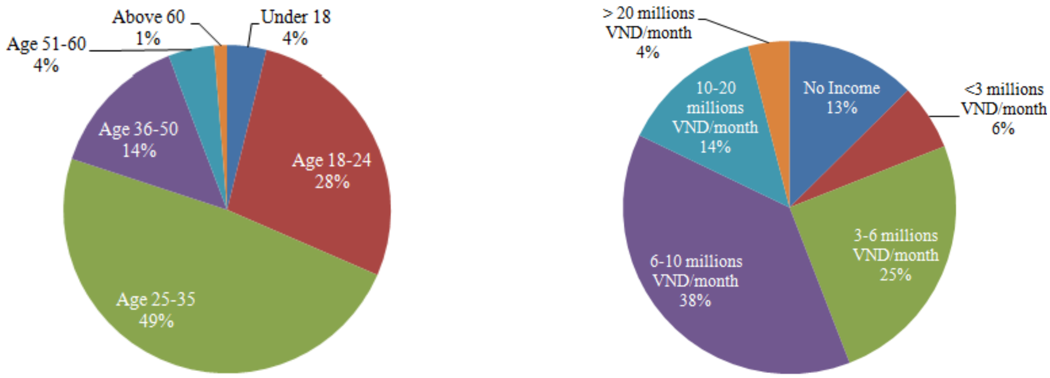

Fig.8. Socioeconomic characteristics of the samples (N=311)
(Exchange rate in 2018: 1 USD = 22,680 VND)

4.2.2. Scenario 1: Possible impact of parking fee

4.2.2.1 Case 1: Comparison among all parking users, commuters, and shoppers

Table 2 gives the results of the multinomial logit regression for travel alternative (use current mode, change to a bus, change to walk, and change the destination) on the attribute of travel parking fee. Generally, the results show that parking fee has a significant influence on travel alternative in three models.

Model 1 uses the parking cost to examine the travel alternative of all parking users. The parking fee increase produces the expected positive coefficient (0.011 for equation a, 0.012 for equation b, and 0.015 for equation c), all with a high level of significance. It means that when parking fee increases, parking users are more likely to shift to the bus, change to walk or change their destination comparing with keeping using their current transport mode. The coefficients of parking fee variable in Model 2 (commuters only) are also significant, that 0.011 for equation a, and 0.02 for equation b. For commuter demand group, there was no option of change destination. The coefficients of parking fee variable in Model 3 (shoppers only) are also significant, that 0.013 for equation a, 0.011 for equation b, and 0.018 for equation C.

The coefficients for three equations in three models indicate that higher parking fee increases the chance that parking users (both commuter and shopper demand groups) choose to use the bus, change to walk or change their destination.

Table 2. Estimated multinomial logit models of stated mode choice

Independent Variable		Model 1: Pool of all parking users (N=924)			Model 2: Commuters Only (N=546)			Model 3: Shoppers Only (N=309)		
		Estimated Coefficient	Std. Error	Sig.	Estimated Coefficient	Std. Error	Sig.	Estimated Coefficient	Std. Error	Sig.
Equation A (Shift to bus)	Intercept	-3.875	0.316	0.000	-4.217	0.454	0.000	-3.732	0.510	0.000
	Parking fee	0.011	0.001	0.000	0.011	0.002	0.000	0.013	0.002	0.000
Equation B (Shift to walk)	Intercept	-6.182	0.906	0.000	-9.240	2.790	0.001	-5.108	1.055	0.000
	Parking fee	0.012	0.004	0.001	0.020	0.010	0.048	0.011	0.004	0.012
Equation C (Change destination)	Intercept	-5.868	0.597	0.000				-5.126	0.652	0.000
	Parking fee	0.015	0.002	0.000				0.018	0.003	0.000
Pseudo R-Square		Cox and Snell:		0.147	Cox and Snell:		0.099	Cox and Snell:		0.255
		Nagelkerke:		0.186	Nagelkerke:		0.159	Nagelkerke:		0.291
		McFadden:		0.101	McFadden:		0.107	McFadden:		0.140

Note: Significant at the 0.05 level. The reference category is: Keep using current transport mode.

Probability predictions

Three models are used to make probability predictions for the mode choice of parking users. This is done by solving the multinomial logit equation for probability using a range of values for a variable using the estimated coefficients and intercept (see Table 3).

The analysis shows that parking users are sensitive to the increase in parking fees. The shoppers are more sensitive than the commuters: they are not only willing to change their current mode but also willing to change their destination.

When people have to pay 100% parking fee, 4% of commuters and 8% of shoppers are willing to shift to the bus, 2% of shoppers are willing to walk, and another 3% of them change their destination.

When the parking fee doubles, people are more willing to change the current mode: 13% of commuters and 20% of shoppers are willing to shift to the bus and, interestingly, 15% of shoppers are willing to change their destination.

Table 3. Effects of parking cost on mode choice probability

Parking fee level	Pool of all users				Commuters Only			Shoppers Only			
	Use current mode	Shift to bus	Shift to walk	Change destination	Use current mode	Shift to bus	Shift to walk	Use current mode	Shift to bus	Shift to walk	Change destination
20%	97%	3%	0%	0%	98%	2%	0%	95%	3%	1%	1%
50%	96%	3%	0%	1%	97%	3%	0%	93%	4%	1%	1%
100%	92%	6%	1%	1%	96%	4%	0%	87%	8%	2%	3%
150%	87%	10%	1%	2%	92%	8%	0%	77%	13%	3%	7%
200%	78%	15%	2%	5%	87%	13%	0%	62%	20%	4%	15%
250%	66%	23%	3%	9%	79%	20%	1%	44%	26%	4%	26%
300%	51%	31%	4%	14%	67%	30%	2%	26%	30%	5%	39%

4.2.2.2. Case 2: Comparison among car users, motorcycle users, and bicycle users

Table 4 shows the results of the multinomial logit regression for travel alternative of three groups of parking users.

In Model 1, the significant is higher than 0.05, then the model is not significant for the conclusion. Model 2 uses the parking cost to examine the travel alternative of motorcycle users. The higher parking fees produce the expected positive coefficient (0.015 for equation a, 0.013 for equation b, and 0.015 for equation c), all with a high level of significance. It means that when parking fees increase, motorcyclists are more likely to shift to the bus, change to walk or change the destination. The coefficients of parking fee variable in Model 3 (bicycle users only) are also significant, that 0.018 for equation a, 0.176 for equation b, and 0.02 for equation c.

The coefficients for two equations in two models (model 2 and model 3) indicate that higher parking fees increase the chance that motorcyclists and bicyclists choose to use the bus, change to walk or change their destination.

Table 4. Estimated multinomial logit models of stated mode choice

Independent Variable		Model 1: Car users (N=72)			Model 2: Motorcycle Users (N=726)			Model 3: Bicycle Users (N=81)		
		Estimated Coefficient	Std. Error	Sig.	Estimated Coefficient	Std. Error	Sig.	Estimated Coefficient	Std. Error	Sig.
Equation A (Shift to bus)	Intercept	-7.280	2.843	0.010	-5.214	0.487	0.000	-5.067	1.198	0.000
	Parking fee	0.020	0.010	0.052	0.015	0.002	0.000	0.018	0.005	0.000
Equation B (Shift to walk)	Intercept				-6.665	1.120	0.000	-54.918	1.059	0.000
	Parking fee				0.013	0.004	0.002	0.176	0.000	0.000
Equation C (Change destination)	Intercept	-5.419	1.962	0.006	-5.950	0.682	0.000	-6.206	1.735	0.000
	Parking fee	0.013	0.007	0.086	0.015	0.003	0.000	0.020	0.007	0.003
Pseudo R-Square		Cox and Snell: Nagelkerke: McFadden:		0.129 0.204 0.138	Cox and Snell: Nagelkerke: McFadden:		0.173 0.227 0.132	Cox and Snell Nagelkerke: McFadden:		0.317 0.378 0.209

Note: Significant at the 0.05 level. The reference category is: Keep using current transport mode.

Probability predictions

The sensitivity analysis shows that when people have to pay 100% parking fee, very few of motorcyclists (2%) and bicyclists (4%) change their current transport mode. Only 1% of motorcyclist and bicyclists are willing to change their destination (Table 5).

However, when the parking fees double, people are more willing to change the current mode: 10% of motorcyclists are willing to shift to the bus, 2% shift to walk and 5% change their destination. The bicycle users are more sensitive to parking fee. When the fee increased to 200%, 18% of them are willing to change to shift to the bus, and 8% change their destination.

Parking pricing measures might have an influence on parking users, especially motorcycle and bicycle user group. It also reveals that there is the higher ability of motorcycle and bicycle users to shift to public transport or use non-motorized traffic (walking).

Table 5. Effects of parking fee on mode choice probability

Parking fee level	Motorcycle Users				Bicycle Users			
	Use current mode	Shift to bus	Shift to walk	Change destination	Use current mode	Shift to bus	Shift to walk	Change destination
20%	99%	1%	0%	0%	99%	1%	0%	0%
50%	98%	1%	0%	1%	98%	2%	0%	1%
100%	96%	2%	0%	1%	95%	4%	0%	1%
150%	88%	6%	2%	4%	88%	9%	0%	4%
200%	84%	10%	2%	5%	73%	18%	0%	8%
250%	71%	18%	3%	9%	52%	33%	0%	16%
300%	54%	28%	4%	14%	28%	45%	4%	24%

4.2.3. Scenario 2: Possible impact of parking fee and bus accessibility

4.2.3.1. Case 3: Comparison among all parking users, commuters, and shoppers

Table 6 gives the results for travel alternative on two attributes (parking fee and the walking time to the bus station). Generally, the results show that both factors have a significant influence on the willingness to change to a bus in three models. Results of other two alternatives (shift to walk and change destination) are not significant to make a conclusion.

Model 1 uses the parking cost and walking distance to bus station to examine the willingness to shift to the bus of all parking users. The higher parking fee generates expected positive coefficient (0.005). Longer walking distance to bus stations produces expected negative coefficient (-0.103), all with a high level of significance. It means that when the parking fees increase, parking users are more likely to shift to the bus, whereas at the longer walking distance to bus station, they are less likely to do so. Model 2, tested with commuters (0.008 coefficient of parking fee, -0.085 coefficient of walking distance), generates the same response. Model 3 with shoppers is not sufficiently significant to make a conclusion.

The coefficients for the first equation (shift to the bus) in two models indicate that with higher parking fee and shorter walking distance, commuter demand group is more willing to choose the bus.

Table 6. Estimated multinomial logit models of stated mode choice

Independent Variable		Model 1: Pool of all parking users (N=924)		Model 2: Commuters Only (N=546)		Model 3: Shoppers Only (N=309)	
		Estimated Coefficient	Sig.	Estimated Coefficient	Sig.	Estimated Coefficient	Sig.
Equation D (Shift to bus)	Intercept	-0.108	0.036	-1.153	0.040	2.094	0.013
	Parking fee	0.005	0.001	0.008	0.000	0.000	0.887
	Bus walking time	-0.103	0.000	-0.085	0.000	-0.136	0.000
Pseudo R-Square		Cox and Snell:	0.128	Cox and Snell:	0.128	Cox and Snell:	0.181
		Nagelkerke:	0.149	Nagelkerke:	0.170	Nagelkerke:	0.198
		McFadden:	0.069	McFadden:	0.098	McFadden:	0.081

Note: Significant at the 0.05 level. The reference category is: Keep using current transport mode.

Probability predictions

The sensitivity analysis (see Table 7) shows that the combination of two factors, parking fee increase (150% level) and improvement of bus accessibility (from 30 minutes to 5 minutes), strongly influences the willingness to shift to the bus of parking users, especially the commuters.

When parking users have to pay 150% of parking fee (scenario 1), 13% of them are likely to shift to the bus. This probability is equivalent to the case of 150% parking fee level combined with 12 minutes walking time in scenario 2. With the same parking fee level, but the walking distance reduces to 10 minutes, more people (20%) are likely to shift to the bus. When the walking time reduces to 5 minutes, 44% of motorcycles users are likely to shift to the bus. The commuters have the same responses, at 150% of parking fee in scenario 1, only 10% of them are willing to shift to the bus. However, when bus stations are within 10 minutes walking time, another more 5% of them are willing to use the bus. When the walking time reduces to 5 minutes, 31% of commuters are willing to shift to the bus.

It is proved that the combination of two measures (increasing parking fees and improving bus accessibility) might have a stronger influence on travel alternatives comparing with the application of parking fee increase only. It also reveals that restricting private vehicle usage by parking fee increasing, on the one hand, and encouraging the utilization of public transport system by improving bus accessibility, on the other hand - a "push and pull" measure - might provide better results in parking demand management.

Table 7. Effects of parking fee and bus walking distance on mode choice - Scenario 2

Parking fee level	Bus walking time	Pool of all users		Commuters Only	
		Use current mode	Shift to bus	Use current mode	Shift to bus
150%	30 minutes	99%	1%	99%	1%
150%	20 minutes	96%	4%	96%	4%
150%	15 minutes	93%	7%	94%	6%
150%	**12 minutes**	**87%**	**13%**	**90%**	**10%**
150%	10 minutes	80%	20%	85%	15%
150%	7 minutes	64%	36%	74%	26%
150%	5 minutes	56%	44%	69%	31%

Comparing with the effects of parking fee on mode choice probability in Scenario 1.

Parking fee level	Pool of all users		Commuters Only	
	Use current mode	Shift to bus	Use current mode	Shift to bus
20%	97%	3%	98%	2%
50%	96%	3%	97%	3%
100%	92%	6%	96%	4%
150%	**87%**	**10%**	**92%**	**8%**
200%	78%	15%	87%	13%
250%	66%	23%	79%	20%
300%	51%	31%	67%	30%

4.2.3.2. Case 4: Comparison among car users, motorcycle users, and bicycle users

In model 2, which was tested with motorcycles users, parking fee increase produces the expected positive coefficient (0.009 for equation a, and 0.011 for equation b), while the improvement of bus accessibility generates the negative coefficient (-0.119 for equation a, and -0.041 for equation b). When parking fees are set at a higher level, people are more likely to shift to bus or change to walk than to keep using their current transport mode. However, having to walking in a longer distance, commuters are less likely to shift to the bus (Table 8). The coefficients of variables in Model 1 (car users only) and Model 3 (bicycle users only) are not significant.

Table 8. Estimated multinomial logit models of stated mode choice

Independent Variable		Model 2: Motorcycle Users (N=726)		
		Estimated Coefficient	Std. Error	Sig.
Equation D (Shift to bus)	Intercept	-0.868	0.516	0.092
	Parking fee	0.009	0.002	0.000
	Bus walking time	-0.119	0.013	0.000
Equation E (Shift to walk)	Intercept	-4.606	1.190	0.000
	Parking fee	0.011	0.004	0.010
	Bus walking time	-0.041	0.024	0.092
Pseudo R-Square		Cox and Snell:		0.166
		Nagelkerke:		0.193
		McFadden:		0.092

Note: Significant at the 0.05 level. The reference category is: Keep using current transport mode.

Probability predictions

The sensitivity analysis (see Table 9) again emphasizes that the combination of two attributes, parking fee increase and improvement of bus accessibility, has a strong influence on the willingness to shift to the bus of parking users, especially the motorcycle users.

When motorcycle users pay at a level of 150% parking fee (scenario 1), 6% of them are likely to shift to the bus. This probability is equivalent to the case of 150% parking fee level combined with 15 minutes walking time in scenario 2. With the same parking fee level, but the walking distance reduced to 10 minutes, more motorcyclists (12%) are likely to shift to the bus. And when the walking time reduces to 5 minutes, 33% of them tend to shift to the bus.

The sensitivity analysis emphasizes that "push and pull" measures might be efficient in parking demand management.

Table 9. Effects of parking cost and bus accessibility on the probability of mode choice

Parking fee increase level	Bus walking distance	Motorcycle Users Use current mode	Shift to bus	Shift to walk	Travel to other locations
150%	30 minutes	91%	0%	1%	8%
150%	20 minutes	90%	2%	1%	8%
150%	**15 minutes**	**88%**	**4%**	**1%**	**7%**
150%	12 minutes	85%	7%	1%	7%
150%	10 minutes	80%	12%	2%	6%
150%	7 minutes	67%	25%	2%	5%
150%	5 minutes	60%	33%	2%	5%

Comparing with the effects of parking cost and bus accessibility on the probability of mode choice in Scenario 1.

Parking fee increase level	Motorcycle Users Use current mode	Shift to bus	Shift to walk	Travel to other locations
20%	99%	1%	0%	0%
50%	98%	1%	0%	1%
100%	96%	2%	0%	1%
150%	**88%**	**6%**	**2%**	**4%**
200%	84%	10%	2%	5%
250%	71%	18%	3%	9%
300%	54%	28%	4%	14%

This study has confirmed that parking pricing and bus accessibility improvement having significant impact on travel alternatives.

The shoppers are more sensitive to parking charge than the commuters. They are not only willing to change their current mode but also willing to change their destination. When the parking fee doubles, people are more willing to change the current mode: 13% of commuters and 20% of shoppers are willing to shift to the bus and, interestingly, 15% of shoppers are willing to change their destination.

Motorcycle and bicycle user group are more sensitive than car user group even the car parking fee is 8-10 times higher than motorcycle parking fee. When the parking fees double, 10% of motorcyclists are willing to shift to the bus, 2% shift to walk and 5% change their destination. The bicycle users are the most sensitive group to parking fee. When the fee increased to 200%, 18% of them are willing to change to shift to the bus, and 8% change their destination.

Parking pricing measures might have an influence on motorcycle and bicycle user group. It also reveals that there is the higher ability of motorcycle and bicycle users to shift to public transport or use non-motorized traffic (walking and cycling).

The combination of “push and pull” measures, representing on parking fee increase and bus accessibility improvement may provide the better results. When parking users pay 150% of parking fee (scenario 1), 13% of them are likely to shift to the bus. This probability is equivalent to the case of 150% parking fee level combined with 12 minutes walking time (scenario 2). With the same parking fee level, but the walking distance reduces to 10 minutes, more people (20%) are likely to shift to the bus. When the walking time reduces to 5 minutes, 44% of motorcycles users are likely to shift to the bus.

5. Conclusions and outlooks

The study has provided with a comprehensive understanding of the parking behavior and the possible impacts of parking management measures on travel alternatives in Hanoi, Vietnam. It has confirmed that parking pricing might help increase public transport use. With higher parking fees, parking users are more likely to shift to public transport. It also reveals that motorcyclists and bicyclists are more sensitive to parking fees than car users. To reduce private usage of vehicles, the commuters and the shoppers should be made to pay for their parking fees. Moreover, parking fees should be increased at central business districts. Time-based parking fee should be applied in combination with the location-based parking fee. Then, the expected number of people, especially motorcyclists, might shift to public transport.

The combination of “push and pull” measures, focusing on parking fee increase and bus accessibility improvement, may provide with better results. It is evident from data analysis that motorcyclist and bicyclists are more willing to shift to public transport than car users, especially when they must pay more for parking. In addition to time-based and location-based parking pricing schemes, the bus network and services should be enhanced to improve accessibility to public transport.

The results of this study would be useful for transport planners and authorities to formulate effective parking policies to manage urban transport in motorcycle-dominated cities. Parking policy has traditionally been supply-oriented. Results of the current study confirmed that emphasis should be shifted to a more market-oriented and demand-focused approach.

References

Anas, A., & Moses, L. N. (1979). Mode choice, transport structure and urban land use. *Journal of Urban Economics*, *6*(2), 228–246. https://doi.org/10.1016/0094-1190(79)90007-X

Barter, P. (1999). *An international comparative perspective on urban transport and urban form in Pacific Asia: the challenge of rapid motorisation in dense cities*. Murdoch University. Retrieved from http://researchrepository.murdoch.edu.au/3332/

Barter, P. (2011). Parking Requirements in Some Major Asian Cities. *Transportation Research Record: Journal of the Transportation Research Board*, *2245*(1), 79–86. https://doi.org/10.3141/2245-10

Barter, P. A. (2011). Parking Policy in Asian Cities Final Consultant ' s Report Parking Policy in Asian Cities, 10–15.

Böcker, L., Prillwitz, J., & Dijst, M. (2012). Climate change impacts on mode choices and travelled distances: a comparison of present with 2050 weather conditions for the Randstad Holland. *Journal of Transport Geography*, *28*, 176–185. https://doi.org/10.1016/j.jtrangeo.2012.11.004

Brown, B. (1986). Modal choice, location demand, and income. *Journal of Urban Economics*, *20*(2), 128–139. https://doi.org/10.1016/0094-1190(86)90002-1

Caicedo, F. (2012). Charging parking by the minute: What to expect from this parking pricing policy? *Transport Policy*, *19*(1), 63–68. https://doi.org/10.1016/j.tranpol.2011.09.006

Calthrop, E., Proost, S., & Van Dender, K. (2000). Parking Policies and Road Pricing. *Urban Studies*, *37*(1), 63–76. https://doi.org/10.1080/0042098002294

Chang, C., Chung, C., Sheu, J., Zhuang, Z., & Chen, H. (2014). The optimal dual-pricing policy of mall parking service, *70*, 223–243.

Chee, W. L., & Fernandez, J. L. (2013). Factors that Influence the Choice of Mode of Transport in Penang: A Preliminary Analysis. *Procedia - Social and Behavioral Sciences*, *91*(225), 120–127. https://doi.org/10.1016/j.sbspro.2013.08.409

DeSalvo, J. S., & Huq, M. (2005). Mode choice, commuting cost, and urban household behavior. *Journal of Regional Science*, *45*(3), 493–517. https://doi.org/10.1111/j.0022-4146.2005.00381.x

Ding, C., Wang, D., Liu, C., Zhang, Y., & Yang, J. (2017). Exploring the influence of built environment on travel mode choice considering the mediating effects of car ownership and travel distance. *Transportation Research Part A: Policy and Practice*, *100*, 65–80. https://doi.org/10.1016/j.tra.2017.04.008

FHWA. (2012). *Contemporary Approaches to Parking Pricing: A Primer*. Retrieved from http://ops.fhwa.dot.gov/publications/fhwahop12026/fhwahop12026.pdf

Glazer, A., & Niskanen, E. (1992, March). Parking fees and congestion. *Regional Science and Urban Economics*. https://doi.org/10.1016/0166-0462(92)90028-Y

He, S. Y., & Thøgersen, J. (2017). The impact of attitudes and perceptions on travel mode choice and car ownership in a Chinese megacity: The case of Guangzhou. *Research in Transportation Economics*, 1–11. https://doi.org/10.1016/j.retrec.2017.03.004

Hess, D. B. (2010). *The Effects of Free Parking on Commuter Mode Choice: Evidence from Travel Diary Data* (Working Paper Series).

ITDP. (2010). Daoli Parking Analysis, 32.

Kelly, J. A., & Clinch, J. P. (2009). Temporal variance of revealed preference on-street parking price elasticity. *Transport Policy*, *16*(4), 193–199. https://doi.org/10.1016/j.tranpol.2009.06.001

Kodransky & Hermann, G., M. (2011). Europe's parking U-turn: From accommodation to regulation. *Institute for Transportation and Development Policy*, 84.

Li, X., Shao, C., Yang, L., Hoz, D. de la, & Monzón, A. (2009). Modeling the Influence of Socioeconomic Characteristics and Land Use on Commute Mode Choice in Madrid. In *2009 Sixth International Conference on Fuzzy Systems and Knowledge Discovery* (Vol. 2, pp. 567–571). IEEE. https://doi.org/10.1109/FSKD.2009.614

Limtanakool, N., Dijst, M., & Schwanen, T. (2006). The influence of socioeconomic characteristics, land use and travel time considerations on mode choice for medium- and longer-distance trips. *Journal of Transport Geography*, *14*(5), 327–341. https://doi.org/10.1016/j.jtrangeo.2005.06.004

Litman, T. (2006). *Parking Management Strategies, Evaluation and Planning*. *Strategies*.

Marsden, G. (2006). The evidence base for parking policies—a review. *Transport Policy*, *13*(6), 447–457. https://doi.org/10.1016/j.tranpol.2006.05.009

Morichi, S., & Acharya, S. R. (2013). *Transport Development in Asian Megacities*. (S. Morichi & S. R. Acharya, Eds.). Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-29743-4

My Thanh, T. T., & Friedrich, H. (2017). Legalizing the illegal parking, a solution for parking scarcity in developing countries. *Transportation Research Procedia*, *25*, 4954–4969. https://doi.org/10.1016/j.trpro.2017.05.374

Nelson, J., & Schrieber, J. (2012). Smart Parking Revisited Lessons from the pioneers. *Planning*, *78*(5), 25–29. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=23h&AN=75121497&site=ehost-live&scope=site

Park, S. (2008). *Defining, Measuring, and Evaluating Path Walkability, and Testing Its Impacts on Transit Users' Mode Choice and Walking Distance to the Station*. *University of California Transportation Center*. Retrieved from http://www.uctc.net/research/diss150.pdf

Rowe, D. H., Bae, C.-H. C., & Shen, Q. (2012). Evaluating the Impact of Transit Service on Parking Demand and Requirements. *Transportation Research Record: Journal of the Transportation Research Board*, *2245*(2245), 56–62. https://doi.org/10.3141/2245-07

Sasaki, K. (1990). Income class, modal choice, and urban spatial structure. *Journal of Urban Economics*, *27*(3), 322–343. https://doi.org/10.1016/0094-1190(90)90005-8

Shoup, D. C. (1997). Evaluating the effects of cashing out employer-paid parking: Eight case studies. *Transport Policy*, *4*(4), 201–216. https://doi.org/10.1016/S0967-070X(97)00019-X

Shoup, D. C. (1999). The trouble with minimum parking requirements. *Transportation Research Part A: Policy and Practice*, *33*(7–8), 549–574.

Shoup, D. C. (2006). Cruising for parking. *Transport Policy*, *13*(6), 479–486. https://doi.org/10.1016/j.tranpol.2006.05.005

Shoup, D. C., & H.Pickrel, D. (1978). Problems With Parking Requirements In Zoning Ordinances.

Torres-montoya, M. (2014). The Impact of Parking Pricing and Transit Fares on Mode Choice to a Major University Campus, (January), 1–15.

VACA, E., & KUZMYAK, J. R. (n.d.). Parking Pricing and Fees. In *Traveler Response to Transportation System Changes*.

Verhoef, E., Nijkamp, P., & Rietveld, P. (1995). The economics of regulatory parking policies: The (IM)possibilities of parking policies in traffic regulation. *Transportation Research Part A*, *29*(2), 141–156. https://doi.org/10.1016/0965-8564(94)E0014-Z

Wan, X., Chen, J., & Zheng, M. (2009). The Impact of Land Use and Traffic Resources Supply on Commute Mode Choice. *2009 Second International Conference on Intelligent Computation Technology and Automation*, *vol.3*, 1010–1013. https://doi.org/10.1109/ICICTA.2009.709

Weinberger, R., Kaehny, J., & Rufo, M. (2012). *U.S. Parking Policies: an overview of Management Strategies Institute for Transportation and Development Policy*. *Institution for Transportation and Development Policy*.

White, M. J. (1977). a Model of Residential Location Choice and Commuting By Men and Women Workers. *Journal of Regional Science*, *17*(1), 41–52. https://doi.org/10.1111/j.1467-9787.1977.tb00471.x

Zahabi, S. A. H., Miranda-Moreno, L. F., Patterson, Z., & Barla, P. (2012). Evaluating the effects of land use and strategies for parking and transit supply on mode choice of downtown commuters. *Journal of Transport and Land Use*, *5*, 103–119. https://doi.org/10.5198/jtlu.v5i2.260

Zhang, M. (2004). The role of land use in travel mode choice - Evidence from Boston and Hong kong. *Journal of the American Planning Association*, *70*(3), 344–360. https://doi.org/10.1080/01944360408976383

Zou, M., Li, M., Lin, X., Xiong, C., Mao, C., Wan, C., … Yu, J. (2016). An agent-based choice model for travel mode and departure time and its case study in Beijing. *Transportation Research Part C: Emerging Technologies*, *64*, 133–147. https://doi.org/10.1016/j.trc.2015.06.006