Analysis of Parking Demand and Impacts of Parking Pricing on Commuter Mode Choice in Hanoi, Vietnam

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Abstract: The objectives of this study are to investigate parking demand and possible impacts of parking pricing on commuter mode choice, then giving the recommendation for transport authorities to achieve the development of urban public transport. To achieve these objectives, the following tasks are addressed. The study firstly gives a basic understanding of how parking pricing might be used as a transport strategy and what objectives they would serve, then, outlines a range of parking pricing strategies based on international experience. Secondly, parking demand is investigated in terms of parking duration, parking turnover rate, parking occupancy and parking generation rate. Finally, multinomial logit models are developed to estimate the probabilities that commuters 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 pricing increase and bus station accessibility improvement. The results of the study might be useful for developing effective parking policies in Vietnamese cities.

Keywords: Parking Management, Parking Pricing, Mode Choice, Regression Model

1. INTRODUCTION

The rapid development of motorcycle traffic in Asian developing countries is a unique phenomenon. During late 1980s-early 2000s, motorcycle population exponentially grew in Asian countries, for instances, China 25% per year, Vietnam 15%, India 11% and Indonesia and Thailand 9%. As a result, Asian cities experienced rapidly increasing and large shares of motorcycle trips (as % of total motorized trips), remarkably 80-90% in Hanoi and Ho Chi Minh City, 60% in Jakarta and around 30% in Taipei and Bangkok (Morichi & Acharya 2013).

The growth in motorcycle populations is deteriorating the parking situation because the available space on the roads has remained unchanged. The construction of public parking spaces has developed slowly and cannot keep up with the demand resulting in a huge gap between parking demand and supply. An important question is how to control and then reduce the traffic demand.

Parking pricing has been used as an effective instrument for traffic management (VACA & KUZMYAK n.d.; Glazer & Niskanen 1992; Kelly & 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 of time, 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.

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.

Theoretical advances and empirical evidence on parking policies have resulted in a significantly improved understanding of the importance of parking for the efficiency of transport and the regional economy (Marsden, 2006). A growing list of policy changes and innovations in parking has been implemented. Several reports of conventional and best practices in parking policy and management in recent years are now available in North America (Litman, 2006; Weinberger et al., 2012; FHWA, 2012; Nelson & Schrieber, 2012), Europe (Kodransky & Hermann, G. 2011), and Asia (Barter 1999; P. Barter 2011; P. A. Barter 2011).

In Vietnam, motorcycles and cars are the two main modes of transport in terms of absolute volume and contribution to cargo transport in the whole country, especially in urban areas and economically developed areas. Motorcycles are by far the dominant mode. At the end of 2013, Vietnam had 37 million registered motorcycles and 1.55 million registered cars in use (the National Traffic Safety Committee and the Traffic Police Road and Railroad Department, 2013).

The studies of Hanoi urban planning by the Ministry of Transport and JICA (Japan International Cooperation Agency) confirmed that motorcycle was the dominant transport mode in Hanoi 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). Apparently, the motorcycle is the preferred choice of urban population, providing personal mobility in relatively short distances and frequent trips, under the condition that land use for transport is about 7.0% of total urban land use, public transport is underdeveloped, cars are beyond the reach of the general public at the current income level, and motorcycles often travel faster than cars.

By the end of 2016, there are about 5 million motorcycles and 0.54 million cars in Hanoi (Hanoi Department of Transport, 2016). In the 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 (according to the analysis results of authors). 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. Therefore, the parking demand in Hanoi is significantly high. Parking supply-demand gap represents a challenge, but also an opportunity for controlling private vehicle traffic and increasing public transport use.

It is also important to note that working trip purpose takes 52% to 65% of total weekday trip (ALMEC, 2015). Additionally, most of the commuters use their private vehicles for working trip. Appropriate parking pricing, on the one hand, can help manage travel demand, and on the other hand, it can attract the private sector to invest in parking facilities. However, little information has been collected and analyzed on parking pricing policies and practices in Vietnam.

To resolve the above issues, this study aims to answer the two following questions:

(1) What are the characteristics of parking demand in Hanoi?
(2) How parking pricing policies might influence commuter mode choice?

Adequately answering the two questions could help us in examining the possibilities to apply parking pricing scheme in Vietnamese cities. In the remainder of this paper, we firstly provide an overview of the current parking regulation Vietnam. 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 mode choice survey, we attempt to reveal and confirm the impacts of parking pricing and bus accessibility on commuter travel demand.

2. PARKING REGULATIONS

Perhaps different from many countries, earlier development of parking regulations was led by the central government in Vietnam and quickly followed by local regulations and standards that conform to or adapt based on national policies. This part of paper starts with the overall regulatory framework at the central and local government levels. It then elaborates on the two most important aspects of parking regulation – supply and price.

2.1. Parking lot regulations

Similar to the practice in many other countries (Kodransky & Hermann, 2011), Vietnamese cities regulate the quantity of off-street parking spaces through minimum parking requirements. The 1988 “Regulations on the design standard of office buildings” was the first national regulation on the minimum size of parking lots for certain buildings and public structures. The regulation, then, was supplemented a specific standard for condominium through “Construction Building Code TCXDVN 323:2004”. The 2010 “Circular No. 02/2010/TT-BXD, promulgation of national technical standards for urban infrastructure” included the first comprehensive national standard on the minimum parking space requirements of different vehicle types.

Table 1. Minimum requirement for parking space in buildings

Type of area	Parking space (% of construction space)	Parking requirement (m2/person)
Parking restriction area	2.0 – 2.5	1.5 – 2.5
Expanding areas	2.5 – 3.0	2.5 – 3.0
New construction area	3.0 – 3.5	(*) 4.0 – 5.0
High-rise apartment	(**) 4.0 – 5.0	(**) 4.0 – 5.0

Source: Decision No.165/2003/QĐ-UB of HN People's Committee

Note: (*) Use the high number for Parking restriction area and Expanding areas

(**) For the apartments over 15 floors, use high number 5% or 5m2/person

2.2. Price regulations

Vietnamese cities not only regulate the supply of parking spaces by minimum parking requirements but also control parking prices extensively. Cities commonly prescribe the price of parking, even in residential areas. The day and night residential parking price standards remained constant in Hanoi during 2002–2011 (40,000VND/120minute/car and 3,000VND/turn/motorcycle) (Decision No. 47/2011/QD-UBND about charging for bicycle, motorcycle, car in the area of Hanoi, 2011) and in Hochiminh city during 2004–2012 (20,000VND/turn/car in daytime and 40,000/turn/car in night time; 3,000VND/turn/motorcycle in day time and 5,000VND/turn/motorcycle in night time) (Decision No. 32/2012/QD-UBND about charging for bicycle, motorcycle, car in the area of Hochiminh city, 2012). Compared to the residential price standards that may be increasingly irrelevant and perhaps laxly enforced, parking prices in non-residential areas remain tightly controlled by the government, who often owns and/or operates a significant portion of non-residential parking facilities. The curb and off-street parking fees in non-residential areas increased in both Hanoi and Hochiminh from 2000 to 2010, with significant increases in curb parking fees recently as a response to market demand.

According to Article 83, section 6, of the Law on Road Traffic (Vietnam Ministry of Justice, 2008) fees for car parking have to be stipulated by the local People’s Committee. Hanoi People’s Committee regulates parking fees for both on-street and off-street parking. The city promulgated Decision No. 47/2011/QD-UBND to guide the setting of parking charges for a bicycle, motorcycle, and car. Both, privately and government-operated parking lots have to comply with the regulations. Motorists are charged per turn, not per hour. However, there is a monthly collected parking fare. During night time, the parking fee is higher. Cars are charged more than motorcycles. Parking fees for cars vary according to their capacity and the parking duration. The maximum length of car parking time per turn is 120 minutes. In fact, parking charges and parking duration fluctuate depending on the areas. Normally, people have to pay actual fees higher than regulated ones at both authorized and unauthorized parking spaces.

3. DATA COLLECTION

For this study, two types of surveys have been conducted, including parking demand survey and parking user interview survey. The survey locations covered different parking areas (office buildings, shopping malls, residences…) at different zones including the core city center (Hanoi Old

Quarter in Hoan Kiem District), the developed area (Dong Da District), and the new development area (Cau Giay District) as illustrated in Figure 1.

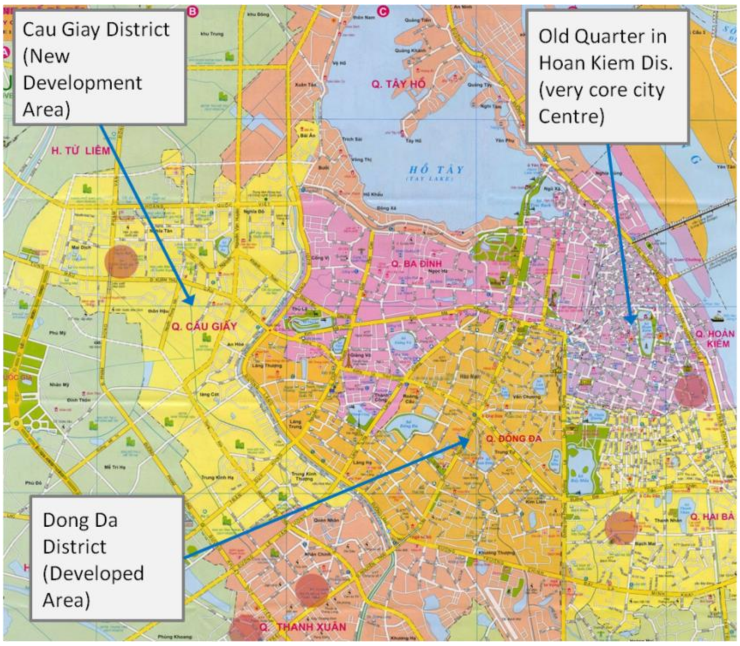

Figure 1. Distribution of parking locations

In order to determine parking turnover rate and parking occupancy, total parking demand was measured by in-out survey. At first, the occupancy count is taken at the beginning; then the number of vehicles entering the parking lot for each 5 minutes is counted and the number of vehicles that leave the parking lot is taken. The final occupancy in the parking lot is also taken. The survey was conducted from 5:00 AM to 24:00 PM.

Parking duration was measured by vehicle license plate survey at three different land-use types, including a shopping mall, commercial buildings, and office buildings. Five parking stalls (total 100 parking spaces) are monitored at a continuous interval of 15 minutes and every license plate number is 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 Section 4.

Additionally, a total of 185 commuters were interviewed in June 2016, including 20 car users, 157 motorcycle users, 3 bicycle users and 5 users of other modes, 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).

Their socioeconomic characteristics are presented in Figure 2.

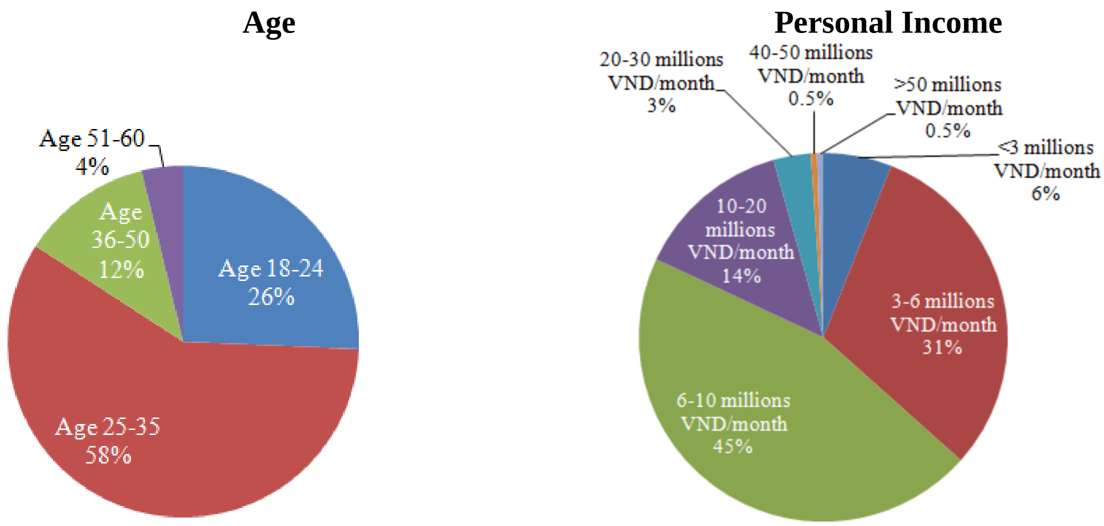

Figure 2. Socioeconomic characteristics of the samples (N=185)
(Exchange rate in 2017: 1 USD = 22,600 VND)

4. PARKING DEMAND

4.1 Parking duration

Parking duration at different parking locations is characterized in Figure 3. It shows that parking duration is dissimilar at different land-use types and the results also comply with trip purposes. At the office buildings, the majority of vehicles have very long parking duration (over 8 hours) with 60%, parking duration between 4-8 hours also takes 26% and only 3% vehicles park less than one hour. On the contrary, the distribution of parking duration is quite similar to which at commercial buildings (utilized for both offices and shopping malls). There is 20% of vehicle parking longer than 8 hours, 14% of vehicles have long parking (between 4h-8h) while 35% of vehicles have medium parking duration (2h-4h). Parking at the shopping mall is dominated by short duration (between 1h-4h) with 76%. Only 12% of vehicles has long parking duration (between 4h-8h) and a similar number of vehicles park less than one hour.

Based on the survey results, it is also important to note that there is no much difference on parking duration between car and motorcycle or bicycle at the same parking location. It reveals that with a similar trip purpose, car users and motorcycle users might park their vehicle with similar duration. Therefore, the selection of parking location or trip mode might depend only on the parking cost which contributing much for total trip cost.

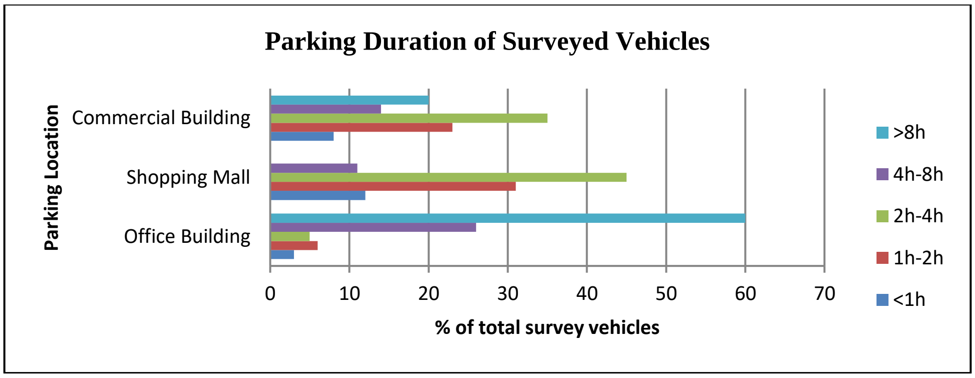

Figure 3. Parking duration of the surveyed vehicles at different land-use

4.2 Parking turnover rate and parking occupancy

The average turnover rate is the rate of usage of a parking facility and is determined by dividing a total number of vehicles parked in a parking facility into the number of available parking spaces of this facility in a certain period of time. To determine parking turnover rate, the following formula is used:

$$\mu_i = \frac{A_i}{D_i} \qquad (1)$$

Where:
μi: average turnover rates
Ai: total number of parking vehicles;
Di: total number of parking spaces

Parking space occupancy refers to the utilization rate of the parking facility and is determined by dividing total parking time of vehicles into total operating of the parking facility. The following formula is used to determine parking occupancy:

$$\gamma_i = \frac{\sum t_{ij}}{D_i T} \quad (j = 1, 2, \cdots D) \qquad (2)$$

Where:
γ_i: parking space occupancy
t_{ij}: parking time in each parking space;
T: working time of parking facility.

The index of parking turnover rate and parking occupancy are shown in Table 2 below. It shows that shopping malls have highest parking turnover rate with 5.7 (on average, 5.7 vehicles can park at one parking space during 24 hours) and also high parking occupancy with 81%. Meanwhile, commercial buildings have a little lower turnover rate (4.4) but very high parking occupancy (98%). High parking turnover rate of shopping malls is reasonable since parking duration of the shopping trip is short (during 1h-4h). Very high parking occupancy at commercial building shows their effective utilization of parking facilities. Such buildings are used for both offices and shops, hence parking facilities are used for officers during day-time and shoppers during evening time on weekdays. During weekends, the parking facilities are used for people coming for shopping, entertainments, and recreations. Office buildings have the lowest parking turnover rate (1.1) and parking occupancy (41%) since the parking facilities are mostly used during daytime of weekdays and they are almost empty at weekends. This data reveals that shared parking might be a good parking management measure to be applied to office buildings. It means that parking facilities should be utilized for not only officers but for other parking users in café, restaurants, fitness centers…

Table 2. Parking turnover and parking occupancy of different land-use types

Parking Type	Parking Turnover Rate	Parking Occupancy
Shopping mall	5.7	81%
Commercial building (office and shop)	4.4	98%
Office building	1.1	41%
High-rise condominium	1.3	51%

4.3 Parking generation rate

The parking generation rate is parking demand quantity generated from land use in per unit area, on the basis of land use types. This index is used to calculate the total parking spaces required for a certain land-use such as residence buildings, offices, restaurants, shopping malls… To determine parking generation rate, the following formula is used:

$$a_i = \frac{y}{R_i \times \mu_i} \qquad (3)$$

Where:

a_i: refers to parking generation rate, which are the quantities of parking demand per unit area;

y: refers to parking demand in a certain area; unit is parking vehicle;

R_i: refers to the individual area m^2

μ_i: average turnover rates

In order to calculate the parking generation rate, the physical information of survey buildings are collected, such as: Total floor, Number of basement floor (for parking), Number of floor for office renting (or residence), Construction area for a floor (m2), Used area for a floor(m2), Total construction area (m2), Total area for office (or live) (m2), Parking area (m2), Maximum of parking vehicle for bicycle, motorcycle and car; Number of apartment in a floor; Total apartment. Then, the parking generation rates are calculated as such index: parking space per $100m^2$ construction area, parking space per $100m^2$ used areas, parking space per apartment.

The parking generation rate of different land-use is illustrated in Table 3. It shows that the office buildings, characterized by low parking turnover and very low parking occupancy, have the highest parking generation rate, each $100m^2$ used area (the real areas utilized for office renting) requires 7.79 parking spaces. On the contrary, shopping malls have lowest parking generation rate since the parking facilities are effectively used in such kind of buildings. The low-income condominium (characterized by small apartments, high density) have higher parking generation rate (2.83 parking space per $100m^2$ used area) than commercial condominium (1.62 parking space per $100m^2$ used area).

Table 3. Parking generation rate of different land-use types

	Commcercial Building	Shopping Mall	Office Building	High-rise Condo	Low Income Condo
Parking space/$100m^2$ construction area	2.81	1.49	5.63	1.18	2.14
Parking space/$100m^2$ used area	3.44	1.82	7.79	1.62	2.83
Parking space/1 apartment				2.15	2.78

From the analysis, it shows that the parking generation rate is highest at an office building, which is 7.79 spaces/$100m^2$ used area, comparing with 1.82 spaces/$100m^2$ at a shopping mall or 1.62/$100m^2$ at a high-rise condominium. However, the office buildings have lowest parking turnover rate (1.1) and parking occupancy rate (41%). It means that parking infrastructure at office buildings are utilized least efficiently comparing with other land-use such as shopping malls, commercial buildings or condominiums. Therefore, reducing parking supply at office building by shifting private vehicle usage of commuters to public transport are very important. In the next part, the study will analyze the possible impacts of parking fee on commuter mode choice to have an in-depth understanding of the possibility of implementing a parking pricing policy.

5. POSSIBLE IMPACTS OF PARKING FEE ON COMMUTER MODE CHOICE

5.1 Stated mode choice

Parking cost is an important part of the trip cost, hence it might have a significant influence on the sensitivity of travel demand. In order to test the influence of parking pricing on travel mode choice, two scenarios were set up.

In the first scenario, commuter mode choice was tested under the impact of parking fee increasing. Parking fee was set at three levels: (1) pay at a current fee (100%), (2) two times higher (200%), and (3) three times higher (300%). Many commuters did not need to pay for parking fee because their companies already paid for them. The respondents were given four options in each parking fee level: (1) still use the current mode, (2) change to use bus, (3) change to walk, and (4) change to use taxi. The samples include 185 respondents, but only two, who currently using cars, reported that they might use a taxi for their working trips. These observations are excluded from further analysis, therefore only 183 respondents are selected for the analysis.

In the second scenario, commuter mode choice was tested under the impact of two factors, including parking fee increase and bus accessibility improvement. Parking fee was also set at three levels: (1) pay at a current fee (100%), (2) two times higher (200%), and (3) three times higher (300%). Bus accessibility was measured by the walking time to the bus station, set at three levels: (1) 5 minutes walking, (2) 10 minutes walking, and (3)15 minutes walking.

The multinomial logit model was employed to estimate the influence of parking fee on commuter mode choice. This study defines three dependent variables: P1 (the probability that a respondent chooses to drive his/her current transport mode), P2 (the probability that a respondent chooses to use the bus), and P3 (the probability that a respondent chooses to walk).

By definition, the three probabilities sum to unity:

$$P1 + P2 + P3 = 1$$

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

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

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

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

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

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

In these equations, x and x_1 and x_2 denote the attributes of alternative (i) that are relevant to the choice being considered; αa and αb are the intercepts, and ßa and ßb are the coefficients of equations a and b that are determined using SPSS software. The dependent variable is mode choice. The model was estimated for three groups: (1) Pool of all users (183 respondents * 3 cases per respondent); (2) Car users (18 * 3); and (3) Motorcycle users (157 * 3).

5.2 Scenario 1: Parking fee increase only

Table 4 gives the results of the multinomial logit regression for travel alternative (use current mode, change to bus, and change to walk) for the commuter trip on the factor of the parking fee. Generally, the results show that parking fee has a significant influence on travel alternative in three models.

Model 1 uses the daily parking cost to examine the mode choice of all type of parking users. The parking fee increase produces the expected positive coefficient (0.011 for equation a, and 0.019 for equation b), both with a high level of significance. It means that at the higher level of parking fee, people are more likely to shift to bus or change to walk comparing with keep using their current transport mode. The coefficients of parking fee variable in Model 2 (car users only) and Model 3 (motorcycle users only) are also significant. In Model 2, this is 0.167 for equation a (respondents are not likely to change to walk), and in Model 3 they are 0.015 for equation a, and 0.02 for equation b.

The coefficients for two equations in three models indicate that higher parking fee increases the chance that they will choose to use the bus or change to walk.

Table 4. Estimated multinomial logit models of stated mode choice

		Model 1: Pool of all users (N=549)			Model 2: Car users only (N=54)			Model 3: Motorcycle users only (N=471)		
	Independent Variable	Estimated Coefficient	Std. Error	Sig.	Estimated Coefficient	Std. Error	Sig.	Estimated Coefficient	Std. Error	Sig.
Equation A (Shift to bus)	Intercept	-4.207	0.454	0.000	-52.312	0.750	0.000	-5.174	0.607	0.000
	Parking fee	0.011	0.002	0.000	0.167	0.000	0.000	0.015	0.002	0.000
Equation B (Shift to walk)	Intercept	-9.229	2.789	0.001				-9.152	2.800	0.001
	Parking fee	0.019	0.010	0.049				0.020	0.010	0.047
Pseudo R-Square		Cox and Snell:		0.097	Cox and Snell:		0.081	Cox and Snell:		0.123
		Nagelkerke:		0.156	Nagelkerke:		0.298	Nagelkerke:		0.206
		McFadden:		0.105	McFadden:		0.266	McFadden:		0.144

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 commuter's working trips. This is done by solving the multinomial logit equation for probability using a range of values for one particular variable using the estimated coefficients and intercept (see Table 5).

The sensitivity analysis shows that when commuters have to pay 100% parking fee, very few of them (1%) change their current transport mode. It is also very interesting to see that, when the parking fee increase double (pay 200%), 100% of car users keep using their current mode.

The results also reveal that car users, who have the highest income level in survey group, are more likely to stick to their current transport mode. They might not take the mobility risk regarding travel time. They really need a stable schedule to be in their offices on time, that the public transport system hardly provides.

However, when the parking fee has extra increase, car users and motorcycle users have different responses. When commuters have to pay the parking fee at 250%, 100% of car users keep using their cars while 17% of motorcycle users are willing to shift to the bus. Only when car users have to pay at 300%, 11% of them are likely to shift to the bus.

It shows that parking pricing measure might have an influence on all parking user, especially motorcycle user group. It also reveals that there is the higher ability of motorcycle user shifting to public transport or using non-motorized traffic (walking).

Table 5. Effects of parking cost on mode choice probability

Parking fee level	Pool of all users			Car users only		MC users only		
	Use current mode	Shift to bus	Shift to walk	Use current mode	Shift to bus	Use current mode	Shift to bus	Shift to walk
20%	98%	2%	0%	100%	0%	99%	1%	0%
50%	97%	3%	0%	100%	0%	99%	1%	0%
100%	96%	4%	0%	100%	0%	98%	2%	0%
150%	92%	8%	0%	100%	0%	95%	5%	0%
200%	87%	12%	0%	100%	0%	90%	9%	0%
250%	79%	20%	1%	100%	0%	81%	17%	1%
300%	68%	30%	2%	89%	11%	68%	30%	3%

5.3 Scenario 2: Parking fee increase and bus accessibility improvement

Table 6 gives the results of the multinomial logit regression for commuter mode choice under two factors: parking fee and bus accessibility (representing by walking time to bus stations). Generally, the results show that both parking fee and bus accessibility have a significant influence on the willing to shift to the bus of commuters in three models; but it does not have a significant influence on the willing to change to walk.

In Model 1, parking fee increase produces the expected positive coefficient (0.008 for equation a, and 0.170 for equation b), while the improvement of bus accessibility generates the negative coefficient (-0.084 for equation a, and -0.031 for equation b). It means that at the higher level of parking fee, people are more likely to shift to bus or change to walk comparing with keep using their current transport mode. In contradiction, at the longer walking distance commuters are less likely to shift to the bus.

The coefficients of parking fee variables in Model 2 (car users only) and Model 3 (motorcycle users only) are significant, but the walking time variables are not significant.

Table 6. Estimated multinomial logit models of stated mode choice

<table>
<tr><th colspan="2" rowspan="2">Independent Variable</th><th colspan="2">Model 1: Pool of all users (N=549)</th><th colspan="2">Model 2: Car users only (N=54)</th><th colspan="2">Model 3: Motorcycle users only (N=471)</th></tr>
<tr><th>Estimated Coefficient</th><th>Sig.</th><th>Estimated Coefficient</th><th>Sig.</th><th>Estimated Coefficient</th><th>Sig.</th></tr>
<tr><td rowspan="3">Equation A (Shift to bus)</td><td>Intercept</td><td>-1.217</td><td>0.030</td><td>34.715</td><td>0.000</td><td>-1.586</td><td>0.011</td></tr>
<tr><td>Parking fee</td><td>0.008</td><td>0.000</td><td>-0.178</td><td>0.000</td><td>0.010</td><td>0.000</td></tr>
<tr><td>Walking time</td><td>-0.084</td><td>0.000</td><td>-0.037</td><td>0.552</td><td>-0.096</td><td>0.000</td></tr>
<tr><td>Equation</td><td>Intercept</td><td>-53.042</td><td>0.000</td><td></td><td></td><td>-52.950</td><td>0.000</td></tr>
</table>

B (Shift to walk)	Parking fee	0.170	0.000			0.170	0.000
	Walking time	-0.031	0.427			-0.036	0.349
Pseudo R-Square		Cox and Snell:	0.126	Cox and Snell:	0.116	Cox and Snell:	0.159
		Nagelkerke:	0.168	Nagelkerke:	0.252	Nagelkerke:	0.210
		McFadden:	0.097	McFadden:	0.199	McFadden:	0.123

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) have a strong influence on the willingness to shift to the bus of motorcycle users but having no impact on car users.

When motorcycle users have to pay at a level of 150% parking fee (scenario 1), 5% 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 motorcyclists (8%) are likely to shift to the bus. And when the walking time reduces to 5 minutes, 18% of motorcycles users are likely to shift to the bus.

It shows that the combination of two measures including parking fee increasing and bus accessibility improvement might have a stronger influence on commuter mode choice comparing with the application of parking pricing only. It also reveals that “push and pull” measures might provide better results in parking demand management.

Table 7. Effects of parking fee and bus accessibility on the probability of mode choice

Parking fee level	Bus walking time	Pool of all users		Motorcycle users only	
		Use current mode	Shift to bus	Use current mode	Shift to bus
150%	30	99%	1%	100%	0%
150%	20	98%	2%	99%	1%
150%	15	97%	3%	98%	2%
150%	12	93%	7%	95%	5%
150%	10	90%	10%	92%	8%
150%	7	85%	15%	88%	12%
150%	5	79%	21%	82%	18%

6. CONCLUSIONS AND RECOMMENDATIONS

This study has provided a comprehensive understanding of the characteristics of parking demand and the possible impacts of parking pricing on commuter mode choice in Hanoi City.

It has investigated parking generation rate, parking occupancy and parking turnover at different land uses. The study reveals that parking infrastructure at office buildings are utilized least efficiently comparing with other land uses such as shopping malls, commercial buildings or condominiums. Office buildings have the highest parking generation rate (7.79 spaces/100m^2 used area) but the lowest parking turnover rate (1.1) and parking occupancy rate (41%). Therefore, it is necessary to reduce parking supply at the office buildings in order to shift the commuters from private vehicle to public transport.

This study has confirmed that parking pricing measure might contribute to increase in public transport use. The higher parking fee, the more likely that commuters shift to public transport. It also reveals that motorcyclists are more sensitive with parking fee than car users. When commuters have to pay the parking fee at 250% of the current fee, 100% of car users keep using their cars while 17% of motorcycle users are willing to shift to the bus. Only when car users have to pay at 300% of the current fee, 11% of them are likely to shift to the bus while 30% of motorcyclists would probably use public transport. To reduce private usage of vehicles, the commuters should pay for their parking fee rather than paid by their companies. Moreover, parking fee 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 commuters, especially motorcyclists might shift to public transport.

The combination of "push and pull" measures, representing on parking fee increase and bus accessibility improvement may provide the better results. When motorcycle users pay at a level of 150% the current parking fee and walk 12 minutes to the bus station, 5% of them are likely to shift to the bus. At the same parking fee level, if the walking distance reduces to 10 minutes, more motorcyclists (8%) are likely to shift to the bus; and when the walking time reduces to 5 minutes, 18% of them are likely to shift to the bus. The study reveals that motorcyclist are more willing to shift to public transport than car users, especially when they have to spend more for parking. Beside 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 developing countries. Further study should be conducted on other transport users and the modal shift should be tested with more policy measures, such as time-restriction and location restriction parking measures.

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