Exploring Mode and Brand Choices in Motorcycle Dependent Cities for Policy Analysis Related to Emission Reduction

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Abstract: This paper presents an integrated analytical framework to highlight environment benefit gained from policies aiming at minimizing the impact of private transportation modes in motorcycle dependent cities. Models integrated in this framework include mode/brand choices, usages of motorcycles and cars, and an international vehicle emission (IVE). The models of mode/brand choices and usages are developed using data collected in Ho Chi Minh City, the motorcycles are accounted for approximately 80%. The developed models are then used to demonstrate the demand and usage changes under scenarios relating to 10% and 30% increases in income, parking fee and travel cost. These changes are imputed into the IVE model to calculate the emissions. The results show that earning a higher income is connected to shifting from the motorcycles and buses to cars and daily increasing CO_2. By contrast, the both policies of increasing parking fee and travel cost lead to reduce CO_2.

*Keywords***:** Motorcycle, Multinomial logit, Emissions, Developing Countries, International Vehicle Emission (IVE)

1. INTRODUCTION

Nowadays, in many Asian countries like Vietnam, Indonesia, Malaysia, China, Taiwan, and Thailand, the urban transportation is seriously dependent on motorcycles. Because of their low cost (in purchasing and running), their flexible movement and convenient parking, the motorcycle ownership has dramatically increased. For instance, a share of motorcycles in total number of motor vehicles is 69% in India (Mohan, 2002), 60% in Malaysia (Umar, 2002), about 70-90% in Thailand (Suriyawongpaisal and Kanchanusut, 2003), nearly 63% in China (Zhang et al., 2004) and 78% in Indonesia (Indriastuti and Sulistio, 2010). In Vietnam, as of 2013, the motorcycles were accounted for 95% of 40.8 million registered vehicles (Truong et al., 2016).

Consequently, traffic congestion, accidents and air pollution related to the motorcycles have become urgent problems in such countries. Indriastuti and Sulistio (2010) reported that approximately 75% fatality victims of traffic accidents were motorcyclists in Indonesia. In China, motorcyclists involved in 7.5% of all accident fatalities and 8.8% of all accident injuries. Meanwhile motorcyclist fatalities in Taiwan accounted for almost 57% (Wen et al., 2012). Similar to Taiwan, Malaysia reported that more than 50% of the accident fatalities came from motorcyclists. The studies in Vietnam (Hung et al., 2008; La et al., 2013) showed that motorcyclists are the most vulnerable road users as they were associated with more than 70% of road traffic crashes. On the other hand, cars can be regarded as a safer mode compared to motorcycles since the motorcycles have limited protection design. The literature has shown that the motorcycles have higher injury rates (8 times) as well as fatality rates (35 times) than that of cars (Ranney et al., 2010). Thus, shifting mode from motorcycles to cars might reduce the injury and fatality rates involved in motorcycles in developing countries. It, however, may cause other problems such as more serious traffic congestion and air pollution, especially in the cities with dense populations. As the economy is growing in developing countries, the trend of choosing cars as a transportation mode is predicted to increase in the near future. Thus, effective management strategies for decreasing the private vehicle ownership including motorcycles and cars are urgently important in these countries.

Like many cities in developing countries, Ho Chi Minh City (HCMC) is the most populous city and the biggest economic center in Vietnam. In the city, the development of transportation infrastructure does not uphold the growth in private motorization. The private modes in HCMC have extremely exploded since the last few decades. With approximately 6.3 million motorcycles and 0.6 million cars in 2014, the ratio of private mode per inhabitant is incredibly high (0.82) meaning that almost one person owns one vehicle. In addition, the increasing trend of motorcycles seems to decline from 10.3% in 2010 to 7.7% in 2014. However, in the same duration, that of cars tends to significantly increase from 9.4% to 20.2% (Chu et al., 2015). Therefore, there is an immediate need to control the explosion of private modes in order to deal with accidents, traffic congestion and to reduce air pollution.

It has been well known that the discrete choice model is widely used in the context of transportation demand modeling for the evaluation and establishment of transportation policy (Yang et al., 2015). Deeply getting insights into mode choice behavior is very important to determine transportation demand management strategies. Additionally, the decision makers, who choose the motorcycles and cars as their transportation mode, face with various brands of motorcycles and cars in the real market. Each motorcycle/car manufactory is currently trying to make products that are more environmental-friendly and more safely. Thus, it is also crucial to understand factors that influence the brand choice of decision makers, which may be significantly related to the traffic accident and air pollution. To deal with these problems, the aim of the current paper is to apply the discrete choice model for estimating mode choice in conjunction with brand choice using revealed preference data collected in HCMC. The model is further utilized to discuss some potential management policies in order to control the private mode in HCMC, which can be applied in other similar cities of developing countries as well.

2. LITERATURE REVIEW

The literature has found numerous studies focusing on travel demand modeling in motorcycle dependent cities in developing countries as shown in Table 1. The table demonstrates that most studies (Leong and Mohd Sadullah, 2007; Wen and Huang, 2012; Prabnasak and Taylor, 2011; Hsu et al., 2007; Lai and Lu, 2007; Tuan and Shimizu, 2005; Senbil et al., 2007) have paid attention to explore the motorcycle ownership within a household.

Table 1. Summary of related studies in motorcycle dependent cities

Study	Country	City	Data type	Travel demand modeling	Policy analysis	Analytical model
Leong and Mohd Sadullah (2007)	Malaysia	Penang	RP	Motorcycle ownership	-	MNL
Wen and Huang (2012)	Taiwan	23 cities	Panel	Motorcycle ownership and usage	License tax, fuel fee, insurance cost, parking fee	MNL*)
Prabnasak and Taylor (2011)	Thailand	Khon Kaen	RP	Motorcycle and car ownership	-	MNL
Hsu et al. (2007)	Taiwan	Taipei, Taichung, Kaohsiung	RP	Motorcycle ownership	-	Poisson
Le and Trinh (2016)	Vietnam	HCMC	RP	Mode choice (motorcycle vs. bus)	-	BL
Lai and Lu (2007)	Taiwan	Taipei,		Motorcycle and car ownership, mode choice, usage	LOS of public transport, license tax, fuel cost	NL
Satiennam et al. (2015)	Thailand	Khon Kaen	SP	Mode choice (car vs. BRT and motorcycle vs. BRT)	Travel time of private mode, travel time of BRT, fare of BRT	BL
Chen and Lai	Taiwan	Taipei, Kaohsiung	RP/SP	Motorcycle use	-	MNL
Dissanayake and Morikawa (2002)	Thailand	Bangkok and 5 adjacent provinces	RP	Car/motorcycle ownership, mode choice	Road pricing and bus fare	NL
Chiou et al (2009)	Taiwan	23 cities	Panel	Car/motorcycle ownership, type choice, and usage	Increasing gas price	NL
Tuan and Shimizu (2005)	Vietnam	Hanoi	RP	Motorcycle ownership	Motorcycle registration tax and annual ownership tax	MNL**)
Senbil et al. (2007)	Indonesia	Jabotabek	RP	Motorcycle ownership	-	OP
Tuan (2015)	Vietnam	Hanoi	RP/SP	Mode choice	-	MNL

Note:

*) They tested NL and Mixed logit but the model was not consistent with utility maximization

**) They also estimated NL but not successfully

MNL – multinomial logit
NL – Nested logit
BL – Binary logit
BP – Binary probit
OP – Ordered probit
HCMC – Ho Chi Minh City
SP – stated preference
RP – revealed preference
LOS – level of service

Performing a study in Penang, Malaysia, Leong and MohdSadullaha (2007) stated that household income, driving license and household size significantly determine the factors governing motorcycle ownership. They demonstrated that motorcycles are a major private mode for low- and middle-income people, however, high-income ones are likely to own cars. It implies that that car and motorcycle ownership within a household may employ a negative relationship. Another study in Hanoi, Vietnam by Tuan and Shimizu (2007) showed that the lower household income results in the higher the degree of motorcycle ownership. Hsu et al. (2007) and Lai and Lu (2007) studied the car and motorcycle ownership in Taiwan and found that income contributes as one of the key factors affecting the ownership. Their findings are in good agreement with studies of Leong and MohdSadullaha (2007). Senbil et al. (2007) explored the motorcycle ownership in Jabotabek, Indonesia. They demonstrated that degree of motorcycle ownership tends to increase by income till a certain level. Beyond that level, the degree of motorcycle ownership declines while that of car ownership increases. Wen et al. (2012) also suggested that household income is an important explanatory variable in the car ownership. They, however, were surprised that household income is not significantly influenced on motorcycle ownership. They explained the reason is due to the low purchase cost of motorcycles and most of the low-income households can afford to buy inexpensive motorcycles as they need, meanwhile, high-income ones more prefer cars than motorcycles. On the other hand, their findings gave an evidence that the higher annual insurance fee, annual license tax/fuel fee and maintenance cost are significant factors in reducing motorcycle ownership. These facts are very important for policy makers to implement strategies that can reduce the ownership of private modes.

Together with motorcycle ownership, few studies attempted to address the mode choice issues. Dissanayake and Morikawa (2002) combined vehicle ownership and household-based mode choices into a two-level nested logit (NL) model for the data collected in Bangkok and five adjacent provinces. They concluded that the distance between traveler's destinations plays an important role in determining the mode choice for travelers in a household. In addition, low household income tends not to own neither cars nor motorcycles. Satiennam et al. (2015) estimated a binary logit (BL) for mode choices of cars/motorcycles versus bus rapid transit (BRT). They found that reducing travel time and cost of BRT results in selecting mode choice of BRT for both car and motorcycle users. And the motorcycle users with older age and female are more likely to change to BRT. In a similar study, Tuan (2015) estimated a mode choice of bicycle, motorcycle, car, BRT and mass rapid transit (MRT) using stated preference. He found that a significant number of users keep using their private modes, trip chaining and the present of under 12-year-old kids in the family might prevent people from shifting to BRT/MRT. Most recently, Le and Trinh (2016) conducted a binary choice model (motorcycle or bus) for students and employees using data collected in HCMC. They found that there exist differences between two travel groups. For example, the longer travel distance is associated with bus mode for student group but not for employee group. The higher income employees seem to choose motorcycles as their mode than buses.

It is worth mentioning that a little attempt has invested effectiveness of some policies by using simulation results of developed choice models. Wen et al. (2012) stated that the management strategies of both increasing license fax/fuel fee and insurance cost do not result in a considerable change of motorcycle ownership. However, raising gas prices and parking fees significantly reduce usage of motorcycle represented by total kilometers traveled. Chiou et al (2009) found that increasing gas price results in shifting from cars to motorcycles and it can reduce CO_2 and NO_x emissions. However, CO and HC emissions increase due to the fact that motorcycles produce more CO and HC emissions than cars. Lai and Lu (2007) also concluded simulation study based on their proposed model. They found that the impact of increasing fuel cost on reducing car/ motorcycle ownership and usage is more significant than the policies of raising the level of service (LOS) of public transportation, increasing license tax or implementing capital cost. Comparing these two modes, the car ownership is much more sensitive to the policies than the motorcycle ownership. Dissanayake and Morikawa (2002) suggested that by introducing road-pricing scheme and reducing public transport fares, car and motorcycle travel can be declined to some extent and the car travel more significantly reduce compared to motorcycle travel. Tuan and Shimizu (2007) suggested that the imposition of sufficiently high taxes (e.g. registration and annual ownership tax) on motorcycle users could be a promisingly applicable measure in order to effectively manage the rapid increase in motorcycle ownership.

In the viewpoint of the analytical method, it is identified from Table 1 that the multinomial logit (MNL) is the main approach with a note that the binary logit (BL) can be considered as a special case of the MNL. Few studies applied the nested logit (NL), however, most of them failed to reject the MNL when the logsum parameter governing the correlation among alternative within a nest is not consistent with the utility maximization. For example, Lai and Lu (2007) applied a three-level NL model to analyze household joint choices of car ownership, motorcycle ownership, and mode to work. They found that the logsum parameter of the upper nest was larger than 1 meaning that the NL is not consistent with the utility maximization. It led to a conclusion that car ownership and motorcycle ownership do not have a significant interaction. Similarly, Chiou et al (2009) and Wen et al (2009) reported having the inconsistency of NL.

In conclusion, the issue of travel demand modeling in motorcycle dependent cities in developing countries has been intensively discussed in the literature. Despite the importance of mode choice modeling, the current literature still lacks a comprehensive analysis of the mode choice behavior in conjunction with brand choice behavior because almost all previous studies have focused on the motorcycle ownership. Deeper understanding this issue can provide more appropriate transportation policies that can reduce negative impacts of private modes (e.g. accidents and air pollution) on the urban environment of motorcycle dependent cities.

3. METHODOLOGICAL FRAMEWORK

3.1. Mode choice model

As aforementioned, the MNL and NL are widely applied in the context of mode choice modeling and they are adopted in the present study as well. For the utilization maximization principle in random utility modeling, the probability that an individual *n* chooses an alternative *i* belonging to a choice set C is:

$$P_n(i|C) = P\left(U_{n,i} > U_{n,j}\right) = P\left(V_{n,i} + \varepsilon_{n,i} > V_{n,j} + \varepsilon_{n,j}\right) \forall i \neq \mathrm{j} \quad (1)$$

Here, $U_{n,i}$, $V_{n,i}$ and $\varepsilon_{n,i}$ are utility, systematic component and error term for the individual *n*, respectively. If the error term is assumed to follow Gumbel distribution and to be independent and identically distributed (IID) across all individuals and alternatives, the model yields MNL form:

$$P_n(i|C) = \frac{e^{V_{n,i}}}{\sum_{j \in C}^{n} e^{V_{n,j}}} \quad (2)$$

It is noted that, a property of the multinomial logit model is the "independence of irrelevant alternatives" (IIA). When IIA property is violated or in other word, there exists the correlation among the subsets of alternatives, NL is preferable. Assuming that the choice set *C* can be divided to *M* nests with N_m alternatives within a nest *m* ($m \in M$), the form of NL is as follows:

$$P_n(i|C) = P_n(i|N_m)P_n(m|C) = \frac{e^{\frac{V_{n,i}}{\mu_m}}}{\sum_{j \in N_m} e^{\frac{V_{n,j}}{\mu_m}}} \frac{e^{I_{n,m}}}{\sum_{k \in M} e^{I_{n,k}}} \tag{3}$$

Where $P_n(i|N_m)$ and $P_n(m|C)$ are the probability of selecting alternative *i* within nest *m* and the probability of having nest *m* belonging to the choice set *C*. $I_{n,m}$ is an inclusive value or a logsum of nest *m* for the individual *n*.

$$I_{n,m} = \mu_m log\left(\sum_{j \in N_m} e^{\frac{V_{n,j}}{\mu_m}}\right) \tag{4}$$

μ_m is logsum parameter representing a degree of independence among the alternatives within nest *m*. For a consistency of utility maximization, μ_m must satisfy the condition $0 < \mu_m \leq 1 \ \forall n$. The bigger magnitude of μ_m indicates the higher degree of independence and less correlation among the alternatives of nest *m*. If the NL model cannot outperform the MNL model, the MNL is the appropriate specification. To verify whether the IID assumption exists or not, the likelihood ratio test can be used to compare the MNL and NL models (Koppelman and Bhat, 2006).

This study used R programming version 3.2.3 with a maxLik package (Henningsen and Toomet, 2011) to implement the codes for estimations of unknown parameters by maximizing the log likelihood function in Equation (5).

$$LL = \sum_n \sum_i y_{n,i} \, log\left(P_n(i|C)\right) \tag{5}$$

3.2. Mode usage model

For the usage model, linear regression is typical used (see, e.g. Chiou et al, 2009; Wen and Huang, 2012). The model is developed by step-wisely regressing *ln*(annual kilometer traveled) on explanatory variables such as demographic characteristics and vehicle characteristics. Interested readers can refer to above studies for more information.

3.3. Analytical frame work

The developed models are then incorporated into an integrated analytical framework for a demonstration of policy effects as shown in Figure 1. An international vehicle emission tool - IVE (ISSRC, 2008) is applied to calculate the emission reduction due to the policy implementation. The IVE was specially developed for developing countries where motorcycles are dominant. The IVE has proved to accurately provide an improved emission estimation in an urban area, in addition to allow the effective analysis of local policies in the developing countries, e.g. Shanghai and Beijing, China (Wang et al., 2008; Liu et al., 2007), Kathmandu

Valley, Nepal (Shrestha et al., 2013), Chennai, India, (Nesamani, 2010) and Hanoi, Vietnam (Oanh et al., 2012). The IVE uses local vehicle technology distributions, power-based driving factors, vehicle soak distributions, and meteorological factors to tailor the model to the local situation. Those factors were analyzed in the earlier study (Chu et al., 2015), which used the data collected in the same period with the data in the current study. Therefore, in this study, we will adopt those necessary factors for a demonstration of emission changed due to some policies. The readers who are interested in IVE and its way of emission calculation can refer to above studies in developing countries.

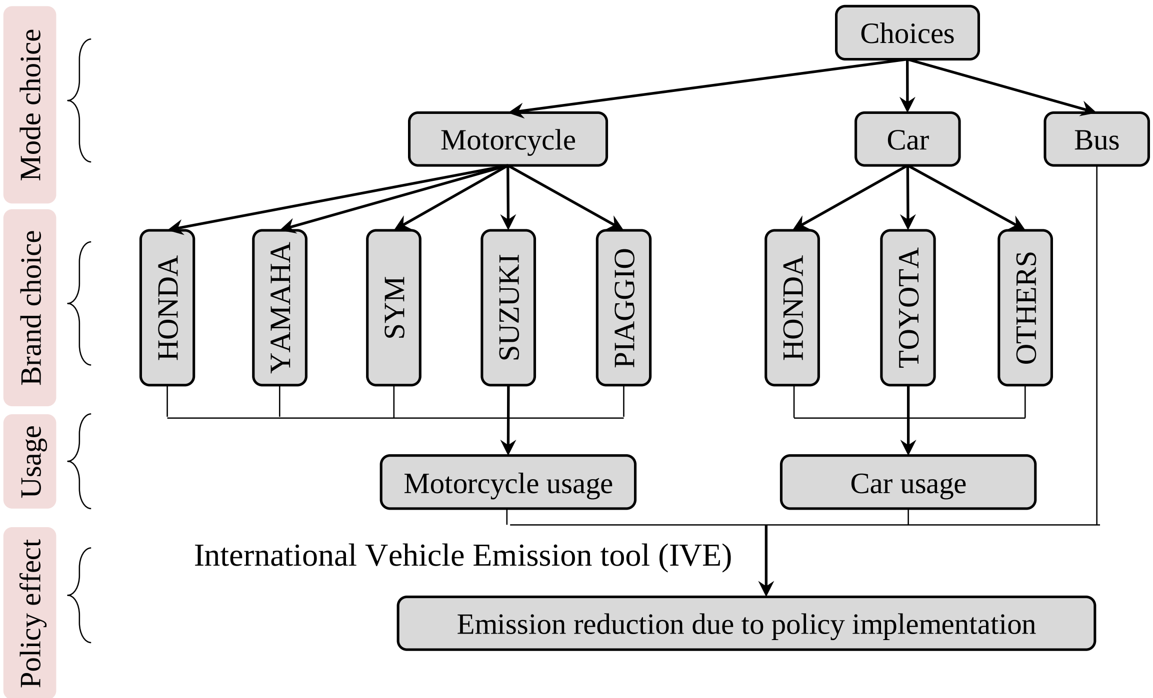


Figure 1. Integrated analytical framework

4. EMPIRICAL MODEL

4.1. Data

The data employed in this study were intensively collected during the period from 15th to 22nd on December 2014 using questionnaire technique. The target area was the center of HCMC. The questionnaire mainly contains three parts. The first part consists of respondents' demographics, such as gender, age, occupation, educational level, income, commuting mode, trip purposes and distance of one-way trip. The second part includes information of respondents if they chose cars/motorcycles as their modes (brand name, year of purchase, cumulative kilometer traveled, engine volume, monthly parking fee, monthly travel cost. The third part concerns respondent opinions on the traffic situation, transportation policies, etc. In this paper, the data of the first two parts are mainly used. Total 3500 questionnaire-sheets were randomly distributed to respondents at their home or company. Finally, a total of 2066 valid questionnaire-sheets were returned, with an effective response rate of 59%. Of 2066 samples, the motorcycle choice is extremely dominant (1707 – 82.62%). The share of choices of car (167 – 8.08%) and bus (174 – 8.42%) is approximately similar. The other modes such as the bicycle, walk or taxi are very rare, only 18 cases (0.87%).

Table 2. *Distribution of respondents' characteristics under various mode choices*

Item	Total		Shared by mode for each category					
	Freq.	%	Freq.			%		
			Motor	Car	Bus	Motor	Car	Bus
Gender								
Male	1143	55.97	948	111	84	82.94	9.71	7.35
Female	899	44.03	753	56	90	83.76	6.23	10.01
Age								
10~19	136	6.66	101	2	33	74.26	1.47	24.27
20~29	791	38.74	684	6	101	86.47	0.76	12.77
30~39	661	32.37	588	47	26	88.96	7.11	3.93
40~49	260	12.73	201	51	8	77.31	19.62	3.07
50~	194	9.50	127	61	6	65.46	31.44	3.10
Education								
High school or less	453	22.18	346	32	75	76.38	7.06	16.56
Associate	490	24	421	32	37	85.92	6.53	7.55
Bachelor	836	40.94	716	63	57	85.65	7.54	6.81
Master or higher	263	12.88	218	40	5	82.89	15.21	1.90
Employment								
Employee	1599	78.31	1386	152	61	86.68	9.51	3.81
Unemployed	134	6.56	116	11	7	86.57	8.21	5.22
Student	309	15.13	199	4	106	64.40	1.29	34.31
Monthly income (million VND) [*)]								
≤ 3	181	8.86	116	4	61	64.09	2.21	33.7
3~4	316	15.48	279	17	20	88.29	5.38	6.33
4~5	359	17.58	309	16	34	86.07	4.46	9.47
5~7	511	25.02	449	27	35	87.87	5.28	6.85
7~9	328	16.06	288	30	10	87.80	9.15	3.05
9~11	200	9.79	172	20	8	86.00	10.00	4.00
> 11	147	7.20	88	53	6	59.86	36.05	4.09
Monthly parking fee (million VND)[*)]								
None	598	29.29	401	23	174	67.06	3.85	29.09
≤ 0.1	980	47.99	928	52	0	94.69	5.31	0
0.1~0.3	369	18.07	332	37	0	89.97	10.03	0
>0.3	95	4.65	40	55	0	42.11	57.89	0
Monthly travel cost (million VND) [*)]								
≤ 0.3	525	25.71	415	9	101	79.05	1.71	19.24
0.3~0.5	529	25.91	480	11	38	90.74	2.08	7.18
0.5~0.75	564	27.62	519	25	20	92.02	4.43	3.55
0.75~1	194	9.5	148	36	10	76.29	18.56	5.15
>1	230	11.26	139	86	5	60.43	37.39	2.18
Household size								
Live alone	365	17.87	308	19	38	84.38	5.21	10.41
2	287	14.05	246	21	20	85.71	7.32	6.97
3	367	17.97	314	26	27	85.56	7.08	7.36
4	594	29.09	499	50	45	84.01	8.42	7.57
≥ 5	429	21.01	334	51	44	77.86	11.89	10.25
Trip purpose								
Working	1145	56.07	1029	77	39	89.87	6.72	3.41
Meeting	215	10.53	162	24	29	75.35	11.16	13.49
Shopping/Entertainment	433	21.2	340	33	60	78.52	7.62	13.86
Others	249	12.19	170	33	46	68.27	13.25	18.48
Distance of one way trip (km)								
≤ 3	375	18.36	303	20	52	80.80	5.33	13.87
3~5	376	18.41	327	27	22	86.97	7.18	5.85
5~10	655	32.08	574	51	30	87.63	7.79	4.58
10~15	313	15.33	248	26	39	79.23	8.31	12.46
15~30	305	14.94	244	31	30	80.00	10.16	9.84
> 30	18	0.88	5	12	1	27.78	66.67	5.55

Note: [*)]As of December 2014, 1 million VND is approximately 46 USD

Because of their very low frequency, those modes are neglected from analysis and modeling. Among 1707 cases of motorcycles, the Japanese brand - Honda accounts for a major share of 71.18%. It is followed by Yamaha (Japanese brand – 19.09%), SanYang Motor – SYM (Taiwanese brand – 6.32%), Suzuki (Japanese brand – 2.05%), and Piaggio (Italian brand – 1.00%). Other brand names of motorcycles are negligible (6 samples, 0.34%). With respect to 167 samples of cars, their brand names include Toyota (49.70%), Honda (27.78%), and other brands (21.56%). Noticed that, although the share of mode choice of collected data fits well to the real choice in HCMC (Chu et al. 2015), the sample of the car is limited due to the big share of the motorcycles, which might result in biases of brand choice of cars. Increasing total sample size can overcome this issue, however, it produces a burden for survey budget.

Table 2 displays the distribution of respondents' characteristics under various mode choices. It is noted that after excluding some samples as mentioned above, the data used for analysis contain 2042 samples. The table shows that males are more likely to choose the car than the bus. The age group under 30 years old prefers using the bus, however, the older one seems to be more dependent on the car compared to the motorcycle and bus. A similar tendency is found for education level, monthly income, household size and distance of one-way trip. The respondents gaining higher education level and earning higher income tend to select car as their transportation mode. It is reasonable to assume that the ones with higher education level can earn more money and they are easy to purchase the car. By contrast, the respondents with lower education level and income have a higher likelihood of selecting bus. Further looking to the employment status, it those of low education level and income may be the students, who show a high possibility of using the bus in comparison to the employee and unemployed groups. In addition, it is logical that the ones living in a big family with more than 5 members possibly choose the car. Regarding trip purpose, Table 2 indicates that the respondents tend to use the motorcycle for going to work. On the other hand, they use car and bus for other purposes such as meeting, shopping, school, etc. Looking into parking fee, of total 2042 respondents, approximately 29% of them (598) did not spend any money for parking. These 598 cases consist of nearly 67% of the motorcycle, 4% of the car and 29% of the bus. It is not surprised that the bus users do not pay for monthly parking fee. However, for motorcycle and car users, a possible reason is that almost all companies/universities/government offices in HCMC provide free parking places for their staffs. Additionally, after going back, the respondents can park their modes at home, especially for motorcycle users. By comparing three modes, it is understandable that the bus users spend lowest parking fee and travel cost while the car users rank as the first ones.

Turning to the characteristics of the private modes, Table 3 indicates that both motorcycle and car are young ages. Approximately 49% of the motorcycle and 44% of the car were purchased 3 years or less. Among brand names, Honda motorcycles and Toyota cars are relatively older than the other groups. Most of the motorcycle users drove less than 10 000 km per year. However, with a large proportion of annual usage more than 12 000 km, the car users tend to drive more than the motorcycle users. From Table 3, it is found that the engine capacity of 110cc (66.43%) is the most popular among motorcycle group and engine capacity from 1500 to 3000cc (53.29%) is common for the car. Noted from Table 3 that a major proportion of motorcycles did not have high technology engine (e.g. electronic fuel injection – EFI) (62.14%) and failed to comply with an emission standard (60.49%). As for the cars, although most of them (71.86%) complied with the emission standard, a common share of the car without high-tech engine (e.g. hybrid) (67.66%) is found. It may lead to a higher emission for the entire fleets of motorcycles and cars in HCMC.

Table 3 Distribution of private modes' characteristics under various brand choices

Item	Motorcycle												Car							
	Total		Shared by brand for each category										Total		Shared by brand for each category					
			Freq.					%							Freq.			%		
	Freq.	%	HON	YAM	SYM	SUZ	PIA	HON	YAM	SYM	SUZ	PIA	Freq.	%	HON	TOY	OTH	HON	TOY	OTH
Vehicle age (year)																				
≤ 3	842	49.50	584	187	46	11	14	69.36	22.21	5.46	1.31	1.66	74	44.31	24	31	19	32.43	41.89	25.68
3~5	400	23.52	280	70	38	10	2	70.00	17.50	9.50	2.50	0.50	33	19.76	15	13	5	45.45	39.39	15.16
5~10	390	22.93	288	66	22	13	1	73.85	16.92	5.64	3.33	0.26	41	24.55	6	26	9	14.63	63.41	21.96
> 10	69	4.06	63	3	2	1	0	91.30	4.35	2.90	1.45	0.00	19	11.38	3	13	3	15.79	68.42	15.79
Annual usage (10^3 km)																				
≤ 8	572	33.63	406	114	31	13	8	70.98	19.93	5.42	2.27	1.40	3	1.80	0	2	1	0	66.67	33.33
8~10	583	34.27	423	107	37	15	1	72.56	18.35	6.35	2.57	0.17	3	1.80	1	1	1	33.33	33.33	33.34
10~12	317	18.64	217	65	27	5	3	68.45	20.50	8.52	1.58	0.95	14	8.38	2	8	4	14.29	57.14	28.57
12~14	175	10.29	130	29	11	1	4	74.29	16.57	6.29	0.57	2.28	51	30.54	15	28	8	29.41	54.9	15.69
>14	54	3.17	39	11	2	1	1	72.22	20.37	3.70	1.85	1.86	96	57.49	30	44	22	31.25	45.83	22.92
Engine capacity (cc)																				
≤ 100	119	7.00	109	4	6	0	0	91.60	3.36	5.04	0.00	0.00	-	-	-	-	-	-	-	-
110	1130	66.43	846	225	33	24	2	74.87	19.91	2.92	2.12	0.18	-	-	-	-	-	-	-	-
> 125	452	26.57	260	97	69	11	15	57.52	21.46	15.27	2.43	3.32	-	-	-	-	-	-	-	-
≤ 1500	-	-	-	-	-	-	-	-	-	-	-	-	56	33.53	17	26	13	30.36	46.43	23.21
1501~3000	-	-	-	-	-	-	-	-	-	-	-	-	89	53.29	25	46	18	28.09	51.69	20.22
> 3000	-	-	-	-	-	-	-	-	-	-	-	-	22	13.17	6	11	5	27.27	50.00	22.73
High technology engine																				
None	1057	62.14	764	221	42	29	1	72.28	20.91	3.97	2.74	0.10	113	67.66	32	62	19	28.32	54.87	16.81
EFI	644	37.86	451	105	66	6	16	70.03	16.30	10.25	0.93	2.49	-	-	-	-	-	-	-	-
Hybrid	-	-	-	-	-	-	-	-	-	-	-	-	54	32.34	16	21	17	29.63	38.89	31.48
Emission standard																				
None	1029	60.49	767	183	59	15	5	74.54	17.78	5.73	1.46	0.49	47	28.14	17	27	3	36.17	57.45	6.38
Comply	672	39.51	448	143	49	20	12	66.67	21.28	7.29	2.98	1.78	120	71.86	31	56	33	25.83	46.67	27.50

Note: HON – Honda
YAM – Yamaha
SYM – SanYang Motor
SUZ – Suzuki
PIA- Piaggio
TOY – Toyota
OTH – Others
EFI – Electronic Fuel Injection

Table 4. Estimation results for the mode and brand choices model

Variables	MNL		NL1		NL 2	
	Coef.	t-Stat	Coef.	t-Stat	Coef.	t-Stat
Alternative-specific constants						
Motorcycle - Honda (base)						
Motorcycle - Yamaha	-1.419	-11.83	-0.553	-2.25	-0.300	-3.49
Motorcycle - SYM	-1.686	-9.06	-0.667	-2.26	-0.364	-3.43
Motorcycle - Suzuki	-4.536	-14.17	-1.776	-2.31	-0.964	-3.61
Motorcycle - Piaggio	-5.929	-7.56	-2.331	-2.18	-1.268	-3.87
Car - Honda	-8.029	-16.42	-8.205	-15.25	-2.361	-2.20
Car - Toyota	-7.481	-15.62	-7.658	-14.61	-4.404	-7.45
Car - Other	-8.317	-16.77	-8.493	-15.61	-1.287	-2.06
Bus	-1.082	-2.99	-1.282	-3.54	-1.342	-3.73
Alternative-specific variables for mode choice						
Income (million VND) - Car	0.160	6.96	0.158	6.87	0.158	6.87
Income (million VND) - Bus	-0.074	-2.39	-0.074	-2.39	-0.074	-2.39
Student - Bus	2.466	12.15	2.453	12.20	2.449	12.37
Age - Car	0.081	10.12	0.081	10.12	0.081	10.12
Age - Bus	-0.035	-3.50	-0.035	-5.00	-0.035	-3.89
Trip purpose: go to work - Car	-0.483	-2.46	-0.483	-2.48	-0.484	-2.48
Distance to work - Car	0.049	3.77	0.047	3.92	0.047	3.92
Male - Bus	-0.659	-3.56	-0.665	-3.67	-0.667	-3.69
Alternative-specific variables for brand choice						
Male: Motorcycle - Yamaha	0.388	3.01	0.154	1.83	0.084	2.40
Male: Motorcycle - SYM	-0.935	-4.39	-0.366	-2.08	-0.199	-2.76
Male: Motorcycle - Piaggio	-1.177	-2.18	-0.462	-1.90	-0.251	-1.81
Government employee: Motorcycle - Yamaha	-0.277	-2.25	-0.120	-2.50	-0.067	-2.16
Bachelor degree or higher: Motorcycle - Piaggio	1.470	2.27	0.583	2.40	0.318	1.90
Distance to work: Motorcycle - SYM	-0.039	-2.17	-0.015	-2.14	-0.008	-2.00
Distance to work: Motorcycle - Suzuki	0.087	4.58	0.034	2.12	0.018	3.00
Trip purpose: go to work: Motorcycle - Piaggio	1.542	2.07	0.596	2.12	0.322	2.22
Cost variables						
Monthly parking fee (million VND): Motorcycle - Car	-0.782	-3.69	-0.783	-3.68	-0.783	-3.73
Monthly travel cost (million VND) - Motor-Car-Bus	-1.557	-5.48	-1.554	-5.35	-1.555	-5.55
Logsum parameter						
Motorcycle nest			0.393	2.31	0.214	3.69
Car nest					3.730	4.41
Goodness of fit						
Number of estimated parameters	26		27		28	
Sample size	2042		2042		2042	
Initial log-likelihood	-4486.73		-4486.73		-4486.73	
Log-likelihood at convergence	-2430.72		-2430.66		-2430.65	
Adjusted rho squared	0.452		0.452		0.452	
AIC	4913.44		4915.32		4917.30	
Chi-squared test versus MNL	-		0.12		NA	
P value at 0.05 significant level	-		0.9438		NA	

Note: NL1 - Nested within motorcycle brands
NL2 - Nested within motorcycle brands and car brands
As of December 2014, 1 million VND is approximately 46 USD

4.2. Estimation results of mode/brand choices

Table 4 presents the estimation results of mode/brand choices for the MNL and NL. The NL model includes two model. The NL1 represents a correlation among the motorcycle brand choice and the NL2 takes into account the correlation for both motorcycle and car brand choices. Although the logsum parameter for motorcycle nest shows that there is a correlation within the brand choice of motorcycle, the logsum parameter for car brand choice in the NL2 felt out of the range 0-1. In addition, the indicators (log-likelihood at convergence, adjusted rho squared) are almost identical among the models. It implies that considering nested logit model cannot improve model performance. More importantly, based on the chi-squared test, the NL1 cannot statistically reject the MNL. Therefore, the following discussion and policy analysis are dependent on the results of MNL.

4.2.1. Constants

With the base of Honda motorcycle, all of the significantly negative constants indicate that the mode choice of the Honda motorcycle is dominant over other choices. In addition, magnitudes of constants indicate that they show a similar proportion to the dataset.

4.2.2. Alternative-specific variables for mode choice

With respect to the explanatory variable, the income is associated with a positive relationship with car mode and an opposite relationship with bus mode. This finding is compared well with the previous studies such as those of Goodwin et al., 2004; Vasconcellos, 2005; Pucher and Renne, 2005; Hensher and Rose, 2007. A very similar tendency is found for the respondents' age. When their ages increase, they have more likelihood of using the car and, however, their probability of selecting the bus is reduced. In the literature, there seems to exist a disagreement of the effects of age on the mode choice. De Witte et al. (2013) pointed out that some studies stated the positive relationship between the ages and the car mode. This is consistent with our current study. On the other hand, other studies (Bhat, 1998; Cirillo and Axhausen, 2006) found that people tend to use public transport more frequently when they get older and this conclusion is not parallel to our finding. A reason that our finding differs from the literature must be due to the positive relationship between the ages and the car mode as earlier discussed, thus reducing the usage of the bus in older age group. In addition, the younger people may be usually correlated with a group of lower income and student and this group shows to prefer bus mode as indicated in Table 4. Another assumption for the less tendency of selecting bus mode within the older ages may come from the poor service of the bus in HCMC, which is not appropriate for use of the older people. However, this assumption may need to further verify since our data are limited to determine this fact.

Regarding trip purpose, our result seems to indicate that people going to work are less likely to choose the car. However, the significant level of this variable is only 0.1. As for the variable of the distance of the one-way trip, it is connected to the positive relationship with car mode. It means that people are likely to use the car for the longer distances. A fact is that the car is the safe, fast, and comfortable for such long distances. In developed countries, as the distance is longer than 30km, the train is the more likely choice for commuting from home to work (De Witte et al., 2008). However, as far as the urban railway in HCMC is not yet available, the car choice for the distances longer than 30km is understandable. As for effects of gender on the mode choice, our finding is similar to the literature (e.g. Bhat, 1998; Limtanakool, et al., 2006) that males are less dependent upon the bus.

4.2.3. Alternative-specific variables for brand choice

As indicated in Table 4, males are more likely to choose the Yamaha motorcycle. It must be due to the sporty design of this brand and it is suitable for males. By contrast, the signs of the male variable for the SYM and Piaggio brands are both negative, implying that females are more likely to select those brands. The possible reason this selection may come from the womanly style of both of those brands. The higher education level and working trip purpose significantly determine the choice of Piaggio motorcycle. The reason behind this is that Piaggio is a deluxe Italian brand, and it may be suitable for working trip. Regarding trip distance, it is found that people tend to select the Suzuki motorcycle for the longer trip while they use the SYM motorcycle for the shorter one.

4.2.4. Cost variables

Both of the cost variables, the monthly parking fee, and travel cost, are negative as expected. It implies that the increment of these fees is a burden for the users, making the utility of a mode and the probability that it will be chosen decreases.

Table 5. *Estimation results for the private mode usage*

Variables	Para.	t-Sta.	VIF
Constant	8.993	229.17	-
ln(income, in million VND), for motorcycle	-0.029	-2.25	2.130
ln(income, in million VND), for car	0.167	11.60	2.109
Age, dummy: less than 60	0.055	1.68	1.051
Employee, dummy	0.068	3.83	1.194
Household size, dummy: 4 members or more	0.025	1.99	1.025
Distance of one way trip, dummy: 10 km or more	0.030	2.35	1.019
Never used bus, dummy	0.025	1.98	1.024
Age of mode	-0.004	-2.03	1.021
Not comply, dummy: modes with none emission standard	-0.028	-2.12	1.058
ln(parking fee, in million VND)	-0.002	-2.31	1.025
ln(monthly travel cost, in million VND), for car	-0.049	-1.79	1.036
R-squared		0.171	
Adjusted R-squared		0.167	
Sample size		1868	

Note: As of December 2014, 1 million VND is approximately 46 USD
. .. . VIF represents variance inflation factor

4.3. Estimation results of usages of private modes

In order to estimate the usage of motorcycle and car for integrated model as shown in Figure 1, the usage model for the private modes is displayed in Table 5. Noteworthy, variance inflation factors – VFI, which quantifies the severity of multicollinearity, was calculated. All of the VFI values are below 5, indicating the low multicollinearity. The effects of explanatory variables are discussed as follows. The variable *ln*(income) has a negative sign for motorcycle users but a positive sign for car users, meaning that as income increases, the motorcycle users drive less while the cars users drive more per year. Our results are very similar to the findings of Chou et al. (2009). Moreover, Wen et al. (2012) also found that the income negatively influences the usage of the motorcycle. They explained the reason that the motorcycle is inferior goods and the preference of high-income group for car usage is over motorcycle usage. Table 5 also implies that the young people (under 60 years old) have the positive relationship with the usage, meaning that the young people drive more intensively than the older ones. Our result is in good agreement with the finding in Lai and Lu (2007); Chiou et al. (2009). Similarly, the employees or people living in a big family (4 members or more) tend to be associated with the higher annual kilometer traveled. It is logical since the employees need to travel more compared to other groups, e.g. students and housewife.

With respect to household size, our finding confirms the result in Wen, et al. (2012) that the bigger family is positively connected to the usage. In addition, it is obvious that the people with one-way distance trip of 10 km or more are correlated to the higher usage. Importantly, the people, who have never used the bus in their life, significantly increase their usage. It suggests that, if the public transportation is more attractive to reduce the dependence of people on the private modes, their usage may be declined. Thus, the impacts of the private modes on emission can be minimized. It is also noteworthy that the modes without complying with any emission standard show to be driven less intensively. Regarding the age of modes, our result gets along well with the previous studies (Chiou, et al., 2009; Wen, et al., 2012). That is, this variable has a negative relationship with the annual usage, suggesting that the older motorcycles and cars are driven less than the newer ones. The coefficients of monthly parking fee and travel are all negative, indicating that the higher usage cost of the private modes decreases usage intensity. It is noted that the monthly travel cost only significantly affected the car usage. A reason for the insignificant impact of monthly travel cost on motorcycle usage is that the motorcycle users are less sensitive to the travel cost on their usage than the car users.

Table 6. Changes in mode choice and annual usage under analyzing assumption

Scenarios	**Base**	**Income**		**Monthly parking fee**		**Monthly travel cost**	
		10%	**30%**	**10%**	**30%**	**10%**	**30%**
Mode choice		Percentage changes compared to the base case (%)					
Motorcycle	84.378	-0.539	-1.812	-0.049	-0.098	-0.392	-1.322
Car	6.954	0.735	2.498	-0.049	-0.098	-0.098	-0.147
Bus	8.668	-0.196	-0.686	0.098	0.196	0.490	1.469
Annual usage[1)]		Percentage changes compared to the base case (%)					
Motorcycle	8962.198	-0.276	-0.759	-0.014	-0.040	0.000	0.000
Car	13293.370	1.607	4.487	-0.014	-0.040	-0.462	-1.267

[1)] Estimated from parameters shown in table 5 and collected data using simulation run in R programming

Table 7. Changes in daily usage and start-up of the whole fleets under analyzing scenarios

Scenarios	**Base**	**Income**		**Monthly parking fee**		**Monthly travel cost**	
		10%	**30%**	**10%**	**30%**	**10%**	**30%**
Number of motorcycle and car fleets in HCMC							
Motorcycle	6,938,906	6,901,505	6,813,173	6,935,506	6,932,106	6,911,705	6,847,174
Car	585,980	590,287	600,618	585,693	585,406	585,406	585,119
Annual usage							
Motorcycle	8,962.198	8,937.439	8,894.209	8,960.901	8,958.629	8,962.198	8,962.198
Car	13,293.370	13,507.040	13,889.860	13,291.450	13,288.080	13,231.950	13,124.980
Daily usage of fleets (10^6 km)[2)]							
Motorcycle	172.744	171.338	168.327	172.634	172.506	172.067	170.460
Car	21.638	22.147	23.174	21.624	21.608	21.517	21.332
Daily start-up of fleets (10^6 starts)							
Motorcycle	32.960	32.782	32.363	32.944	32.928	32.831	32.524
Car	2.520	2.538	2.583	2.518	2.517	2.517	2.516

[2)] Daily usage = (annual usage/365)*(number of motorcycle/car)

5. POLICY ANALYSES

5.1. Base scenario

As shown in Table 6, the share of mode choice for the base case, which was estimated from the mode choice model, is 84.38% (motorcycle), 6.94% (car), and 8.67% (bus). The share is negligibly different from the original share presented earlier. According to HCMC department of transportation (HCMDOT, 2015), the registered motorcycles and cars in 2014 were 6,938,906 and 585,980. Moreover, from the usage model, the annual usages of motorcycles and cars are estimated as 8,962.20 and 13,293.37 km, respectively. The daily usages of the whole fleets of motorcycles and cars are then calculated as 172.74 (10^6 km/day) and 21.64 (10^6 km/day). It is noted that the IVE's output consists of running and start-up emissions. The running emission is mostly dependent on the usage, driving condition, engine size, fuel delivery technology, etc. Whereas, the start-up emission depends on the daily start-ups, and engine soak time (how long the engine has been turned off). Chu et al., (2015) has shown that the daily start-ups for motorcycles and cars in HCMC are 4.75 (times) and 4.30 (times). It means that the daily start-ups for the whole fleets of motorcycles and cars are 32.96 (10^6 times/day) and 2.52 (10^6 times/day). The daily usage, start-up, and other related data from Chu et al. (2015) are used to estimate emissions of the base scenario, which include start-up and running emission, as shown in Table 8.

Table 8. Emissions reduced under analytical scenarios

Emissions	**Scenarios**	**Base**	**Income**		**Monthly parking fee**		**Monthly travel cost**	
			10%	**30%**	**10%**	**30%**	**10%**	**30%**
Motorcycle		2014 emissions	Emission changes in comparison with the base scenario					
Start-up	CO	193,424.724	-1,042.559	-3,504.856	-94.778	-189.556	-758.225	-2,557.075
	NO_x	10,776.320	-58.084	-195.267	-5.280	-10.561	-42.243	-142.463
	CO_2	67,772.216	-365.292	-1,228.033	-33.208	-66.417	-265.667	-895.949
	CH_4	8,004.322	-43.143	-145.038	-3.922	-7.844	-31.377	-105.817
Running	CO	1,688,868.972	-13,743.531	-43,182.243	-1,071.837	-2,326.988	-6,620.366	-22,326.848
	NO_x	40,956.681	-333.294	-1,047.211	-25.993	-56.432	-160.550	-541.447
	CO_2	14,979,845.518	-121,901.685	-383,015.703	-9,506.930	-20,639.799	-58,720.994	-198,033.558
	CH_4	104,255.550	-848.402	-2,665.683	-66.166	-143.647	-408.682	-1,378.258
Total (motorcycle)	CO	*1,882,293.696*	*-14,786.090*	*-46,687.099*	*-1,166.616*	*-2,516.544*	*-7,378.591*	*-24,883.923*
	NO_x	*51,733.000*	*-391.378*	*-1,242.477*	*-31.273*	*-66.992*	*-202.793*	*-683.910*
	CO_2	*15,047,617.734*	*-122,266.978*	*-384,243.735*	*-9,540.138*	*-20,706.216*	*-58,986.662*	*-198,929.506*
	CH_4	*112,259.872*	*-891.545*	*-2,810.721*	*-70.088*	*-151.491*	*-440.059*	*-1,484.076*
Car		2014 emissions	Emission changes in comparison with the base scenario					
Start-up	CO	7,568.123	55.626	189.052	-3.708	-7.417	-7.417	-11.125
	NO_x	471.149	3.463	11.769	-0.231	-0.462	-0.462	-0.693
	CO_2	20,946.399	153.956	523.241	-10.264	-20.527	-20.527	-30.791
	CH_4	113.150	0.832	2.826	-0.055	-0.111	-0.111	-0.166
Running	CO	284,850.500	6,705.827	20,216.445	-180.698	-392.397	-1,593.972	-4,021.689
	NO_x	27,917.788	657.228	1,981.385	-17.710	-38.458	-156.223	-394.160
	CO_2	6,165,465.960	145,144.722	437,576.214	-3,911.138	-8,493.255	-34,500.840	-87,047.723
	CH_4	5,877.849	138.374	417.163	-3.729	-8.097	-32.891	-82.987
Total (car)	CO	*292,418.623*	*6,761.452*	*20,405.497*	*-184.407*	*-399.813*	*-1,601.389*	*-4,032.814*
	NO_x	*28,388.937*	*660.691*	*1,993.154*	*-17.941*	*-38.920*	*-156.685*	*-394.853*
	CO_2	*6,186,412.359*	*145,298.678*	*438,099.455*	*-3,921.402*	*-8,513.782*	*-34,521.368*	*-87,078.514*
	CH_4	*5,991.000*	*139.205*	*419.990*	*-3.784*	*-8.208*	*-33.002*	*-83.153*

5.2. Effects of income increment

As we have mentioned in the introduction, the increment of income may encourage the motorcycle users to shift to cars. In this section, we quantitatively examine the changes by assuming the increment of income as 10% and 30%. Table 6 shows that when income increase by 10% and 30%, the motorcycles reduce approximately 0.54% and 1.81%. On the other hand, the cars increase about 0.74% and 2.50%. Accordingly, as detailed in Table 7, the changes of daily usage and start-ups were calculated and later used in the IVE model. It is noteworthy that, the outputs of the IVE model consist of 14 types of emissions. However, our paper selected 4 typical emissions for the demonstration of policy analysis. They include carbon monoxide (CO), nitrogen oxides (NO_x), carbon dioxide (CO_2), and methane (CH_4). The emission changes due to increment of income in comparison to the base scenario are displayed in Table 8. As seen in the table, with the increment of the income, the emissions from the motorcycle fleets are reduced, however, that from the car fleets are increased. In order to address a total impact, the emissions produced from both motorcycle and car fleets are summed up and compared in Figure 2. The figure demonstrates that the increment of the income leads to cut down CO and CH_4. On the other hand, it leads to step-up NO_x and CO_2. In addition, CO and CO_2 are associated with significant changes. This result implies that shifting from the motorcycles to cars is not always be negative from CO perspective. A possible reason, as stated in Chiou, et al., (2009), is because the motorcycles generally produce larger CO than the cars. By contrast, shifting from the motorcycles to cars is correlated to more serious problems since CO_2 is the biggest contribution with respect to the global warming and climate change. Figure 2 indicates that by increasing income 10% and 30%, the private modes in HCMC produce more approximately 23ton and 54ton CO_2 per day in comparison to the base scenarios. Therefore, in the near future, if the people in HCMC will earn more income, they would shift from using public transport to the motorcycles or from the motorcycles to the cars. This would cause more negative impacts on global warming and climate change.

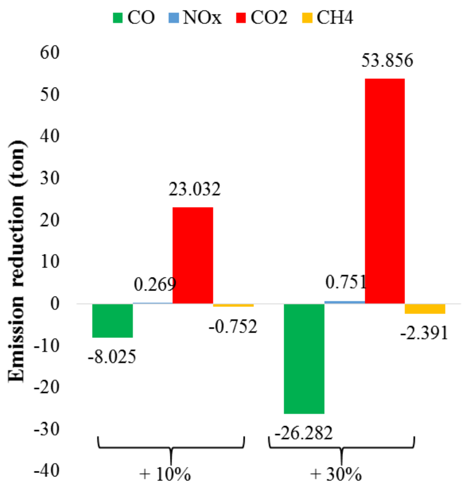
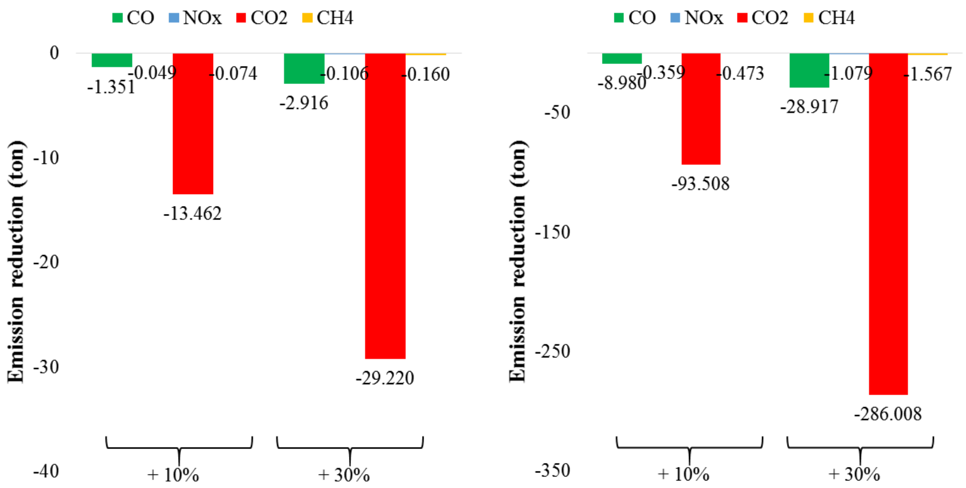


Figure 2. Comparison of emission changes due to increment of income

5.3. Parking fee or travel cost increments

As above discussion indicated, the growth of economy represented by income leads to a shift from public transport to private modes and from motorcycles to cars, which result in increment of CO_2 emissions. In this section, the policies including parking fee and travel cost increments of 10% and 30% are tested. Table 6 indicates that the increments of monthly parking fee or travel cost could shift both motorcycles and cars to bus. In addition, increasing parking fee or travel cost could be able to reduce the usages. Noteworthy however that, as discussed earlier, the travel cost variable was not significant for the usages of motorcycles, it does not have any impact on reducing the motorcycle usages when the travel cost is increased. Based on Table 6, the daily usage and start-up are estimated for inputting in the IVE model as shown in Table 7. Table 8 shows the changes of emissions in comparison to the base scenario. Generally speaking, increasing parking fee and travel cost can reduce the emission, however, the reduction amount of CO, NO_x and CH_4 are almost negligible in comparison to CO_2, as shown in Figure 3. Furthermore, comparing Figure 3 a) and b) indicates that increasing monthly travel cost lead to more remarkable reduction of emission than the monthly parking fee. It would be reminded here that some private mode users do not have to pay the parking fee due to the free parking lot in their work places. Therefore, in order to make more effective policy, it may be needed to impose the parking fee on every parking lot.



a) increment of monthly parking fee b) increment of monthly travel cost

Figure 3. Comparison of emission changes due to increment of parking fee and travel cost

6. CONCLUSIONS AND SUGGESTIONS

This paper presents an integrated analytical framework to demonstrate policy analyses with respect to emission reduction from various perspectives. The integrated framework contains a MNL model for mode/brand choice, a linear model for usage and an IVE model for emission estimation.

With respect to the mode/brand choice model, the results indicate that earning higher income motivates users to select cars, however, the low-income group tends to use buses. It is concluded that the young people prefer buses and as they get older, they tend to use cars. This finding is somewhat contrasted with some studies in developed countries where people tend to use public transport when they become older. A possible reason for this discrepancy may come from a poor service of buses in HCMC, which is not always suitable for old people. As far as the subway and urban train system is being constructed, public transport in HCMC is heavily relied only on bus system, our results indicate that people tend to use cars for the long distances, even more than 30km. This differs from developed countries that the trips longer than 30km are usually made by train. It is also confirmed the literature that males are more dependent on the private modes than females, who more prefer buses. As for usage model, the income has different effects on the usages of motorcycles and cars. The motorcycle users tend to drive less while the car users tend to drive more as income increases. Interestingly, we found that the people, who has never used buses, have a tendency of increasing usages of private modes. Thus, making the public transport more attractive to increase frequency of using public transport can reduce dependency of users on private mode and their usages.

In this paper, the scenarios of 10% and 30% increases of income, parking fee and travel cost are analyzed. Four typical emissions including CO, NO_x, CO_2, and CH_4 produced from the IVE model are selected for the analysis. Our results show that the changes of NO_x and CH_4 produced from the whole fleets of motorcycles and cars are not significant in comparison to CO and CO_2. The CO tends to reduce when income increases due to the fact that the motorcycles exhaust more CO than the cars. However, the CO_2 of the whole fleet increases quickly as income increases. Since CO_2 is the main cause of global warming and climate change problems, it is needed to control the CO_2 by management strategies.

The management strategies demonstrated in this work include increasing the monthly parking fee and monthly travel cost. Generally, increasing the monthly parking fee and monthly travel cost can reduce the emissions. And among four selected emissions, reduction amount of CO, NO_x and CH_4 are almost negligible compared to CO_2. In addition, between the two policies, the parking fee increment is less effective than the travel cost increment. A fact is that many motorcycle users do not need to pay monthly parking fee since the motorcycles are flexible and the users can park at home or in the parking lots which are freely provided by work places such as school/company. Thus, it is suggested to impose a fee on parking lots in the work places. It may lead to a more powerful policy in reducing the dependences of users on the private modes, especially the motorcycles. With respect to monthly travel cost, the most significant factor that influences on it is gasoline price. This suggests that levying a higher tax on gasoline is more affective policy to increase a shifting rate from the motorcycles and cars to public transport. However, it is noteworthy that up to date, the public transport in HCMC only relies on the bus system since subway and urban train systems are under developments. Furthermore, due to a poor service and limited capacity of bus system, it is not strongly expected that implementing the policies, *i.e.* increments of parking fee and travel cost can lead to the significant shifting rate from the private modes to public transport. Therefore, in order to achieve a more significant shifting rate and emission reduction, it is necessary to implement the policies analyzed in this work together with improvements of bus service and developments of subway/urban railway system.

Although the results of modeling and policy in this paper are promising, some limitations still remain. Firstly, very small proportion of car and bus users in the dataset may lead to inaccuracy in performance evaluation of policy analysis. Therefore, future work needs to collect more data of this group to verify our results. Secondly, even we tried to analyze the brand choice, it was unable to take into account the effect of this choice on emissions. In the future, the detail data related to emission factor for each brand of motorcycle and car should be collected to investigate the effect of brand choice on emissions. Lastly, it may be interested to build only the mode choice model and a comparison between the model estimated in this work and the mode choice model can be made.

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