An exploration of vehicle ownership and mode choice behaviour in a mid-sized Asian city: a case study in Khon Kaen City, Thailand

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ABSTRACT

Wholesale use of motorcycles is commonly found in most cities in Southeast Asia. It causes many serious transport issues when viewed in terms of sustainable transport and road safety perspectives. The importance attached to this concern is reflected by the increase of reported studies year by year. However, most previous studies have only considered the Asian megacities. This paper provides a preliminary analysis of the nature of mode choice and vehicle ownership in these mid-sized cities, using Khon Kaen City, Thailand, as the principal study area. Potentially important factors are examined using an econometric method based on the Khon Kaen Daily Travel Survey 2007 (KKDTS07) database. Regarding the models estimated in the study, several household and socio-demographic characteristics and trip characteristics were found to influence travel demand in the study area. Trade-off between private cars and motorcycles is also captured in both vehicle ownership and mode choice models. It is also found that, in the study area, predictions of travel demand associated with cars seem to be much less complicated and more likely to provide a reliable outcome than those related to motorcycles.

KEYWORDS

Travel demand; Southeast Asia; Medium-sized urban area; Motorcycle ownership; Mode choice

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1. INTRODUCTION

Wholesale use of motorcycles is commonly found in most cities in Southeast Asia. Several studies have suggested that the special characteristics of the motorcycle provide many benefits to the owner, but this mode also causes many serious transport issues when viewed in terms of sustainable transport and road safety perspectives. The importance attached to this concern is reflected by the increase of reported studies year by year. However, most previous studies have only considered the Asian megacities. In fact, a majority of the urban population in Southeast Asia lives in mid-sized cities (population of between 50k and 500k). Additionally, there are many differences between the mid-sized cities and the megacities, which could contribute to different behaviours and lifestyles of their respective inhabitants. Thus the policies and development techniques suggested by most of the previous studies perhaps do not fit to the mid-sized cities and their populations.

This paper provides a preliminary analysis of the nature of mode choice and vehicle ownership in these mid-sized cities, using Khon Kaen City, Thailand, as the principal study area. Potentially important factors are examined using an econometric method based on the Khon Kaen Daily Travel Survey 2007 (KKDTS07) database. The findings of this paper are intended to initiate a more advanced study to define potentials of introducing more sustainable transport systems into mid-sized cities in Thailand and perhaps Southeast Asia in the future. The rest of this paper is organized as follows. Section 2 reviews previous studies on travel demand under motorcycle dominant environments in Southeast Asia. Section 3 presents the methodology including mathematical derivation and model specification. Section 4 introduces the KKDTS07 database. This section includes general statistical analysis and discussion on the information extracted from the database. Model estimation results and findings interpretation are then presented in Section 5. Final discussion, conclusions and recommendations leading to further work are provided in the last section.

2. PREVIOUS STUDIES

In the last decade, the number of studies on travel demand in Southeast Asia has increased markedly. Most of them have attempted to investigate the correlation between potential contributing factors (e.g. socio-demographic characteristics of traveller, land-use and traffic environment of the study area) and the travel demand and behaviour. Two essential aspects to be investigated in this field are vehicle ownership and mode choice behaviour, and both aspects are found to be strongly interrelated.

In terms of vehicle ownership, there have been many studies on the ownership conducted in western countries in previous decades. However, vehicle ownership in Southeast Asia is unique because, as well as private cars, there is a massive number of motorcycles. Some recent studies have been undertaken to investigate car and motorcycle ownership in Asia. Tuan & Shimizu (2005) undertook a study in Hanoi City to investigate the relationship between retrospective vehicle transaction choice and the ownership behaviour in household. They suggested that household income and cost of using a motorcycle are crucial factors governing the ownership. Jaensirisak (2007) found that vehicle ownership also seemed to be influenced by occupation. Leong & MohdSadullaha (2007) investigated the behaviour of motorcycle owners in Penang. They found that a trade-off between motorcycle and car ownership is likely to occur if the household income is high enough. Senbil, Zhang & Fujiwara (2007) studied car and motorcycle ownerships in Jarkata, Kuala Lumpur and Manila. They found that the socio-demographic characteristics such as size, average age and number of workers in household affected the level of ownership; however the size of effect

varied between study areas. They also found that, in Jakarta, urban density and distance from CBD also influenced the ownership. Hsu, Tsai & Lin (2007) conducted a study to explore motorcycle ownership in Taiwan. In the same year, Lai & Lu (2007) undertook another study to understand car and motorcycle ownership in Taiwan, and also to define the correlation between the ownership and mode choice behaviour. Both studies found the same thing that the number of vehicles in household can be used to roughly indicate the household travel demand, and perhaps mode choice behaviour.

Mode choice behaviour is perhaps the most important concern in travel demand studies. It governs the demand of each alternative mode available in the market. Good understanding of mode choice behaviour can help transport planners to develop more accurate prediction tools, which provides the basis for the development of better policies, planning and infrastructure investments. Santosa & Tsunokawa (2005) undertook a study on mode choice behaviour in Ho Chi Minh City and Phnom Penh City. They found that the characteristics of mode choice in both cities were different even though the share of trips generated by motorcycles was about the same. Ibrahim et al. (2006) developed a mode choice model to forecast the mode shift between motorcycle and public transit. Among socio-demographic variables, gender and age were found to significantly influence mode choice behaviour. The model also showed that the travel time and fare of public transit (bus) were significantly associated with in mode shift of motorcyclists. Hsu, Tsai & Lin (2007) suggested that the trade-off between private vehicle (both car and motorcycle) and public transit depended on service quality of public transit, trip distance, income and age of traveller. Lai & Lu (2007) found that fuel price, age, household structure and disposable income of household were the factors affecting both car and motorcycle usage behaviour. The size of impact on motorcycle usage was however notably smaller. They also suggested that "money" (any economic and financial factors e.g. income, expense, cost of travel and fuel price) seemed to be a key factor dominating mode choice behaviour, and was therefore also an effective tool for transport planners. Kamba, Rahmet & Ismail (2007) modelled mode choice behaviour of residents in Kuala Lumpur considering household characteristics. They found that the number of vehicles in household had a strong negative relationship with public transit usage. Chang & Wu (2008) also investigated relationships between socio-demographic characteristics and motorcycle dependency. They affirmed that age, monthly income, household vehicle ownership, parking space and trip characteristics were major factors reinforcing motorcycle dependency in Taipei.

Most findings of these previous studies seem to support each other. Vehicle ownership and mode choice behaviour in most megacities are related to the advantages offered by available alternative modes, traffic conditions, trip characteristics and the socio-demographic characteristics of each traveller. Even when comparing only among those megacities, the characteristics can be quite different between study areas. In mid-sized cities where most conditions are much different, it is reasonable to believe that the findings for the megacities might not apply, although they can be used as guidelines for further study. This paper is therefore intended to start filling the gap of knowledge on travel demand in a mid-sized city in Southeast Asia.

3. METHODOLOGY

Mathematical formulation

In this section, multinomial logit choice model (MNL) is used to examine the nature of household vehicle ownership and mode choice behaviour in Khon Kaen City. MNL is basically a behavioural model purposing to simulate manner of an individual when facing a

set of alternatives. Based on the microeconomic theory of Utility Maximisation, an individual would always select the alternative which provides him/her the greatest profit (usually called Utility, 'U'). In mathematical form, an individual would choose alternative 'i' in choice set 'C' if:

$$U_i > U_j, \forall j \in C, j \neq i \quad (1)$$

U_i is dominated by several factors, such as features of alternative 'i' relative to other alternatives in choice set and characteristics of that individual. These factors are usually called Attributes. To accommodate relationship between U_i and its attributes to a matter of mathematical computation, linear regression model is commonly used. In practical, many attributes behave randomly and/or unobservable, U_i is therefore split into two major components: deterministic component 'V_i' and unobserved component 'ε_i'; as follow:

$$U_i = V_i + \varepsilon_i \quad (2)$$

Combining equation (1) and (2), the mathematical form of Utility Maximisation will be:

$$V_i + \varepsilon_i > V_j + \varepsilon_j, \forall j \in C, j \neq i \quad (3)$$

U_i contains ε_i, thus cannot be determined straightforwardly. Probability Theory is then adopted to yield the problem. The probability for an individual choosing alternative 'i' in choice set C can be formulated as:

$$\begin{aligned} P(i) &= Pr(V_i + \varepsilon_i > V_j + \varepsilon_j, \forall j \in C, j \neq i) \\ &= Pr(V_i - V_j \geq \varepsilon_j - \varepsilon_i, \forall j \in C, j \neq i) \end{aligned} \quad (4)$$

Assume the unobserved component is independently and identically distributed (IID), called property of Gumbel Distribution, MNL model can be derived as:

$$P(i) = \frac{e^{V_i}}{\sum_{\forall j \in C} e^{V_j}} \quad (5)$$

Model specification

In this paper, two models are built up: (1) a model of household vehicle ownership and (2) a model of mode choice behaviour. It is noted that 'vehicle' in this paper means both cars and motorcycles.

The household vehicle ownership model is separated into two sub-models, i.e. a car ownership model and a motorcycle ownership model. The specifications of both models are similar. For brevity, only the specification process of car ownership model is presented as here. Initially, the stage of household car ownership is classified into three levels: low (no car in the household), intermediate (single car in the household), and high (multiple cars in the household). The deterministic component of the utility of each car ownership level is a function of household characteristics. Several models with different specifications are estimated. Those are validated using indices of model efficiency, such as rho-square, AIC,

total numbers of parameters in the model and number of parameters with statistically significant at the 0.05 level, market share prediction using cross-tab matrix and elasticity analysis. Each model specification is also estimated using half and full dataset and then compared together as another validation approach. The best model is selected to represent the nature of household car ownership in this paper.

For the model of mode choice, three alternatives (car, motorcycle and public transit) are specified. Public transit is set as the base alternative. While the main mode other than car, motorcycle and public transit in the study area is walking, this is not taken into account. That is because walking is only capable of serving short distance trips which are not the consideration of this study – according to the database (more details will be mentioned in Section 4), average walking distance in the study area is 635 metres with the 85th percentile of 1,000 metres. The deterministic component of the utility of each alternative is a function of socio-demographic characteristics of the individual, their household, and the trip characteristics. Several models with different specifications are estimated and validated, and the best model is selected using a similar basis to the model of household vehicle ownership.

4. DATASET AND SAMPLE DESCRIPTION

The dataset used for analysis and model estimation in this paper is extracted from the Khon Kaen Daily Household Travel Survey 2007 (KKDTS07). A very detailed description of the survey and the survey sample is reviewed in SIRDC (2008). Only a very brief description of the survey sample is provided in this paper. The survey took a sample of 873 households with 2,484 respondents and 5,833 weekday-trips recorded in metropolitan area of Khon Kaen city (approximately 0.75 per cent of population). Regarding the database, the household characteristics are presented in Table 1 while the individual and trip characteristics are presented in Table 2. In both tables, three information blocks are presented. The left block contains the information obtained across the database. The other two blocks point up the information segmented by inside and outside the CBD area. The two additional blocks are aimed to observe the effect of land-use and traffic conditions in mid-sized city.

From Table 1, the overall average household size is 3.42, while inside the CBD area it is 3.59 and outside it is 3.28. The proportion of households with one, two and three members outside the CBD area is higher but the proportion of household with four members and larger is lower than the inside. This phenomenon can be explained that a household inside the CBD area is more likely to be an older family (established and living in there for long time). New families, such as singles and young couples, may not be able to afford accommodation inside the CBD area. Additionally, there have been many real estate development projects recently established surrounding the CBD area. In addition, Khon Kaen is not a large city, and travelling from outside areas to the CBD using private vehicle is not difficult or hugely time consuming. Brand new housing with reasonable prices could lead new families to locate outside the CBD area.

As expected, average income of households inside the CBD area is approximately 33 per cent higher than the outside. Proportions of households with medium and high income inside the CBD area are found to be higher. It is however noted that the average size of households inside the CBD area is also larger. To take account of the size, the average income per member is estimated. The average income per member inside the CBD area remains 20 per cent higher. This indicates that residents inside the CBD area are likely to be richer and more affluent than people outside the CBD area.

Table 1 Household characteristics of KKDTS07 database

Characteristics	Whole database	In CBD	Out CBD
Sample size	**873**	**388**	**485**
Household size			
Average	3.42	3.59	3.28
1 member	9.0%	7.7%	10.1%
2 members	18.7%	16.8%	20.2%
3 members	26.6%	25.8%	27.2%
4 members	26.7%	27.6%	26.0%
5 members or more	19.0%	22.2%	16.5%
Monthly income			
Average household income (THB)	25,416	29,450	22,189
Low (less than THB 10K)	18.7%	11.9%	24.1%
Medium (THB 10K ~ THB 50K)	71.1%	73.7%	69.1%
High (more than THB 50K)	10.2%	14.4%	6.8%
Average income per member (THB)	7,428	8,197	6,755
Car ownership			
Average household car ownership	0.81	0.81	0.81
0 car	38.6%	43.0%	35.1%
1 cars	47.4%	41.8%	52.0%
2 cars or more	14.0%	15.2%	13.0%
Average cars per member	0.237	0.225	0.247
Motorcycle ownership			
Average household motorcycle ownership	1.38	1.46	1.32
0 motorcycle	12.6%	10.8%	14.0%
1 motorcycle	50.2%	49.7%	50.5%
2 motorcycles or more	37.2%	39.4%	35.5%
Average motorcycles per member	0.404	0.407	0.402
Presence of workers			
Average	2.11	2.16	2.08
0 worker	2.6%	4.4%	1.2%
1 worker	22.0%	18.8%	24.5%
2 workers or more	75.4%	76.8%	74.2%
Presence of children			
Child < 6 years old	17.0%	19.1%	15.3%
Household location			
in CBD	44.6%	-	-
out CBD	55.4%	-	-

In the study area, about 64 per cent of households own at least one car. The average number of cars per household inside and outside the CBD area is the same, at 0.81 cars/hhld. After taking account of household size, the average number of cars per household member outside the CBD area is approximately ten per cent higher than the inside. This is an important finding. The average car ownership per member outside the CBD area is ten per cent higher than the inside although the average income per member inside the CBD area is about 20 per cent higher. Income may not be only factor dominating the number of cars in the household. More importantly, in a mid-sized city where the land-use is not so dense and traffic conditions inside the CBD are not very poor, land-use and traffic conditions still influence the number of cars in household apparently.

For household motorcycle ownership, the characteristics are quite different. Across the study area, about 87 per cent of households own at least one motorcycle. The average number of motorcycles per household inside the CBD area is about 11 per cent higher than the outside. After taking account of household size, the average motorcycle ownership per member is found to be consistent across the study area (0.4 motorcycles per member). This implies that in whichever inside or outside the CBD area, the needs for motorcycle are basically equal.

For the number of workers in household, on average the households inside the CBD area have more workers, but the discrepancy is tiny. The distribution shows that the majority of households consist of two workers or more. Proportion of single-worker households outside the CBD area is higher. This finding agrees with earlier discussion regarding household size and income. A household with smaller size is more likely to have less workers and result lower average income. Households with no workers are found to be special cases as retired couples and students living alone.

Table 2 Individual and trip characteristics of KKDTS07 database

Characteristics	Whole database	In CBD	Out CBD
Sample size (persons)	**2117**	**1018**	**1099**
Age			
Average	39.33	39.26	39.39
Young (15-24 years old)	15.3%	15.8%	14.7%
Middle (25-60 years old)	77.5%	76.0%	78.9%
Old (61-70 years old)	7.2%	8.2%	6.4%
Gender			
Male	47.5%	48.5%	46.6%
Female	52.5%	51.5%	53.4%
Main occupation			
Work (as employee + business owner)	73.6%	73.7%	73.6%
Study	10.0%	11.5%	8.6%
Other	16.3%	14.8%	17.7%
Monthly income			
Average (THB)	10,784	11,339	10,270
Low (less than THB 6K)	32.8%	29.3%	36.0%
Medium (THB 6K ~ THB 30K)	61.9%	65.8%	58.3%
High (more than THB 30K)	5.3%	4.9%	5.6%
Driving license (car and/or motorcycle)	62.4%	66.3%	58.8%
#Trips/day			
Average	2.42	2.35	2.48
0 trip/day	12.0%	12.1%	12.0%
1-2 trips/day	56.0%	58.9%	53.3%
3-4 trips/day	26.5%	24.1%	28.8%
>4 trips/day	5.4%	4.9%	5.9%
#Trips by purpose			
Work trips	32.0%	26.5%	36.5%
Business trips	8.7%	12.4%	5.7%
Education trips	15.4%	18.1%	13.1%
Other trips	44.0%	43.0%	44.7%
#Mode share			
Car	33.3%	28.2%	37.6%
Motorcycle	45.4%	49.0%	42.3%
Public transit	7.5%	7.9%	7.1%
Other	13.9%	14.9%	13.0%

Note: Respondents with age under 15 years old and elderly over 70 years old are not taken into account.

Regarding Table 2, it is important to note that the information contained in the table is not obtained from whole respondents involved the survey. Rather, only information from respondents in the age range 15-70 years is selected. This is because the table only considers respondents who can possibly impact travel demand in the study area by self trip-generating. The average age of respondents from inside and outside the CBD area are approximately equal (39.3 years old). The distributions of respondents' age in both segments are roughly similar. Additionally, the proportions between genders in both segments are consistent (male is slightly lower than female). The majority of respondents are workers (including employees

and business owners). The proportions of workers inside and outside the CBD area are identical. However the proportion of students inside the CBD area seems to be slightly higher.

In agreement with Table 1, the average personal income of the respondents inside the CBD is higher than the outside by about ten per cent. Outside the CBD area, obviously, the proportion of low income respondents is higher and the proportion of medium income respondents is lower. On the other hand, the proportions of high income respondents inside and outside the CBD area are not so different. It is important to note that the average personal income in Table 2 is different from the average household income per member presented in Table 1. That is because the calculation of average income in Table 2 does not include respondents with ages less than 15 or over 70 years old, but the calculation in Table 1 does.

For driving licence holding, about 62 per cent of respondents in the study hold driving licence – car and/or motorcycle. The proportion of respondents holding driving licences inside the CBD area is apparently higher than the outside. This might be because police and regulations applied inside the CBD area are stricter. Unfortunately, the information regarding driving licence in the database does not consider car separately from motorcycle. The information therefore does not imply much significance.

The average number of trips per person per day across the samples is 2.42. The average number of trips per person per day outside the CBD area is slightly higher than the inside. It is possible that travelling outside the CBD area is commonly more relaxed – less traffic congestion and more parking available. Supposing if most people typically generate a daily trip-pair on weekday e.g. home-based work or home-based education trip-pair, people living outside the CBD area possibly feel more comfortable about undertaking additional trips before or after hours.

The proportion of trips by different purposes is one factor governing mode choice behaviour. In this paper, trip purpose is simply classified into four trip categories: work, business, education and other. The proportion of trip in the 'other' category is about 44 per cent across the study area and there is a small difference between inside and outside the CBD area. But for work, business and education categories, differences between inside and outside the CBD area can be easily seen. The proportion of work trips inside the CBD area is 26.5 per cent while for the outside it is 36.5 per cent. In contrast, the proportion of business trips made inside the CBD area is 12.4 per cent while the outside it is 5.7 per cent. This reflects differences of activities inside and outside the CBD area – apparently the main activities inside the CBD area are associated with business. Incidentally, the proportion of education trips inside the CBD area relative to the outside is about 38 per cent higher (education trips inside the CBD area is 18.1 per cent while outside it is 13.1 per cent). This is perhaps not surprising as the proportion of students inside the CBD area relative to the outside is about 34 per cent higher (students inside the CBD area 11.5 per cent, outside 8.6 per cent).

Mode share is the most important information in Table 2 and will be used to develop a model in the following section. In the study area, 45.4 per cent of trips are made by motorcycles and 33.3 per cent are made by cars while only 7.5 per cent of trips are made by public transit on average. Comparatively, shares of public transit and mode 'other' inside the CBD area are slightly higher than the outside. On the other hand, shares of cars and motorcycles inside and outside the CBD area are quite varied and the trade-off between two alternative modes can be obviously seen. Relative to outside the CBD area, the proportion of trips made by car inside the CBD area is visibly lower while the proportion of trips made by motorcycle is higher. Possible factors influencing this phenomenon could be the effects from traffic condition,

parking availability and perhaps travel distance. Traffic congestion and difficulty in finding parking space inside the CBD area may reduce attractiveness of using a car. Motorcycle, on the other hand, provides more manoeuvrability passing through traffic congestion and also less problems with parking space. This is another clue suggesting that land-use and traffic conditions continue to influence travel demand even in mid-size cities. Incidentally, public transit takes share of 7.5 per cent while about 14 per cent of trips are made by the mode 'other' (majority of mode 'other' is walking). This shows that public transit does not attract people in the study area in general.

5. MODEL ESTIMATION RESULTS

This section presents estimation results for the developed models. The variables used to explicate the choice behaviour are mostly in the form of scale data, except gender and living inside CBD which are category variables – the category variables take a value of one if the condition is satisfied and minus one otherwise (called Effect Coding technique). For the trip distance variable, KKDTS07 database contains only travel time from origin to destination. Rough approximation of trip distance is done by multiplying the travel time recorded with the average travel speed of mode generating that trip; the average travel speeds can be found in SIRDC (2008).

5.1. Vehicle ownership models

Estimation results for car and motorcycle ownership models are provided in Table 3. The left block of the table presents the estimation results for the car ownership model while the right block presents the estimation results for the motorcycle ownership model.

Table 3 Vehicle ownership model estimation results

Variable	Car ownership		MC ownership	
	Parameter	t-test	Parameter	t-test
Single-car/Single-motorcycle in the household				
Constant	-1.263	-5.13	0.048	0.16
Household size	0.095	1.34	0.393	3.70
Household workers	-0.044	-0.41	0.522	3.01
Household income	0.085	10.43	-0.009	-1.37
Living in CBD	-0.509	-5.71	0.106	0.92
Motorcycles in household	-0.312	-2.94	-	-
Cars in household	-	-	-0.538	-3.35
Multiple-cars/Multiple-motorcycles in the household				
Constant	-4.962	-11.27	-2.032	-5.79
Household size	0.208	1.90	0.622	5.51
Household worker	0.216	1.41	0.945	5.20
Household income	0.129	13.40	-0.003	-0.49
Living in CBD	-0.628	-4.48	0.110	0.90
Motorcycles in household	-0.424	-2.71	-	-
Cars in household	-	-	-0.660	-3.86
Log-likelihood function				
at convergence	-683.375		-769.161	
at market share	-869.733		-851.092	
Rho-square	0.214		0.096	
Crosstab: accuracy of prediction	51.8%		46.3%	
Sample size	873		873	
Number of parameters	12		12	

Car ownership model

Considering the estimation results for the car ownership model, relative to households with no car, eight of twelve parameters estimated are statistically significant at the 0.05 level. Household size parameters are found to be positive, but they are statistically insignificant in both single car and multiple cars utility functions. This implication shows that the household size is likely to contribute household car ownership; however this relationship is not obvious. Number of workers in household is estimated as negative for the single car utility function, but it is positive for the multiple cars utility function. The parameters estimated are nevertheless statistically insignificant in both utility functions. Household income parameters, on the other hand, have a positive sign, and also are statistically significant in both utility functions. Income certainly influences car ownership since the purchasing and operating costs of car are much higher than other alternative modes. In contrast, living in CBD parameters are likely to have a negative relationship with owning car. This supports the discussion in the last section that the average number of cars per person outside the CBD area is higher. As expected, the number of competitive-mode vehicles in household (motorcycles in this case) is negatively associated with car ownership in that household – the parameters of number of motorcycles in household are found to be negative and statistically significant in both utility functions.

Motorcycle ownership model

The motorcycle ownership model used a similar specification to the car ownership model. Seven of twelve parameters estimated are statistically significant at the 0.05 level. It is interesting that, excluding the alternative specific constants, all statistically significant parameters estimated in car ownership model are found to be insignificant in motorcycle ownership model, and vice versa. The household size parameters and the number of workers in household parameters have a positive sign, and they are also statistically significant in both single motorcycle and multiple motorcycles utility functions. The household income parameters are negative and statistically insignificant; however the magnitudes of those parameters are tiny in both utility functions. Living in CBD parameters have a positive sign, but they are statistically insignificant in both utility functions. This supports the earlier finding that, although the average number of motorcycles per member inside CBD area is higher than the outside, the discrepancy is very small. As expected, the phenomenon of vehicles in household is found in the same way to car ownership model. The number of competitive-mode vehicles in household (cars in this case) has a negative correlation with motorcycle ownership in that household – the parameters of number of cars in household are found to be negative and statistically significant in both utility functions.

Mutual analysis

As mentioned earlier, trade-off between cars and motorcycles can be clearly seen from the parameters of competitive-mode vehicles in the household in both models. In addition, all statistically significant parameters estimated in car ownership model are insignificant in motorcycle ownership model, and vice versa – only the income, living in CBD and number of motorcycles parameters are significant to car ownership, while only the household size, number of workers and number of cars parameters are significant to motorcycle ownership. Since the variables associated with car ownership model are totally different from motorcycle ownership model, perhaps it can be said that car and motorcycle are likely to satisfy different needs. Car may be the answer to need for comfortable, luxury and caste. If income is greater, a household is likely to own more cars, and then the number of motorcycles in that household

is likely to decrease. Motorcycle, in contrast, seems to be a suitable alternative under the condition of living in dense urban area and economical reason. Advantage of motorcycle over dense urban area condition can be indicated by the living in CBD parameters in car ownership model which are negative and statistically significant. Economical reason seems to be a great advantage of motorcycle. Motorcycle ownership is not associated with household income; it is however interrelated with household size and number of workers in household. When the household size and/or number of workers are greater, needs for travel and also private vehicles are commonly increasing. Again, if a household earns larger amount of income, that household is likely to purchase more cars, in general. However, if the amount of income is still insufficient, motorcycle might be purchased in order to satisfy some or all travellers in the household who are not satisfied by car. From this economical reason, motorcycle can possibly be defined as a 'gap alternative'. Nevertheless, in some households, even if they have high income and own enough cars, a small number of motorcycles (one or two) still exist in the households since motorcycle can be the answer of different needs.

Regarding the performance of the models, car ownership model seems to be acceptably fitted to the dataset if considering rho-square and accuracy of prediction from crosstab matrix (the crosstab matrices are not presented in this paper for brevity). In contrast, the rho-square of motorcycle ownership model is still lower than the expected range 0.2-0.4, which indicates that the model is perhaps poorly fitted to the dataset (Jaensirisak 2005). Besides, the accuracy of prediction for motorcycle ownership model is less than 50 per cent although the model consists of only a small number of alternatives. Another note can be made here; both car and motorcycle ownership models presented in this paper account only a few fundamental variables. There are several more variables, such as total trips made by household, member occupations, main source of household income and land-use surrounding household, which should be involved the model. These additional variables may help us to understand the vehicle ownership behaviour more deeply.

5.2. Mode choice models

Estimation results for mode choice models are provided in Table 4. The model includes three major modes used in the study area: car, motorcycle and public transit. Public transit is set as a base utility for the model. The parameters associated with household size are negative and statistically significant for both car alternative and motorcycle alternative. As opposed to the vehicle ownership model, in mode choice behaviour, increase of household size leads to more likelihood of insufficient vehicles to serve all members in the household. Some members may then have to travel by public transit. Household income parameter is positive and statistically significant for car alternative; however it is negative and insignificant for motorcycle alternative. This implies that the travellers from higher income families are more likely to travel by car; nevertheless such a relationship is not apparent for motorcycles, relative to public transit. Perhaps this is because motorcycle users and public transit users come from various income-level families, different from the car users which are mostly from upper-income families. As expected, household vehicle ownership is likely to contribute the use of private vehicles to household members. Household car ownership is positively associated with trips made by car alternative, but the relationship with trips made by motorcycle is obscure, and vice versa. Living in CBD is negative and statistically significant for car alternative; however it is statistically insignificant for motorcycle. Consistent with earlier discussion, this phenomenon emphasises the conditions inside CBD area which possibly reduce likelihood of owning and also using private cars. Contrastingly, the relationship between motorcycle and living inside the CBD area is indistinct.

Table 4 Mode choice model estimation results

Variable	All-trips	
	Parameter	t-test
Car		
Constant	-3.116	-8.95
Household size	-0.372	-7.97
Household income	0.021	4.70
Motorcycles in household	0.130	1.43
Cars in household	1.372	12.18
Living in CBD	-0.261	-3.90
Gender	0.507	7.50
Age	0.033	6.20
Trips made in the day	0.410	7.86
Trip distance	0.158	10.51
Motorcycle		
Constant	-0.305	-0.98
Household size	-0.222	-5.34
Household income	-0.002	-0.50
Motorcycles in household	0.901	10.52
Cars in household	0.163	1.53
Living in CBD	0.057	0.95
Gender	0.353	5.70
Age	0.008	1.73
Trips made in the day	0.295	5.97
Trip distance	0.065	4.52
Log-likelihood function		
at convergence	-2967.334	
at market share	-4067.508	
Rho-square	0.270	
Crosstab: accuracy of prediction	60.8%	
Sample size	4,437	
Number of parameters	20	

Parameters associated with gender are significantly positive in both utility functions – gender is coded as one for male and minus one for female. The model shows that males are more likely to use private vehicles than females. Parameters estimated for age are positively significant for car alternative, but it is insignificant for the motorcycle. This agrees with the expectation that owning and using car is costly; older people are more likely to be workers and earning sufficient amount of income to afford such expenditure. In contrast, age parameter is statistically insignificant for motorcycle alternative. The number of trips made per day is positively included in both private vehicle alternatives. This proves a tough disadvantage for public transit which is not suitable for serving such multi-stop trips and complex-trip journeys. Trip distance is the other variable contributing to both private vehicle alternatives, especially private car. Travelling by public transit with no priority as in the study area requires much longer time for the same origin-destination, compared to private vehicles. Incidentally, for the model performance, the rho-square is found to be in the acceptable range. The accuracy of model prediction is slightly above 60 per cent. These indices illustrate an adequate goodness of fit of the model over the dataset.

6. DISCUSSION AND CONCLUSIONS

This paper provides a preliminary analysis of the nature of mode choice and vehicle ownership in mid-sized cities in Southeast Asia. Factors potentially affecting the nature are defined using MNL models based on the KKDTS07 database. Regarding the models presented in this paper, one common finding observed by all models is that there are more statistically insignificant parameters estimated in any utility function related to motorcycles, compared to the equivalent utility functions related to cars. This implies one crucial nature of

motorcycle ownership and usage in the study area, which is that there is much more variety amongst motorcycle owners and users relative to car and public transit. By comparison, the variety of motorcycle owners and users leads to inconsistency in the dataset resulting in statistically insignificant estimated parameters. This evidence tells us that the prediction of travel demand associated with cars seems to be much less complicated and more likely to provide a reliable outcome. In contrast, modelling the nature of motorcycle owners and users is more complex and difficult.

Household size seems to be a crucial factor governing number of vehicles, while income is the factor dominating the type of vehicles in household. The number of vehicles, especially motorcycle, is more likely to be greater if household size becomes larger. Trade-off between car and motorcycle is also captured by both vehicle ownership and mode choice models. As discussed earlier, car and motorcycle perhaps properly satisfy different needs. If considering parameter magnitudes in mode choice model, the number of vehicles in household is found to be the main factor influencing mode choice behaviour of household members. From these results, suppose if good understanding of mode choice behaviour is the prime goal, a more comprehensive study on household vehicle ownership is required. Perhaps, accounting some other variables, e.g. total trips made by household, member occupations, main source of household income and land-use surrounding the household, may enhance the vehicle ownership model performance. The other evidence found is that, even in mid-sized cities with populations of 300k, land-use and traffic conditions continue to influence both household vehicle ownership and mode choice behaviour, especially for private cars. In addition, trip characteristics, such as trip distance, number of trips generated per day and perhaps trip-chain patterns, also seem to reasonably affect mode choice behaviour. Study on trip-chain and activity-based trip analysis are therefore another fascinating topic for further research.

The performance of models developed is one crucial aspect to be considered. From the indices of model efficiency, the motorcycle ownership models are not yet well fitted to the dataset, further improvement is thus required. Additionally, unifying car and motorcycle ownership models together is another interesting area for further work for modelling of vehicle ownership model. Various model specification techniques, such as interaction and non-linear utility function, and more advanced modelling techniques e.g. nested logit, latent class logit and mixed logit models, will also be adapted to both vehicle ownership and mode choice model to examine how much those techniques can improve the models. Eventually, due to the limitations of the existing database, some of expected further works cannot yet be achieved and a new survey may be required.

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