Inter-Temporal and Inter-Regional Analysis of Household Cars and Motorcycles Ownership Behaviours in Asian Big Cities

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Abstract

We investigated household cars and motorcycles ownership behaviours in Asian big cities: Bangkok, Kuala Lumpur, Manila and Nagoya. The behaviours are modelled using bivariate ordered probit models and the impact of accessibility obtained from mode choice models on vehicle ownership is carefully examined. Comparison and temporal and spatial transferability analysis have brought insights into the accessibility measures useful for the modelling.

Keywords: Vehicle ownership, accessibility, bivariate ordered probit model, Asian cities, transferability

1. Introduction

Most of the Asian cities are experiencing severe transport problems resulting from rapidly increasing vehicle ownership and usage. One of the reasons may be due to insufficient supply and inferior quality of public transportation. As a result, supply of transport facilities always stays behind the level of transport demand. Especially in Asian countries, mobility is rising very rapidly in conjunction with economic growth. On the other hand, public transport facilities are getting improvements in increasing supply and improving quality, with economic growth. However, there is a considerable gap between demand and supply of transport facilities in most Asian cities. Consequently, travellers' attraction for owning and using private vehicles are increasing very rapidly that may finally devastate the urban environment with traffic congestion and air pollution.

It is clear that there is a direct relationship between vehicle ownership and ridership on public transportation. In a car-dependent society, public transport services decline in quality. Therefore, investigations of travel demand and vehicle ownership are important to understand the future transportation system including expediency and role on public transport. Therefore, this research investigates household cars and motorcycles ownership behaviours in four Asian cities of Bangkok, Kuala Lumpur, Manila, and Nagoya.

2. Modelling framework

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2.1. Overview

This study attempts to investigate vehicle ownership behaviours in Asian cities of Bangkok, Kuala Lumpur, Manila, and Nagoya. The whole process can be divided into four steps. First, multinomial logit model is estimated to analyse the travel demand in the cities concerned. Second, the estimation results of the developed travel demand models are used to obtain accessibility measures to be used as one of explanatory variables of vehicle ownership models. Third, since it is believed that car and motorcycle ownership has some relationships, bivariate ordered probit model is estimated, and estimation results are compared inter-temporally and inter-regionally. Fourth, temporal and regional transferability of the models is evaluated. In the following subsections, accessibility and bivariate ordered probit model are explained.

2.2. Accessibility

Accessibility measures are calculated based on the utility functions of mode choice models. The maximum utility, *log-sum term*, can be used as accessibility measures (Ben-Akiva and Lerman, 1985), and the followings are considered for individual n residing in zone z_n ($z_n = 1, \ldots, Z$):

1. *accessibility to transit*:

$$AT_{z_n n} = \sum_{z=1, z \neq z_n}^{Z} ln\left(exp\left(V_{Rzn}\right) + exp\left(V_{Bzn}\right)\right); \tag{1a}$$

2. *additional accessibility of car availability*:

$$AAC_{z_n n} = \sum_{z=1, z \neq z_n}^{Z} \left[ln\left(exp\left(V_{Rzn}\right) + exp\left(V_{Bzn}\right) + exp\left(V_{Czn}\right)\right) - ln\left(exp\left(V_{Rzn}\right) + exp\left(V_{Bzn}\right)\right)\right]; \text{ and} \tag{1b}$$

3. *additional accessibility of motorcycle availability*:

$$AAMC_{z_n n} = \sum_{z=1, z \neq z_n}^{Z} \left[ln\left(exp\left(V_{Rzn}\right) + exp\left(V_{Bzn}\right) + exp\left(V_{MCzn}\right)\right) - ln\left(exp\left(V_{Rzn}\right) + exp\left(V_{Bzn}\right)\right)\right]. \tag{1c}$$

where, V_{Rzn}, V_{Bzn}, V_{Czn} and V_{MCzn} denote the systematic component of utility functions when individual n travels to zone z by rail, bus, car and motorcycle respectively. Accessibility to transit means the convenience of using transit in zone z_n. On the other hand, the other two additional accessibilities indicate the convenience of car and motorcycle if the individual can use these alternatives in addition to transit which is usually available to all citizens. We expect that the lower accessibility to transit and higher additional accessibilities lead to cars and motorcycles ownership intentions.

Besides, three accessibility measures considering traffic volume between origin and destination are examined. These are defined as follows for individual n residing in zone z_n ($z_n = 1, \ldots, Z$):

4. *weighted accessibility to transit*:

$$WAT_{z_n n} = \sum_{z=1, z \neq z_n}^{Z} w_{RBz}\, ln\left(exp\left(V_{Rzn}\right) + exp\left(V_{Bzn}\right)\right); \tag{1d}$$

5. *weighted additional accessibility of car availability*:

$$WAAC_{z_n n} = \sum_{z=1, z \neq z_n}^{Z} \left[w_{RBCz}\, ln\left(exp\left(V_{Rzn}\right) + exp\left(V_{Bzn}\right) + exp\left(V_{Czn}\right)\right) - w_{RBz}\, ln\left(exp\left(V_{Rzn}\right) + exp\left(V_{Bzn}\right)\right)\right];$$

and (1e)

6. *weighted additional accessibility of motorcycle availability*:

$$WAAMC_{z_n n} = \sum_{z=1, z \neq z_n}^{Z} \left[w_{RBMCz} \, ln\left(exp(V_{Rzn}) + exp(V_{Bzn}) + exp(V_{MCzn}) \right) - w_{RBz} \, ln\left(exp(V_{Rzn}) + exp(V_{Bzn}) \right) \right] \tag{1f}$$

where:

$$w_{RBz} = \left(Q_{Rz} + Q_{Bz} \right) \Big/ \sum_{z=1, z \neq z_n}^{Z} \left(Q_{Rz} + Q_{Bz} \right),$$

$$w_{RBCz} = \left(Q_{Rz} + Q_{Bz} + Q_{Cz} \right) \Big/ \sum_{z=1, z \neq z_n}^{Z} \left(Q_{Rz} + Q_{Bz} + Q_{Cz} \right)$$

$$w_{RBMCz} = \left(Q_{Rz} + Q_{Bz} + Q_{MCz} \right) \Big/ \sum_{z=1, z \neq z_n}^{Z} \left(Q_{Rz} + Q_{Bz} + Q_{MCz} \right)$$

where, Q_{Rz}, Q_{Bz}, Q_{Cz} and Q_{MCz} denote traffic volume between zone z_n and z by rail, bus, car and motorcycle respectively. Weighted accessibility measures consider zones which have traffic volume with zone z_n. If the survey area is very large, considering accessibility to all zones equivalently is questionable and examining zones which are believed to be in the choice set seems reasonable. One potential problem is that people may travel to close and convenient zones only and inconvenient but attractive zones may be excluded from the evaluation.

2.3. Bivariate ordered probit model

In the presentation of the model structure in this subsection, for each household h, let j represent the number of cars owned ($j = 0, 1, \ldots, J$), and let k represent the number of motorcycles owned ($k = 0, 1, \ldots, K$). The equation system can be written as:

$$y_{1h}^{*} = \beta_1 x_{1h} + \varepsilon_{1h}, \qquad y_{1h} = j \qquad \text{if } \mu_{1,j} < y_{1h}^{*} \le \mu_{1,j+1}, \tag{1a}$$

$$y_{2h}^{*} = \beta_2 x_{2h} + \varepsilon_{2h}, \qquad y_{2h} = k \qquad \text{if } \mu_{2,k} < y_{2h}^{*} \le \mu_{2,k+1}, \tag{1b}$$

where y_{1h}^{*} and y_{2h}^{*} denote the propensity for household h to own cars and motorcycles respectively. y_{1h} and y_{2h} denote observed number of cars and motorcycles owned by household h respectively. The x's are vectors of exogenous variables. The β's are corresponding vectors of parameters that are estimated alone with the threshold values (i.e. the μ's). The random error terms ε_{1h} and ε_{2h} are assumed to be distributed identically and independently across households in accordance with the standard normal distribution.

The number of cars owned and that of motorcycles owned by a household interact as shown in (1). In the bivariate ordered probit modelling approach, interactions can be divided into observed and unobserved ones. Examples of the observed interactions are that: 1) the household, which already has enough cars, may not intend to own motorcycles; and 2) the household, which has given up buying a car and bought a motorcycle, may intend to own a car as salary increases. Dummy variables can capture this interaction. On the other hand, an example of the unobserved interactions is the existence of inherent propensity for vehicle ownership. For example, a household may have a propensity for owing both cars and motorcycles. Another household may have a propensity for owing either cars or motorcycles. The correlation of the random error terms ε_{1h} and ε_{2h} can capture this interaction. A standard normal bivariate distribution function is specified such that:

$$\phi_2(\bullet) = \phi_2\left(\varepsilon_{1h}, \varepsilon_{2h}, \rho_{\varepsilon_{1h},\varepsilon_{2h}}\right) \tag{2}$$

ρ represents the correlation between the random error terms. Likewise, the corresponding cumulative density function is given as:

$$\Phi_2(\bullet) = \Phi_2\left(\varepsilon_{1h}, \varepsilon_{2h}, \rho_{\varepsilon_{1h},\varepsilon_{2h}}\right) \tag{3}$$

From (1) and (3), the joint probability that the household h will own j cars and k motorcycles is:

$$\begin{aligned} P_{hjk} = & \Phi_2\left[\mu_{1,j+1} - \beta_1 x_{1h}, \mu_{2,k+1} - \beta_2 x_{2h}, \rho_{\varepsilon_{1h},\varepsilon_{2h}}\right] \\ & - \Phi_2\left[\mu_{1,j} - \beta_1 x_{1h}, \mu_{2,k+1} - \beta_2 x_{2h}, \rho_{\varepsilon_{1h},\varepsilon_{2h}}\right] \\ & - \Phi_2\left[\mu_{1,j+1} - \beta_1 x_{1h}, \mu_{2,k} - \beta_2 x_{2h}, \rho_{\varepsilon_{1h},\varepsilon_{2h}}\right] \\ & + \Phi_2\left[\mu_{1,j} - \beta_1 x_{1h}, \mu_{2,k} - \beta_2 x_{2h}, \rho_{\varepsilon_{1h},\varepsilon_{2h}}\right] \end{aligned} \tag{4}$$

The parameters to be estimated in the bivariate ordered probit model are the $J + K - 2$ threshold values ($\mu_{1,0}, \mu_{2,0} = -\infty$; $\mu_{1,1}, \mu_{2,1} = 0$; $\mu_{1,J+1}, \mu_{2,K+1} = +\infty$), the β's and ρ. The parameters are obtained by maximising the log-likelihood function:

$$L^* = \sum_{h=1}^{H}\sum_{j=0}^{J}\sum_{k=0}^{K} Z_{hjk} \ln P_{hjk}, \tag{5}$$

where:

$Z_{hjk} =$ 1 if the household h owns j cars and k motorcycles,
0 otherwise.

3. Data and case study cities

This study investigates data from four major cities in Asia: Bangkok, Kuala Lumpur, Manila and Nagoya. Bangkok, Kuala Lumpur and Manila are known as the most congested cities in Asia and therefore, investigating travel behaviours and related vehicle owning behaviours are found to be important. In addition, Asian city like Nagoya that has efficient transportation system is also considered in the analysis to fulfil the task of comparing cities with different transportation settings. Following subsections explain the area and brief introduction of the data used in this study.

3.1 Bangkok Metropolitan Region (BMR) in Thailand

Bangkok Metropolitan Region (BMR) in Thailand has developed substantially for several decades providing successful outcomes on infrastructure, industry and business sectors. Bangkok has numerous rivers and canals, and several decades ago, ferry was an effective transportation mode for the travellers. In conjunction with the industrial revolution, the city has considerably expanded, and it has been finally changed into a road-based city. Vehicle ownership is one of the main elements in discussing social status of a country. Several decades ago, it was observed that the vehicle ownership in Bangkok was a requirement only for people with high incomes as an indication of power and social status. But finally, it became a very important aspect for people regardless of their income levels to manage their mobility rather than suffering from inefficient level of service offered by public transportation.

Accordingly, vehicle ownership is increasing with increasing income and motorcycle ownership is higher than car ownership for low-income households. Additionally, owning two or more vehicles is very low even with high-income households indicating the difficulty of affording multiple vehicles due to prevailing economic instability.

The study area covers Bangkok Metropolitan Area (BMA) and five adjacent provinces. There are 505 internal traffic zones in BMR covering 7,758 km^2. According to the recent estimations, the population in BMR was 13 million in the year 2001. Data used in this study were obtained from a household travel survey in BMR during 1995/96. The survey was conducted as a part of a major transport project in the BMR named Urban Transport Database and Model Development (UTDM) Project. Additional database for home interview survey conducted by Bangkok Environmental Improvement Project (BEIP) was used to strengthen the overall database.

3.2 Kuala Lumpur Metropolitan (KLMP) in Malaysia

The Malaysian economy has been rapidly expanding since 1987. The expansion of the economy has encouraged rapid urbanisation and motorisation. The number of vehicles in Kuala Lumpur has increased from 541,000 vehicles in 1991 to 861,000 in 1995 with an annual average growth rate of 10.8%. Compared with the modal composition in 1985, the share of the private mode of transport, consisting of motorcycles and cars, has significantly increased from 65.7% to 80.3% in 1997. The modal share of public transport has decreased from 34.3% to 19.7%, and more specifically, the share of stage bus/mini bus decreased remarkably from 24.3% to 7.9%. Traffic congestion, frequent traffic accidents and air pollution in Kuala Lumpur and in its conurbation is a crucial issue. It seems, however, very difficult to construct new roads or widen roads due to the fact that the area has been already built-up; land acquisition is difficult and also expensive.

The study area, Klang Vally Region, covers the Federal Territory of Kuala Lumpur and its conurbation about 10 km from the boundary. KLMP covers an area of 243 km^2, and in total, the study area of Klang Vally Region is about 500 km^2. As estimated in 2000, population in the study area was about 4.1 million and average annual growth rate of population is 3.7%. The data for the study were obtained from a household travel/ person trip survey that was conducted by Japan International Cooperation Agency (JICA). The study started in March 1997 and ended in February 1999. The survey was conducted as a part of a major transport project in Kuala Lumpur called “Strategies for Managing Urban Transport in Kuala Lumpur - SMURT-KL”. The database provides useful information related to households, individual members and person trips.

3.3 Metro Manila in Philippines

The study area consists of Metro Manila and the adjacent municipalities in the adjoining provinces. Metro Manila covers an area of 636 km^2, and metropolitan area is expanding rapidly towards the outer areas covering 3,670 km^2. The population in the study area is about 14.4 million in 1995 and annual growth rate of population in Metro Manila is 4.2%. Motorisation in Metro Manila has been increasing very rapidly with a 6% yearly rate of vehicle registration. However, car ownership level in Metro Manila is still low in contrast to other Asian cities. Also, motorcycle is not a popular transport mode in Metro Manila.

The data for the study were obtained from a survey that was conducted in 1996 under the project of the Metro Manila Urban Transportation Integration Study (MMUTIS).

MMUTIS was conducted upon request of the Philippine Government with technical assistance of the Japan International Cooperation Agency (JICA). MMUTIS study area has 394 zones and 265 of them are in Metro Manila. The database provides information about households, household members, trips, vehicle users, elderly people and environment.

3.4 Chukyo Metropolitan Region (CMR) (Nagoya City and Surrounding Areas) in Japan

The study area, Chukyo Metropolitan Region (CMR), is a large urban area centring Nagoya. CMR consists of Nagoya city and the surrounding. CMR covers about 5,000 km^2. As estimated in 1990, population in CMR was about 8 million. This study uses data obtained from CMR in 1971, 1981, 1991 and 2001. In the databases for 1971, 1981, 1991 and 2001, survey areas considered were found as different such as 4096 km^2, 5656 km^2, 5173 km^2, 6696 km^2 respectively. There are 341 traffic zones in the study area for all cases. In CMR, various measures have been taken over past 2-3 decades to induce urban traffic to the efficient public transport means by the formation of a subway network and by the improvement of bus and taxi services. At present, CMR is facilitated with efficient transport system that includes bus, subway in the central city and rail services from city to suburbs.

4. Empirical findings

4.1. Mode choice models

Estimation results for mode choice models of NGO71-01, BKK, KL and Manila are presented in Table 4-1. In NGO71-01 and Manila models, 15,000 samples are drawn randomly to save the computation time. In order to make the comparison easier, models are basically estimated with the same set of explanatory variables and some of the variables not estimated significantly are remained. A cost variable is not included, since the travel cost information is not available in some of the case study cities. A visual comparison of the models suggests that their respective parameter estimates show very little difference. All respective parameter estimates of a level of service and socio-economic variables have the same signs across seven models with an exception of student dummy.

Table 4-1
Mode choice model results

Variable	NGO71		NGO81		NGO91		NGO01		BKK		KL		Manila	
	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.
Constant (R)	0	--	0	--	0	--	0	--	0	--	--	--	0	--
Constant (B)	-0.42	-9.8	-1.30	-21.2	-1.54	-19.1	-1.69	-17.3	0.04	2.0	0	--	1.03	14.4
Constant (C)	-2.15	-24.6	-1.95	-18.2	-1.27	-10.1	-0.66	-4.3	-1.54	-6.6	-0.72	-8.6	-0.52	-5.2
Constant (MC)	--	--	-4.46	-38.8	-4.15	-30.9	-3.90	-23.9	-1.75	-7.6	-1.62	-21.0	-0.82	-9.2
Time (60 min.)	-0.43	-5.7	-1.92	-21.8	-1.95	-23.3	-2.53	-24.7	-0.17	-4.1	-0.14	-1.2	-0.30	-5.2
Male (C, MC) †	2.10	40.5	1.74	24.5	1.49	16.9	1.02	9.7	0.72	19.0	0.95	10.3	0.40	9.7
Age ≥ 65 (B)	1.57	10.6	1.78	13.4	1.83	14.3	1.29	11.2	--	--	--	--	--	--
Female (R)	-0.79	-13.6	-0.75	-9.6	-0.77	-8.1	-0.54	-4.8	-0.57	-2.0	--	--	-0.43	-4.2
City (C)	-0.64	-16.1	-0.75	-19.2	-0.81	-19.1	-1.02	-23.2	-0.01	-1.3	-0.27	-5.3	-0.91	-15.3
Student (R)	0.63	9.0	0.64	8.3	0.97	11.3	1.04	10.1	-0.35	-2.0	--	--	-0.64	-5.1
Age ≥ 20 (C, MC) †	1.59	23.7	1.36	18.0	1.23	14.5	1.02	9.4	1.17	26.5	4.30	40.8	0.79	16.1
Summary statistics														
N	15,000		15,000		15,000		15,000		13,882		12,667		15,000	
L (**β**)	-10,595.2		-10,834.2		-9,254.1		-8,223.8		-9,433.7		-9,212.4		-9,513.2	
L (**0**)	-13,572.4		-15,702.5		-15,140.8		-14,787.2		-12,249.1		-13,434.0		-12,948.8	
Adjusted ρ^2	0.219		0.309		0.388		0.443		0.229		0.313		0.265	

† In NGO 71, variables are alternative specific to auto only.

4.2. Bivariate ordered probit models

The choice of explanatory variables was guided by the findings from the data section and intuitive arguments regarding the effects of variables designed to capture cars and motorcycles ownership behaviours. The variables included in the final model specifications are found in Table 4-2, alone with their definitions. The first group of variables measures socio-economic characteristics of the household. The second group is accessibility measures defined in the subsection 2.2. and these are averaged over household members. The last group is an interaction term.

Table 4-2
Independent variables used in the bivariate ordered probit model

Variable	Definition
Socio-economic characteristics	
Male 20 – 65 †	Number of males in the household ≥ 20 years old and ≤ 65 years old
Male – 19, 66 – †	Number of males in the household ≤ 19 years old or ≥ 66 years old
Male 20 – 29	Number of males in the household ≥ 20 years old and ≤ 29 years old
Male – 19, 30 –	Number of males in the household ≤ 19 years old or ≥ 30 years old
Female 20 – 65 †	Number of females in the household ≥ 20 years old and ≤ 65 years old
Female – 19, 66 – †	Number of females in the household ≤ 19 years old or ≥ 66 years old
Female 20 – 29	Number of females in the household ≥ 20 years old and ≤ 29 years old
Female – 19, 30 –	Number of females in the household ≤ 19 years old or ≥ 30 years old
Worker	Number of workers in the household
Accessibility measures	
AT	Average accessibility to transit of household members
AAC	Average additional accessibility of car availability of household members
AAMC	Average additional accessibility of motorcycle availability of household members
WAT	Average weighted accessibility to transit of household members
WAAC	Average weighted additional accessibility of car availability of household members
WAAMC	Average weighted additional accessibility of motorcycle availability of household members
Interaction	
MCOWN	Number of motorcycles owned by the household

† Male 20 – 65, Male – 19, 66 –, Female 20 – 65, Female – 19, 66 – are Male 20 – 64, Male – 19, 65 –, Female 20 – 64, Female – 19, 65 – respectively in NGO01 since the age information is available on a category basis.

12 bivariate ordered probit models were estimated for each case study city and time point based on which type of accessibility is used, if correlation is estimated, and if interaction term is introduced. Four types of accessibility measures considered are: 1) accessibility to transit, 2) additional accessibility of car and motorcycle availability, 3) weighted accessibility to transit, and 4) weighted additional accessibility of car and motorcycle availability. For each accessibility measure, three kinds of models are evaluated estimating: i) correlation but not interaction, ii) neither correlation nor interaction, and iii) both correlation and interaction. In model iii), number of motorcycles owned is included in the propensity function of the car ownership, which gives better result than including number of cars owned in the function of motorcycle ownership. Summarised estimation results are presented in Table 4-3. Due to the data limitation in the developing countries, two kinds of accessibility measures, 1) and 2), are estimated only in NGO81-01. Analysis on Manila data is excluded since the model has not been estimated successfully due in part to the data problem.

As examples, estimation results using weighted additional accessibility of car and motorcycle availability and weighted accessibility to transit (estimating correlation but not interaction) models are presented in Tables 4-4 and 4-5 respectively.

Table 4-3
Summary of estimation results of bivariate ordered probit model

	NGO81		NGO91		NGO01		BKK		KL	
	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.
(a) Accessibility to transit model										
AT (C)	-0.20	-3.7	-0.43	-7.7	-0.28	-6.0				
AT (MC)	-0.12	-1.3	-0.24	-2.9	-0.16	-2.2				
Correlation	0.16	3.3	0.08	1.7	0.11	2.1				
$L^a(\boldsymbol{\beta})$		-1597.3		-1594.1		-1385.2				
(b) Additional accessibility of car and motorcycle availability model										
AAC (C)	0.24	3.6	0.36	4.6	0.32	6.1				
AAMC (MC)	0.04	0.2	0.28	1.6	0.24	1.9				
Correlation	0.17	3.5	0.10	2.0	0.13	2.3				
$L^b(\boldsymbol{\beta})$		-1598.7		-1607.8		-1385.3				
(c) Weighted accessibility to transit model										
WAT (C)	-0.38	-2.9	-0.53	-5.3	-0.68	-8.5	-1.86	-2.5	-0.34	-0.6
WAT (MC)	-0.20	-1.4	-0.27	-2.4	-0.20	-1.8	1.57	0.7	-0.34	-0.1
Correlation	0.24	5.2	0.08	1.8	0.04	0.8	-0.24	-5.3	-0.25	-5.8
$L^c(\boldsymbol{\beta})$		-1607.0		-1596.6		-1429.0		-1540.3		-1896.4
(d) Weighted additional accessibility of car and motorcycle availability model										
WAAC (C)	0.44	4.3	0.59	7.1	0.48	9.2	0.54	3.1	0.12	0.1
WAAMC (MC)	1.13	2.7	0.92	2.0	0.27	0.6	0.89	3.3	-0.30	-0.3
Correlation	0.25	5.7	0.08	1.8	0.04	0.9	-0.21	-4.0	-0.25	-6.5
$L^d(\boldsymbol{\beta})$		-1600.6		-1584.3		-1419.7		-1531.0		-1896.4
(e) Accessibility to transit model without correlation										
AT (C)	-0.20	-2.2	-0.43	-7.6	0.00	-5.9				
AT (MC)	-0.20	-2.1	-0.24	-2.9	0.00	-2.1				
$L^e(\boldsymbol{\beta})$		-1602.9		-1595.5		-1387.1				
$-2[L^e(\boldsymbol{\beta}) - L^a(\boldsymbol{\beta})]$		11.24		2.90		3.88				
(f) Additional accessibility of car and motorcycle availability model without correlation										
AAC (C)	0.32	5.9	0.36	4.6	0.32	5.9				
AAMC (MC)	0.24	1.7	0.24	1.5	0.24	1.7				
$L^f(\boldsymbol{\beta})$		-1604.8		-1609.8		-1387.7				
$-2[L^f(\boldsymbol{\beta}) - L^b(\boldsymbol{\beta})]$		12.18		4.06		4.88				
(g) Weighted accessibility to transit model without correlation										
WAT (C)	-0.39	-3.5	-0.53	-5.3	-0.68	-8.5	-1.91	-2.5	-0.34	0.0
WAT (MC)	-0.21	-1.3	-0.27	-2.3	-0.21	-1.9	1.47	1.6	-0.34	0.0
$L^g(\boldsymbol{\beta})$		-1620.4		-1598.0		-1429.3		-1552.5		-1914.8
$-2[L^g(\boldsymbol{\beta}) - L^c(\boldsymbol{\beta})]$		26.72		2.84		0.56		24.32		36.74
(h) Weighted additional accessibility of car and motorcycle availability model without correlation										
WAAC (C)	0.48	9.3	1.33	19.2	0.48	9.3	0.58	3.1	0.01	0.0
WAAMC (MC)	0.27	0.6	0.92	2.0	0.27	0.6	1.08	4.9	-0.52	-0.6
$L^h(\boldsymbol{\beta})$		-1420.0		-1585.7		-1420.0		-1539.3		-1915.0
$-2[L^h(\boldsymbol{\beta}) - L^d(\boldsymbol{\beta})]$		0.58		2.88		0.58		16.66		37.3
(i) Accessibility to transit model with interaction										
AT (C)	-0.20	-3.5	-0.43	-7.6	-0.28	-6.1				
AT (MC)	-0.12	-1.3	-0.24	-2.9	-0.16	-2.2				
MCOWN (C)	0.14	0.8	0.00	-0.2	-0.13	-0.3				
Correlation	0.07	0.5	0.08	1.7	0.19	0.8				
$L^i(\boldsymbol{\beta})$		-1597.1		-1594.1		-1385.1				
$-2[L^a(\boldsymbol{\beta}) - L^i(\boldsymbol{\beta})]$		0.46		0.02		0.14				
(j) Additional accessibility of car and motorcycle availability model with interaction										
AAC (C)	0.18	3.6	0.36	4.5	0.32	6.3				
AAMC (MC)	0.04	0.3	0.28	1.6	0.28	2.0				
MCOWN (C)	0.14	0.7	-0.01	-0.4	-0.23	-0.7				
Correlation	0.08	0.6	0.10	2.0	0.26	1.3				
$L^j(\boldsymbol{\beta})$		-1598.5		-1607.7		-1385.0				
$-2[L^b(\boldsymbol{\beta}) - L^j(\boldsymbol{\beta})]$		0.46		0.12		0.50				
(k) Weighted accessibility to transit model with interaction										
WAT (C)	-0.37	-3.2	-0.52	-5.2	-0.68	-8.5	-1.93	-2.6	-0.26	0.0
WAT (MC)	-0.21	-5.1	-0.27	-2.4	-0.20	-1.7	1.64	0.8	-0.22	0.0
MCOWN (C)	0.21	2.0	0.06	0.5	-0.14	-0.4	0.24	1.3	-0.75	-8.5
Correlation	0.11	1.2	0.03	0.3	0.12	0.5	-0.39	-3.2	0.32	3.6
$L^k(\boldsymbol{\beta})$		-1606.3		-1596.5		-1428.8		-1539.4		-1886.0

-2[$L^c(\boldsymbol{\beta}) - L^k(\boldsymbol{\beta})$]		1.42		0.26		0.48		1.92		20.88
(l) Weighted additional accessibility of car and motorcycle availability model with interaction										
WAAC (C)	0.43	4.2	0.59	7.1	0.48	9.2	0.56	3.0	-0.11	-0.2
WAAMC (MC)	1.08	2.6	0.92	2.0	0.28	0.6	1.04	4.7	-0.37	-0.3
MCOWN (C)	0.13	0.5	0.09	0.6	-0.17	-0.5	-0.23	-2.1	-0.76	-8.8
Correlation	0.17	0.9	0.01	0.1	0.14	0.6	-0.05	-0.5	0.33	3.8
$L^l(\boldsymbol{\beta})$		-1600.3		-1584.0		-1419.4		-1530.6		-1886.1
-2[$L^d(\boldsymbol{\beta}) - L^l(\boldsymbol{\beta})$]		0.56		0.5		0.68		0.8		20.66

Note: 1,000 samples are drawn randomly.

Table 4-4
Estimation results of bivariate ordered probit model

Variable	NGO81		NGO91		NGO01		BKK		KL	
	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.
Car ownership										
Constant term	-0.66	-4.8	-1.63	-10.5	-0.64	-4.6	-1.41	-9.7	-0.41	-1.2
Socio-economic characteristics										
Male 20 – 65	0.38	6.0	0.64	8.8	0.57	7.4	0.29	14.6	0.20	3.5
Male – 19, 66 –	0.06	1.6	0.29	6.2	0.41	4.4	0.10	1.8	0.09	1.7
Female 20 – 65	0.03	0.6	0.50	7.6	0.66	9.7	0.14	2.4	0.18	3.5
Female – 19, 66 –	0.11	2.5	0.32	6.0	0.54	5.9	0.23	4.4	-0.01	-0.1
Worker	0.21	4.0	0.40	7.7	0.34	4.9	0.10	1.9	0.11	2.2
Accessibility measure										
WAAC	0.44	4.3	0.59	7.1	0.48	9.2	0.54	3.1	0.12	0.1
Threshold values										
One and two cars	1.59	27.3	1.75	24.1	1.82	24.4	1.17	20.3	1.42	25.2
Two and three cars	2.48	14.0	3.08	19.1	3.21	21.7	3.11	9.1	2.33	11.3
Motorcycle ownership										
Constant term	-1.46	-12.3	-1.67	-12.8	-1.60	-11.5	-1.42	-7.5	-0.24	-1.6
Socio-economic characteristics										
Male 20 – 29	0.22	2.0	0.54	4.9	0.36	2.9	0.45	5.6	0.36	6.0
Male – 19, 30 –	0.06	1.1	0.29	5.5	0.25	2.4	0.22	4.1	0.16	3.4
Female 20 – 29	0.02	0.2	0.04	0.4	0.11	0.9	-0.12	-1.5	-0.17	-2.6
Female – 19, 30 –	0.03	0.6	0.07	1.2	0.18	2.2	-0.03	-0.6	-0.11	-2.7
Worker	0.20	3.4	0.15	2.6	0.03	0.3	0.11	2.2	0.14	3.2
Accessibility measure										
WAAMC	1.13	2.7	0.92	2.0	0.27	0.6	0.89	3.3	-0.30	-0.3
Threshold values										
One and two motorcycles	1.26	14.2	1.07	14.6	1.03	10.7	1.50	17.3	1.61	22.2
Correlation										
Correlation	0.25	5.7	0.08	1.8	0.04	0.9	-0.21	-4.0	-0.25	-6.5
Summary statistics										
N	1,000		1,000		1,000		1,000		1,000	
L(β)	-1,600.6		-1,584.3		-1,419.7		-1,531.0		-1,896.4	
L(C)	-1,782.0		-1,984.3		-1,699.1		-1,631.3		-2,007.1	
Adjusted ρ^2	0.0945		0.1950		0.1568		0.0535		0.0487	

Table 4-5
Estimation results of bivariate ordered probit model

Variable	NGO81		NGO91		NGO01		BKK		KL	
	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.
Car ownership										
Constant term	-0.88	-3.2	-1.76	-8.0	-1.41	-6.3	-1.37	-9.4	-0.39	-3.7
Socio-economic characteristics										
Male 20 – 65	0.53	6.4	0.81	11.8	0.72	9.3	0.34	5.2	0.20	3.1
Male – 19, 66 –	0.10	1.8	0.33	6.6	0.52	5.6	0.06	1.2	0.09	1.7
Female 20 – 65	-0.07	-0.9	0.33	5.0	0.46	6.7	0.14	2.4	0.18	2.9
Female – 19, 66 –	0.02	0.4	0.19	3.8	0.40	4.4	0.17	3.3	-0.01	-0.2
Worker	0.22	3.8	0.42	8.0	0.34	4.9	0.09	1.8	0.11	2.2
Accessibility measure										
WAT	-0.38	-2.9	-0.53	-5.3	-0.68	-8.5	-1.86	-2.5	-0.34	-0.6
Threshold values										
One and two cars	1.58	23.4	1.73	23.9	1.79	24.6	1.17	18.7	1.42	26.0
Two and three cars	2.47	13.1	3.04	19.0	3.17	21.8	2.11	7.9	2.33	11.4
Motorcycle ownership										
Constant term	-1.70	-5.7	-2.10	-7.8	-2.08	-6.3	-0.75	-4.4	-0.30	-1.0
Socio-economic characteristics										
Male 20 – 29	0.28	2.6	0.58	5.3	0.40	3.2	0.46	5.8	0.37	5.2
Male – 19, 30 –	0.08	1.6	0.32	5.8	0.28	2.7	0.19	3.9	0.16	3.1
Female 20 – 29	-0.03	-0.3	-0.01	-0.1	0.08	0.7	-0.16	-2.0	-0.17	-2.3
Female – 19, 30 –	-0.01	-0.2	0.04	0.7	0.15	1.9	-0.10	-2.3	-0.10	-2.2
Worker	0.21	3.3	0.14	2.5	0.00	0.0	0.12	2.1	0.14	2.6
Accessibility measure										
WAT	-0.20	-1.4	-0.27	-2.4	-0.20	-1.8	1.57	0.7	-0.34	-0.1
Threshold values										
One and two motorcycles	1.26	14.1	1.07	14.6	1.04	10.7	1.48	15.4	1.61	25.3
Correlation										
Correlation	0.24	5.2	0.08	1.8	0.04	0.8	-0.24	-5.3	-0.25	-5.8
Summary statistics										
N	1,000		1,000		1,000		1,000		1,000	
L(β)	-1,607.0		-1,596.6		-1,429.0		-1,540.3		-1,896.4	
L(C)	-1,782.0		-1,984.3		-1,699.1		-1,631.3		-2,007.1	
Adjusted ρ^2	0.0909		0.1888		0.1513		0.0478		0.0487	

4.3. Assessment of predictive ability

5. Conclusions

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References