INTER-TEMPORAL ANALYSIS OF HOUSEHOLD CAR AND MOTORCYCLE OWNERSHIP BEHAVIORS

–The Case in the Nagoya Metropolitan Area of Japan, 1981-2001–

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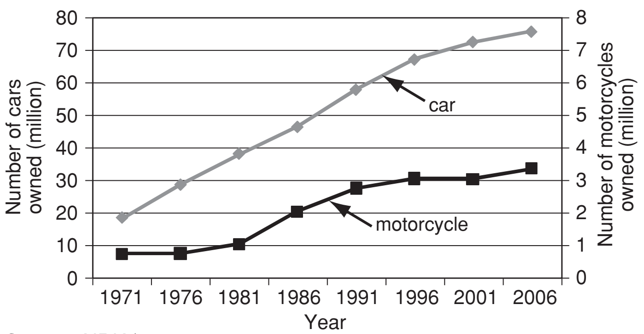
This study investigates household car and motorcycle ownership in Nagoya metropolitan area of Japan. Bivariate ordered probit models of household vehicle ownership were developed using the data from the case study area at three time points, 1981, 1991, and 2001. The accessibility that is generally known to be correlated with vehicle ownership decisions is incorporated as an input for the proposed vehicle ownership model to investigate the potential relationship between them. The mode choice models for the area were first estimated to quantify the accessibility indexes that were later integrated into the vehicle ownership models. Inter-temporal comparison and temporal transferability analysis were conducted. Some of the major findings suggest: 1) that age and gender differences have become less important in modal choices and car ownership as motorization proceeds; 2) that the accessibility seems to have a significant correlation with vehicle ownership; 3) that car and motorcycle ownership may not be independent and may have a complementary relationship; and 4) that the deep insights concerning the model selection are obtained from the viewpoints of the temporal transferability.

Key Words: Car ownership, Motorcycle ownership, Accessibility, Bivariate ordered probit model, Inter-temporal analysis

1. INTRODUCTION

Private car and motorcycle ownership in Japan have been steadily increasing from the 1970s (Fig.1)[1]. According to Figure 1, car and motorcycle ownership in Japan in 2006 is more than 75 million and 3.3 million respectively.

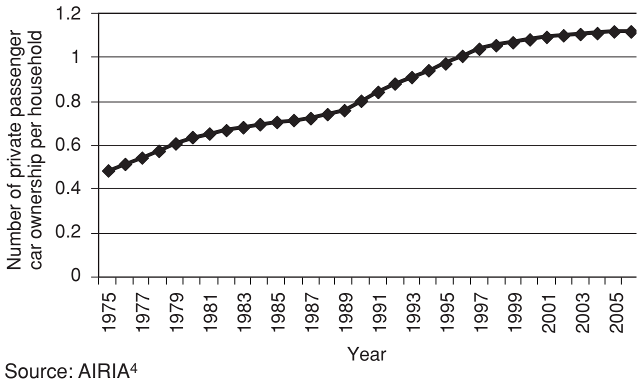


Source: AIRIA[1]

Fig. 1 Historical trend of the number of cars and motorcycles owned in Japan

The total population of Japan in 2006 was 127 million[2]. On average, the car ownership ratio is 59%, and the motorcycle ownership ratio is 2.6%, indicating that cars are particularly widespread. Meanwhile, driving license holders have grown from 28 to 79 million over the period of 1971-2006[3].

The greater demand for cars had a great impact on car usage behaviors of individuals and car ownership behaviors of households. (Discussions on car usage behaviors of individuals are given in section 4.) Concerning household car ownership, Figure 2[4] shows the trend of household car ownership in Japan over the period of 1975-2006. In the mid-1970s, household car ownership was reported to be 0.5. It has been increased to 1.0 car per household in 1996 and then up to 1.112 cars per household in 2006, reflecting the demand for multiple car ownership within households. Meanwhile, the population composition in Japan has been changing over the years. The elderly population (65 years old and over) increased from 7.16% (in 1971) to 20.82% (in 2006)[2, 5]. This may cause



Source: AIRIA[4]

Fig. 2 Historical trend of number of private passenger car ownership per household

significant changes to household characteristics in Japan.

The analysis is based on data collected in the Nagoya metropolitan area (hereinafter sometimes abbreviated to "NGO"), which is the third largest metropolitan area in Japan. Greater explanation on the metropolitan area is given in section 4. Three issues motivating this research are explained in the following paragraphs.

First, the relationships between 'the accessibility related to public transportation, cars, and motorcycles' and 'cars and motorcycles ownership' are analyzed. When a household owns cars or motorcycles, the accessibility related to public transportation is important, and sometimes the household decides not to own cars or motorcycles in case that accessibility is better. In addition to the accessibility related to public transportation, the accessibility related to cars and motorcycles can also be one of the factors in decision making. That is, the relative importance between the accessibility related to public transportation and the accessibility related to car and motorcycle accessibility can be one of factors in decision making. In order to control vehicle ownership, accessibility is one of the key determinants, and analyzing the relationships between the accessibility and vehicle ownership levels can be useful to find a better transportation policy. The authors' hypothesis is that accessibility measures have some effects on car and motorcycle ownership (Hypothesis 1).

Second, the relationships between car and motorcycle ownership are analyzed. Both cars and motorcycles are private transportation modes, but their characteristics are different. Cars are relatively expensive, while motorcycles are relatively inexpensive. Cars provide closed private space, while motorcycles do not. Cars are suitable for longer trips, while motorcycles are suitable for shorter trips. That is, both have relative advantages and disadvantages. Understanding the relationships between car and motorcycle ownership (complementary or substitutability relationship) can bring insights into useful policy measures. The authors' hypothesis is that there is some relationship between car and motorcycle ownership (Hypothesis 2).

Third, household car and motorcycle ownership behaviors are analyzed inter-temporally. The models are developed using data collected in 1981, 1991, and 2001, implying that long-term dynamics of car and motorcycle ownership are identified. As the economy grows and as the population characteristics change, car and motorcycle ownership behaviors can be changed. Inter-temporal analysis brings insights into the household behavioral change, and temporal transferability analysis brings insights into the model predictability. The authors' hypothesis is that car and motorcycle ownership changes over time (Hypothesis 3).

Finally, analyzing the three points above simultaneously brings additional insights. The relationships between the accessibility and car and motorcycle ownership (the first point) and the relationships between car and motorcycle ownership (the second point) can change over time. Understanding the long-term dynamics in developed countries will bring insights for predicting future ownership behaviors where vehicle ownership is now growing. (The public transportation service in Japan in urban areas is very high, but the service in developing countries is now growing. Land use policy in Japan is not suitable for a compact city, and suburbanization often happens.) When analyzing cities where motorcycles are very popular, such as in Asian developing countries, the long-term dynamics of relationships between car and motorcycle ownership behaviors are useful. In Asian developing countries, the motorcycle is treated as a main mode as well as an intermediate mode before switching to car ownership. In Japan, a motorcycle might be considered as a complementary mode. Applying the findings of this study to developing countries can be a challenging task.

The following is the paper structure. Section 2 explains existing studies and clarifies the need for the study. Section 3 describes the modeling framework, accessibility measures, and car and motorcycle ownership model (bivariate ordered probit model). Section 4 depicts the data used in the study. In section 5, estimates are presented and model transferability is evaluated. In section 6, concluding remarks are presented.

2. PREVIOUS STUDIES ON VEHICLE OWNERSHIP AND THE NEED FOR THE STUDY

Even though a number of investigations on vehicle ownership and usage were conducted on an aggregate and disaggregate basis from decades[6-9], car ownership and usage continue to grow causing deterioration the local and global environments. Decisions of vehicle ownership are usually made at the household level (or an outcome of interactions of household members), and the disaggregate approach is therefore selected as an appropriate technique for modeling vehicle ownership[10-14]. In the vehicle ownership models, the number of cars or motorcycles owned by a household is generally used as the dependent variable, and the explanatory variables may include all other household related information, for example, number of household members, household income, availability of transit, number of workers in the household, and information about household members including gender, age, and occupation.

The disaggregate vehicle ownership models developed in the past can be divided into two main categories: 1) Non-ordered discrete choice model like multinomial logit model considering number of vehicles owned as discrete values[11]; and 2) Ordered response model assumes a latent propensity measure to determine the level of vehicle ownership[11, 12, 14]. Non-ordered discrete choice models are more flexible than ordered response models in the error structure among alternatives in the choice set. Bhat and Pulugurta[11] compared multinomial logit model and ordered response logit model, and suggest that the non-ordered discrete choice model outperforms the ordered response model from the viewpoint of goodness-of-fit with their dataset. However, the non-ordered discrete choice models cannot properly account for the ordinal nature of the number of vehicles owned. That is the reason why many researchers have applied the ordered response model for investigating household vehicle ownership. The count model is also capable of considering the ordinal nature, but the application of the count model in the field of vehicle ownership is rare. One of the exceptions is work by Zhao and Kockelman[15], who applied a multivariate negative binomial model of the number of vehicles by type. They obtained reasonable estimation results with their dataset, showing the applicability of the model structure. The comparison between the ordered response model and the count model remains a further research task.

The first aim of this study was to analyze the relationships between accessibility and car and motorcycle ownership. The impact of accessibility on car and motorcycle ownership is believed to be high; many models include accessibility as one of the explanatory variables. For example, Chu[12] considered an accessibility index using travel times between origins and destinations by each mode which are weighted by the number of workers in destination zones. The relative importance of these accessibility measures is introduced as explanatory variables. However, there are only a few attempts to quantify accessibility measures taking into account individual travel behavior in the framework of the disaggregate model. In our study, accessibility measures are calculated based on expected maximum utility of mode choice models and are adopted as explanatory variables of car and motorcycle ownership models. The accessibility calculated in this study does not pose any endogeneity problem. When we calculate the mode choice model, no information of vehicle ownership is used. This is the great advantage of this paper from a theoretical viewpoint.

The second aim of this study was to analyze the relationships between car and motorcycle ownership. Most of the previous investigations on vehicle ownership have paid attention only to car ownership[11, 12, 14]. The disaggregate models that analyze both car and motorcycle ownership in households are often technologically advanced as to take account of interdependencies between them even though such attempts are rare in the travel behavior context due to modeling complexities. It can be reasonable to assume that there are some relationships between car and motorcycle ownership because both are personal mobility tools. Accordingly, the authors expect that joint modeling can bring further insights. One of the limited examples analyzing car and motorcycle ownership simultaneously is Lee and Shiaw[16] where diffusion modeling techniques were adopted. Another example is Senbil et al.[17], who applied the bivariate ordered probit (BOP) model to car and motorcycle ownership modeling for Jabotabek (Indonesia), Kuala Lumpur (Malaysia), and Manila (Philippines) metropolitan areas. An earlier work using the BOP model can be found in Scott and Axhausen[18], where the BOP model was applied to analyze the relationship between season tickets and cars, season tickets and small cars, and season tickets and large cars. The BOP model has been found to be an appropriate modeling technique for this paper over the commonly used multinomial logit (MNL) model with independence of irrelevant alternatives (IIA) restrictions. Our study develops bivariate ordered probit models taking into account the interdependencies between car and motorcycle ownership.

The third aim of this study was to analyze long-term dynamics of household car and motorcycle ownership behaviors. Pendyala et al.[14] modeled the vehicle ownership as an ordered response probit model at six time points to observe the income elasticity of car ownership over time. According to their investigation, the relationship between car ownership and income is changing over time, and the changes varied by the type of household structure. However, the data used in Pendyala et al.[14] were collected over only a six year period, and studies analyzing 20 years are rare. Our study analyzes the long-term dynamics of ownership behaviors over 20 years. Our study also analyzes the long-term temporal transferability of the models estimated.

3. MODELING FRAMEWORK

3.1 Overview

In order to achieve the objectives, the analysis was conducted in four steps as follows:

1 Estimate mode choice models to analyze the travel demand (MNL models, on a trip basis);
2 Calculate accessibility measures based on expected maximum utility of mode choice models estimated in step 1;
3 Estimate car and motorcycle ownership models including accessibility measures calculated in step 2 as explanatory variables (BOP models, on a household basis); and
4 Repeat step 1 through 3 for each time point, compare results inter-temporally, and investigate temporal transferability.

In the following subsections, theoretical backgrounds that relate to the calculation of accessibility measures and BOP modeling are explained.

3.2 Accessibility

Accessibility measures (log-sum term) are calculated based on the utility functions of mode choice models (MNL model estimated step 1 shown in subsection 3.1). The maximum utility, log-sum term, can be used as accessibility measures[10]. Readers note that log-sum values represent not the sum of the utility of each mode but the expected highest utility of each mode. According to existing studies, accessibility measures are based on both of 1) an attractiveness of the location, and 2) a resistance factor of traveling. Sánchez-Silva et al[19] mention that many researchers define accessibility measures based on these two factors. Chu[12] uses this kind of accessibility measure in the car ownership model. The following are considered for individual n residing in zone z_n, where z_n = 1, …, Z, and Z : number of zones in the study area.

a) accessibility by transit:

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

b) additional accessibility of car and motorcycle availability:

b1) additional accessibility of car availability

$$WAAC_n = \sum_{z=1, z\neq z_n}^{Z} \left[w_{RBCz} \ln\left(\exp\left(V_{Rzn}\right) + \exp\left(V_{Bzn}\right) + \exp\left(V_{Czn}\right)\right) - w_{RBz} \ln\left(\exp\left(V_{Rzn}\right) + \exp\left(V_{Bzn}\right)\right) \right] ; \quad \text{and} \tag{2a}$$

b2) additional accessibility of motorcycle availability

$$WAAMC_n = \sum_{z=1, z\neq z_n}^{Z} \left[w_{RBMCz} \ln\left(\exp\left(V_{Rzn}\right) + \exp\left(V_{Bzn}\right) + \exp\left(V_{MCzn}\right)\right) - w_{RBz} \ln\left(\exp\left(V_{Rzn}\right) + \exp\left(V_{Bzn}\right)\right) \right] . \tag{2b}$$

where:

$$w_{RBz} = \left(Q_{Rz} + Q_{Bz}\right) \Big/ \sum_{z=1, z\neq z_n}^{Z} \left(Q_{Rz} + Q_{Bz}\right) , \tag{3a}$$

$$w_{RBCz} = \left(Q_{Rz} + Q_{Bz} + Q_{Cz}\right) \Big/ \sum_{z=1, z\neq z_n}^{Z} \left(Q_{Rz} + Q_{Bz} + Q_{Cz}\right) , \tag{3b}$$

$$w_{RBMCz} = \left(Q_{Rz} + Q_{Bz} + Q_{MCz}\right) \Big/ \sum_{z=1, z\neq z_n}^{Z} \left(Q_{Rz} + Q_{Bz} + Q_{MCz}\right) . \tag{3c}$$

where, V_{Rzn}, V_{Bzn}, V_{Czn}, and V_{MCzn} denote the systematic component of the utility functions when individual n travels from zone z_n to zone z by rail, bus, car, and motorcycle, respectively. 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. (Only destination zones are mentioned in the suffix of V, w, and Q. The origin zones are always the residing zone of individual n, that is, z_n, and are removed for simplicity.)

The accessibility measures considered here are defined in Eqs. (1) and (2) and are called weighted accessibility. The ratio of trip records are used as an indicator of the attractiveness, assuming that a more attractive area has more trip records. If the attractiveness in the entire study area is considered, the number of trip generations and attractions to and from the entire study area should be considered. However, in Eqs. (1) and (2) the number of trip records to and from a residing zone is considered, since the survey area of the case study city is very large (see section 4). One of the disadvantages of this accessibility indicator is that, when the trip records are concentrated in the area close to the residing zone, the area which is very attractive but not traveled to and from the residing zone is not included in the calculation. More theoretically, mode and destination choice models can be estimated to calculate weights, but for simplicity travel record data are used in this study.

On the other hand, cases where the weights w_{RBz}, w_{RBCz}, and w_{RBMCz} are set to unity are also considered. (Accessibility measures are denoted as AT_n, AAC_n, and $AAMC_n$, respectively, removing the initial letter W in Eqs. (1) and (2). These are called non-weighted accessibility measures in contrast with weighted accessibility measures.) In the non-weighted accessibility, accessibility to any destination in the study area is equally evaluated. Therefore this accessibility is a potential accessibility where the zones in the entire study area have the same attractiveness. However, one of the disadvantages of this accessibility is that, even zones which are not included in the choice set due to long distance from the residing zone or have low attractiveness have an equal weight. (However, in this study, all zones are in the metropolitan area, and we consider that there might be a chance that all zones are in the choice set.)

Weighted and non-weighted accessibility have different characteristics. However, in both cases accessibility by transit accounts for a convenience of transit at the residing zone. The other two additional accessibilities indicate the travel convenience if the individual can use these alternatives in addition to transit which is usually available to all citizens. The lower accessibility by transit and the higher additional accessibility will lead to higher intensity of vehicle ownership.

3.3 Bivariate ordered probit (BOP) model

In the presentation of the model structure in this subsection, for each household (h = 1, 2, …, H), let j represent the number of cars owned (j = 0, 1, …, J), and let k represent the number of motorcycles owned (k = 0, 1, …, K). The equation system can be written here as:

$$y_{1h}^* = \boldsymbol{\beta}_1'\mathbf{x}_{1h} + \varepsilon_{1h}, \quad y_{1h} = j \quad \text{if } \mu_{1,j} < y_{1h}^* \le \mu_{1,j+1} \tag{4a}$$

$$y_{2h}^* = \boldsymbol{\beta}_2'\mathbf{x}_{2h} + \varepsilon_{2h}, \quad y_{2h} = k \quad \text{if } \mu_{2,k} < y_{2h}^* \le \mu_{2,k+1} \tag{4b}$$

where y_{1h}^* and y_{2h}^* denote the propensity for household h to own cars and motorcycles respectively. y_{1h} and y_{2h} denote the observed number of cars and motorcycles owned by household h respectively. The $\mathbf{x}_{1h}$ and $\mathbf{x}_{2h}$ are vectors of exogenous variables. The $\boldsymbol{\beta}_1$ and $\boldsymbol{\beta}_2$ are corresponding vectors of parameters that are estimated with the threshold values (i.e. the $\boldsymbol{\mu}_1$ and $\boldsymbol{\mu}_2$). 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 interactions between the number of cars owned and the number of motorcycles owned by a household can be incorporated into Eq. (4). In the BOP modeling approach, interactions can be divided into observed and unobserved ones. An observed interaction (hereinafter called interaction) is a direct relationship between car and motorcycle ownership. In this study, specifically, the numbers of cars owned and motorcycles owned are tried to be included in the functions of motorcycle ownership and car ownership respectively. On the other hand, unobserved interaction (hereinafter called correlation) can be found in the error correlation between car and motorcycle ownership propensity functions. That is, unobserved factors that influence car ownership can be correlated with those that influence motorcycle ownership. A standard normal bivariate distribution function is specified such that:

$$\phi_2(\bullet) = \phi_2\left(\varepsilon_{1h}, \varepsilon_{2h}, \rho_{\varepsilon_{1h},\varepsilon_{2h}}\right) \tag{5}$$

Likewise, the corresponding cumulative density function is given as:

$$\Phi_2(\bullet) = \Phi_2\left(\varepsilon_{1h}, \varepsilon_{2h}, \rho_{\varepsilon_{1h},\varepsilon_{2h}}\right) \tag{6}$$

ρ represents the correlation between the random error terms.

From Eqs. (4) and (6), the joint probability that the household h will own j cars and k motorcycles is:

$$\begin{aligned} P_{hjk} = {} & \Phi_2\left[\mu_{1,j+1} - \boldsymbol{\beta}_1'\mathbf{x}_{1h}, \mu_{2,k+1} - \boldsymbol{\beta}_2'\mathbf{x}_{2h}, \rho_{\varepsilon_{1h},\varepsilon_{2h}}\right] \\ & - \Phi_2\left[\mu_{1,j} - \boldsymbol{\beta}_1'\mathbf{x}_{1h}, \mu_{2,k+1} - \boldsymbol{\beta}_2'\mathbf{x}_{2h}, \rho_{\varepsilon_{1h},\varepsilon_{2h}}\right] \\ & - \Phi_2\left[\mu_{1,j+1} - \boldsymbol{\beta}_1'\mathbf{x}_{1h}, \mu_{2,k} - \boldsymbol{\beta}_2'\mathbf{x}_{2h}, \rho_{\varepsilon_{1h},\varepsilon_{2h}}\right] \\ & + \Phi_2\left[\mu_{1,j} - \boldsymbol{\beta}_1'\mathbf{x}_{1h}, \mu_{2,k} - \boldsymbol{\beta}_2'\mathbf{x}_{2h}, \rho_{\varepsilon_{1h},\varepsilon_{2h}}\right] \end{aligned} \tag{7}$$

The parameters to be estimated 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 $\boldsymbol{\beta}_1$, $\boldsymbol{\beta}_2$, and ρ. The parameters are obtained by maximizing the log-likelihood function:

$$L^* = \sum_{h=1}^{H} \sum_{j=0}^{J} \sum_{k=0}^{K} Z_{hjk} \ln P_{hjk} \tag{8}$$

where:

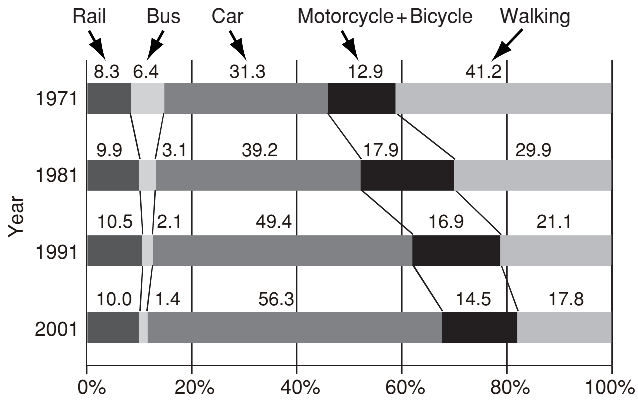
$$Z_{hjk} = \begin{cases} 1\text{: if the household } h \text{ owns } j \text{ cars and } k \text{ motorcycles;} \\ 0\text{: otherwise.} \end{cases}$$

As mentioned above, one of the advantages of the BOP model is its ability to consider interaction and correlation.

4. CASE STUDY CITY

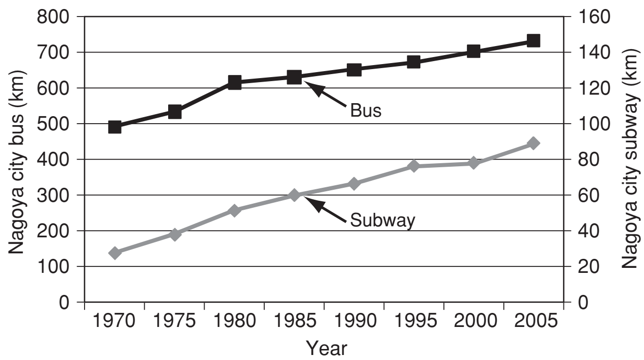
The case study city selected is the Nagoya metropolitan area, which is the third largest metropolitan area in Japan. The core of the metropolitan area is Nagoya city, and some satellite cities are located around Nagoya. Nowadays, Nagoya metropolitan area has a 40 km radius. Although the area is very urbanized, the characteristics related to transportation are very unique. Figure 3 shows the transition of line-haul modal split from 1971 to 2001 in the Nagoya metropolitan area[20]. The rail share was found to be stable during the period of 1971-2001. It is understood that the bus share has been decreasing with time. There was a significant increase in the car share from 1971 to 2001. While the motorcycle and bicycle share have remained stable, the walking share has been decreasing during that period. When limiting to shares of motorized modes, the car shares are increasing much more, and the rail and bus shares are shrinking much more. (Rail, bus, car, and motorcycle are considered as motorized modes, but motorcycle and bicycle cannot be separated in these statistics.) Suburbanization in the Nagoya metropolitan area can cause significant rise in car usage. In addition, compared to other metropolitan areas in Japan, car use in the Nagoya metropolitan area is significant. In the Tokyo metropolitan area, the largest metropolitan area in Japan, the car share was 33.1% in 1998; and in the Osaka metropolitan area, the second largest metropolitan area, car share was 31.7% in 2000[20]. Meanwhile, the Nagoya city government has invested a lot of money and has increased the service level of the public transportation. Operating kilometers of the Nagoya city subway line in 2005 was more than three times compared to that in 1970; and operating kilometers of the Nagoya city bus service in 2005 was almost 1.5 times compared to that in 1970 (Fig.4)[21, 22]. In addition to the Nagoya city government, JR (Japan Railways) and some private companies, for example, Meitetsu and Kintetsu, operate railway services. There also exists some bus companies which operate buses in the metropolitan area. There is a considerable gap between the public transportation investment and the public transportation usage, suggesting that motorization is overwhelming (Fig.3 and Fig.4).

The data used in this study is a household travel survey conducted in 1971, 1981, 1991, and 2001. A brief description of the survey is shown in Table 1[23]. Due to the urban area expansion and the policy of the survey designers at that time, the survey area is changed. In this study, the analysis is limited to the 1971 survey area, which has been included in all four survey time points. Since motorcycles and bicycles were in the same category in 1971, the analysis of 1971 was omitted in the car and motorcycle ownership models. However, the mode choice models are estimated for all four time points for comparison purposes. The dataset consists of information on household vehicle ownership, information on household members, all trip records of household members made on the date of the survey. Descriptive statistics of the explanatory variables used in the mode choice models and BOP models are shown in Table 2 and Table 3 respectively. Table 2 is statistics based on trip makers. Travel time information is



Source: CTSTKK[20]

Fig. 3 Transition of line-haul modal split in the Nagoya metropolitan area



Source: TBCN[21, 22]

Fig. 4 Operating kilometers of the Nagoya city bus and Nagoya city subway

Table 1 Household travel survey in Nagoya metropolitan area

Survey year	1971	1981	1991	2001
Population (million)*	6.11	7.79	8.10	9.04
Survey area (km^2)	4,096	5,656	5,173	6,696
Number of households surveyed	67,475	102,266	81,178	97,543

* Population is people aged 5-year-old and over.
Source: CTSTKK[23] (population and survey area)

Table 2 Descriptive statistics for the variables used for mode choice models

	NGO71		NGO81		NGO91		NGO01	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Travel time (Rail) [hr]	0.595	0.420	0.637	0.407	0.606	0.419	0.563	0.405
Travel time (Bus) [hr]	0.483	0.359	0.372	0.360	0.303	0.348	0.289	0.357
Travel time (Car) [hr]	0.460	0.245	0.460	0.268	0.475	0.268	0.438	0.256
Travel time (MC) * [hr]	--	--	0.171	0.204	0.188	0.233	0.173	0.192
Male	0.689	0.463	0.679	0.467	0.594	0.491	0.551	0.497
Age ≥ 65	0.020	0.140	0.030	0.170	0.041	0.198	0.101	0.301
City **	0.390	0.488	0.386	0.487	0.312	0.463	0.307	0.461
Student	0.115	0.318	0.116	0.321	0.117	0.322	0.093	0.290
Age ≥ 20	0.863	0.344	0.882	0.323	0.885	0.319	0.921	0.270

* MC denotes motorcycle.
** Central city resident dummy (Nagoya city resident dummy).

Table 3 Descriptive statistics for the variables used for BOP models

	NGO81		NGO91		NGO01	
	Mean	SD	Mean	SD	Mean	SD
Male 20 – 65 (yrs old) *,†	1.025	0.737	0.996	0.633	0.901	0.687
Male – 19, 66 – (yrs old) *,†	0.604	0.825	0.516	0.764	0.419	0.631
Female 20 – 65 (yrs old) *,†	1.091	0.756	1.007	0.672	0.919	0.674
Female – 19, 66 – (yrs old) *,†	0.604	0.810	0.531	0.717	0.441	0.663
Male 20 –29 (yrs old) *	0.219	0.453	0.216	0.435	0.211	0.459
Male – 19, 30 – (yrs old) *	1.410	1.148	1.296	0.970	1.109	0.833
Female 20 – 29 (yrs old) *	0.238	0.460	0.213	0.469	0.202	0.462
Female – 19, 30 – (yrs old) *	1.457	1.201	1.325	0.950	1.158	0.850
Worker *	1.565	1.144	1.613	1.059	1.413	1.060
AT **	−914.443	225.958	−855.503	222.897	−1,136.252	272.757
AAC **	373.691	185.114	425.748	187.159	520.781	243.464
AAMC **	128.726	140.896	99.792	105.112	134.709	139.185
WAT **	−1.996	0.357	−2.031	0.412	−2.591	0.502
WAAC **	1.258	0.437	1.595	0.537	2.105	0.763
WAAMC **	0.140	0.114	0.110	0.104	0.131	0.112

* number of members in the household
** averaged over household members
† Following is applied to NGO01, since the age information is only available in a categorical data.
"Male 20 – 65" will be "Male 20 – 64". "Female 20 – 65" will be "Female 20 – 64".
"Male – 19, 66 –" will be "Male – 19, 65 –". "Female – 19, 66 –" will be "Female – 19, 65 –".

calculated considering availability, and the travel time is not the time of the mode actually chosen. A larger percentage of trip makers are males, which has a decreasing trend, suggesting that females have become more active. People aged 65 years or older make more trips in recent years, suggesting that older people have become more active. The percentage of Nagoya city residents is decreasing, suggesting suburbanization of the population. Slightly fewer student mean and a slightly larger mean of number of people aged 20 years or older in 2001 suggest a low birth-rate. Table 3 shows statistics based on household information. All variables categorized based on age and gender show a decreasing trend, suggesting that household size is decreasing. Concerning accessibility measures, AAC and WAAC is increasing, suggesting that car ownership brings higher additional accessibility.

Although number of private passenger cars owned per household in 2006 was 1.112 in Japan as shown in section 1, the ownership in the Nagoya metropolitan area is surprisingly higher. The Nagoya metropolitan area is constituted by the prefectures of Aichi, Gifu, and Mie. Private passenger car ownership per household is 1.379 in Aichi, 1.694 in Gifu, and 1.506 in Mie[4]. The sample distribution of household car and motorcycle ownership is shown in Figure 5. The number of households owning more than one car is increasing over time, eg., households

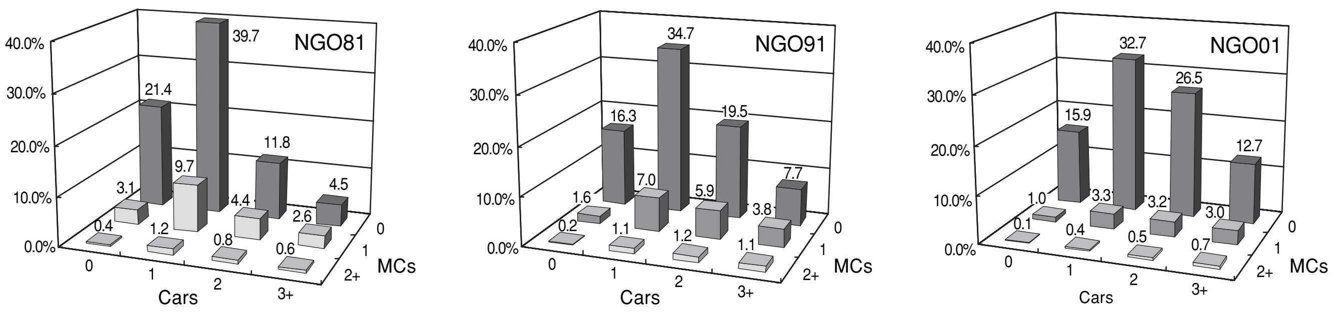


Fig. 5 Sample distributions of vehicle ownership in the Nagoya metropolitan area

owning two cars and zero motorcycle is 11.8% and 26.5% in 1981 and 2001, respectively.

5. EMPIRICAL FINDINGS

5.1 Mode choice models

Estimation results of mode choice models are presented in Table 4. In NGO71-01 models, 15,000 samples are drawn randomly to save computation time. The choice set includes rail, bus, car, and motorcycle, and line-haul modes obtained from the survey are modeled. (Motorcycle is not included in NGO71 model.) In order to make the comparison easier, the models were basically estimated with the same set of explanatory variables. Cost variable was not included, since this information was not available at some time points. (Cost is zero for some trips such as commuting, business purposes since it is compensated by companies. Accordingly, the authors assumed that omitting the cost variable is not critical in the analysis.) Driver's license information is not included because some papers do not include the driver's license ownership, since driver's license ownership and vehicle ownership are so closely related, and regarded as endogenous to some extent.

A visual comparison of the models suggests that their respective parameter estimates show very little difference. All respective parameter estimates of level of service and socio-economic variables have the same signs

Table 4 Mode choice model results

Variable*	NGO71		NGO81		NGO91		NGO01	
	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.
Constant (R)	0	--	0	--	0	--	0	--
Constant (B)	−0.42	−9.8	−1.30	−21.2	−1.54	−19.1	−1.69	−17.3
Constant (C)	−2.15	−24.6	−1.95	−18.2	−1.27	−10.1	−0.66	−4.3
Constant (MC)	--	--	−4.46	−38.8	−4.15	−30.9	−3.90	−23.9
Time [60 min.]	−0.43	−5.7	−1.92	−21.8	−1.95	−23.3	−2.53	−24.7
Male (C, MC)**	2.10	40.5	1.74	24.5	1.49	16.9	1.02	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
City (C)†	−0.64	−16.1	−0.75	−19.2	−0.81	−19.1	−1.02	−23.2
Student (R)	0.63	9.0	0.64	8.3	0.97	11.3	1.04	10.1
Age ≥ 20 (C, MC)**	1.59	23.7	1.36	18.0	1.23	14.5	1.02	9.4
Summary statistics								
N	15,000		15,000		15,000		15,000	
L ($\boldsymbol{\beta}$)	−10,595.2		−10,834.2		−9,254.1		−8,223.8	
L (**0**)	−13,572.4		−15,702.5		−15,140.8		−14,787.2	
Adjusted ρ^2	0.219		0.309		0.388		0.443	

0 in Coef. column indicates a constant term set to zero.
-- in Coef. and *t*-stat. indicates parameter not estimated and *t*-stat. not calculated respectively.
* R, B, C, and MC in parentheses denote rail, bus, car, and motorcycle alternative specific, respectively. No alphabet after variable means generic.
** In NGO 71, variables are alternative specific to car only since the usage of motorcycle is not included in the database.
† Central city resident dummy (Nagoya city resident dummy).

across four models. Travel time has a significant negative effect on all mode usages as expected. In NGO71-01 models, an increasing trend in the magnitudes of travel time estimates indicates a growing importance attached to the travel time. Estimates of constant terms suggest that people hesitate to travel by motorcycle in NGO81-01. An increasing trend of the car constant in NGO suggests the progress of motorization.

Three socio-economic variables were found to have significant effects on car and motorcycle usage. Adult (i. e. 20 – years old) and male dummies have significant and positive effects. Legal age for driving cars is 18 years, and the legal age for driving motorcycles is 16 or 18 years (different for the size of motorcycle); however, adult (i.e. 20 – years old) dummy is used, since the age information is given as categorical data in 2001. This legal system and higher income of adults promote car and motorcycle usage. The attractiveness of cars and motorcycles for males and their higher income levels can explain the presence of the male dummy. The magnitudes of these two estimates are decreasing, suggesting that gender and age differences have become less important. A city dummy has a negative effect on car usage, suggesting that people hesitate to drive in very crowded cities. A growth of motorization and an investment in public transportation network can explain an increasing trend of the magnitude of the city dummy estimate. Also, in central areas accessibility by transit might increase, and this might induce an inclination toward transit.

The other three socio-economic variables were found to have significant effects on public transportation usages. For example, the female dummy has a negative effect on rail usage, suggesting that females are less likely to travel by rail. (This does not mean that females are reluctant to travel by rail. Men are more likely to travel by rail probably for commuting.) Taking into account the positive coefficient estimate of the male dummy for the car and motorcycle, the result suggests that the female has a higher probability of choosing a bus than the male. The smaller magnitude of the estimate in NGO01 can suggest a decreasing trend of the gender difference. Moreover, the student dummy has a significant positive impact on rail usage. The densely constructed railway network in NGO attracts students for rail usage. The investment in the railway network can also explain an increasing trend of the magnitude of the estimate. In addition, the age dummy (i.e. 65 – years old) has a significant positive impact on bus usage. Shorter access and egress times to and from bus stops and free bus tickets, which have been offered to NGO city residents aged 65 years and over by the Nagoya city government since 1973, explain the strong relationship between elderly travel and bus use. The smaller magnitude of the estimate in NGO01 may suggest a decreasing trend of the age difference.

Next, accessibility measures are discussed based on the model estimation results. The model specification in Table 4 suggests that only travel time and the city dummy have an effect on accessibility measures defined in subsection 3.2 when individual socio-economic characteristics are the same. That is to say, regional differences of accessibility measures are heavily dependent on the differences of these two variables. The magnitudes of these two parameter estimates are increasing, suggesting that accessibility measures are becoming sensitive to the differences and changes of these two variables. If travel time is not changed, regional accessibility differences are increasing. When weighted accessibility measures are considered, differences of weights are also found to make an impact.

5.2 Bivariate ordered probit models

In total 12 BOP models are estimated considering type of accessibility measure (4 types) and also a type of correlation and/or an interaction estimation (3 types) (Table 5). Here as an example, the estimation result using weighted additional accessibility of car and motorcycle availability and estimating correlation but not interaction models is shown in Table 6 (D2 in Table 5). (As will be

Table 5 Twelve BOP models considered

	1) Estimating neither correlation nor interaction	2) Estimating correlation but not interaction	3) Estimating both correlation and interaction
(a) Non-weighted accessibility by transit model [AT, AT]*	A1	A2	A3
(b) Non-weighted additional accessibility of car and motorcycle availability model [AAC, AAMC]*	B1	B2	B3
(c) Weighted accessibility by transit model [WAT, WAT]*	C1	C2	C3
(d) Weighted additional accessibility of car and motorcycle availability model [WAAC, WAAMC]*	D1	D2	D3

* [accessibility index included in the function of car ownership, accessibility index included in the function of motorcycle ownership]
Note: A1-D3 will be refereed to later part of the paper.

found in the later part of this subsection, this is the best model for comparison purpose.) In order to make a comparison easier, models are estimated with the same set of explanatory variables and some of the variables not estimated significantly are retained. 1,000 samples were drawn randomly to save computation time. Four categories are set for car ownership, that is, 0, 1, 2, and 3+ cars, and three categories for motorcycle ownership, that is, 0, 1, and 2+ motorcycles based on the information obtained from the databases. NGO71 data was excluded since the number of motorcycles owned was not included in the database.

The choice of explanatory variables was guided by the findings from the existing research and intuitive arguments; that is, explanatory variables include a) accessibility measures (subsection 3.2), b) number of workers in

Table 6 Estimation results of bivariate ordered probit model

Variable	NGO81		NGO91		NGO01	
	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.
Car ownership						
Constant term	−0.66	--	−1.63	--	−0.64	--
Socio-economic characteristics						
Male 20 – 65 (yrs old) *,†	0.38	6.0	0.64	8.8	0.57	7.4
Male – 19, 66 – (yrs old) *,†	0.06	1.6	0.29	6.2	0.41	4.4
Female 20 – 65 (yrs old) *,†	0.03	0.6	0.50	7.6	0.66	9.7
Female – 19, 66 – (yrs old) *,†	0.11	2.5	0.32	6.0	0.54	5.9
Worker *	0.21	4.0	0.40	7.7	0.34	4.9
Accessibility measure						
WAAC **	0.44	4.3	0.59	7.1	0.48	9.2
Threshold values						
One and two cars	1.59	--	1.75	--	1.82	--
Two and three cars	2.48	--	3.08	--	3.22	--
Motorcycle ownership						
Constant term	−1.46	--	−1.67	--	−1.60	--
Socio-economic characteristics						
Male 20 – 29 (yrs old) *	0.22	2.0	0.54	4.9	0.29	2.3
Male – 19, 30 – (yrs old) *	0.06	1.1	0.29	5.5	0.29	2.9
Female 20 – 29 (yrs old) *	0.02	0.2	0.04	0.4	0.13	1.0
Female – 19, 30 – (yrs old) *	0.03	0.6	0.07	1.2	0.15	1.9
Worker *	0.20	3.4	0.15	2.6	0.03	0.4
Accessibility measure						
WAAMC **	1.13	2.7	0.92	2.0	0.26	0.6
Threshold value						
One and two motorcycles	1.26	--	1.07	--	1.03	--
Correlation						
Correlation	0.25	5.7	0.08	1.8	0.04	0.9
Summary statistics						
N	1,000		1,000		1,000	
L($\boldsymbol{\beta}$)	−1,600.60		−1,584.29		−1,420.28	
L($\mathbf{c}$)	−1,781.96		−1,984.31		−1,699.13	
Adjusted ρ^2 ††	0.0945		0.1950		0.1565	

-- indicates *t*-stat. not mentioned.
* number of members in the household
** averaged over household members
† Following is applied to NGO01, since the age information is only available in a categorical data.
"Male 20 – 65" will be "Male 20 – 64". "Female 20 – 65" will be "Female 20 – 64".
"Male – 19, 66 –" will be "Male – 19, 65 –". "Female – 19, 66 –" will be "Female – 19, 65 –".
†† Calculated based on L($\boldsymbol{\beta}$) and L($\mathbf{c}$).

the household, and c) number of household members based on gender and age information. For the car ownership number of males and females aged between 20 and 65 years and those aged less than 20 or over 65 are employed, considering legal age for driving and the lifestyle. For the motorcycle ownership number of males and females aged between 20 and 29 years and those aged less than 20 or over 29 are adopted, considering attractiveness of motorcycles for younger people. (Since the age information is given in categorical data in 2001, ranges of age do not match with the legal age for driving.) The results obtained based on these variable selection provides the best model out of ones estimated. The income variable is not included in the database due to the lack of the information. Driver's license information is not included for the same reason described in mode choice models.

At first, the estimation result of car ownership function was examined. Weighted additional accessibility of car availability was positively and significantly estimated as expected. Most of the socio-economic characteristics are estimated positively and significantly. Ratio of 'Male 20 – 65' to 'Female 20 – 65' and that of 'Male – 19, 66 –' to 'Female – 19, 66 –' suggest that 'Male 20 – 65' is overwhelming in NGO81 but that the difference has been less important in NGO91 and NGO01. The ratio of 'Male 20 – 65' to 'Male – 19, 66 –' and that of 'Female 20 – 65' to 'Female – 19, 66 –' also suggest the decreasing trend of the age difference. The finding suggests that the age and gender differences are becoming less important as motorization proceeds.

Next, the estimation result of motorcycle ownership function was examined. Weighted additional accessibility of motorcycle availability was estimated positively (sometimes significantly and sometimes insignificantly). Accessibility in motorcycle ownership function is estimated less significantly than that in car ownership function. This suggests that the motorcycle ownership is less affected by the accessibility than car ownership. Or the area considered in this study is too large to capture the accessibility of the motorcycle; that is, accessibility used in this study is not appropriate to capture motorcycle ownership from some geographical reason. Socio-economic characteristics are estimated positively and significantly, or sometimes insignificantly. The worker variable is more significantly estimated in car ownership function. This suggests that workers with a high income lead to car ownership. The ratio of 'Male 20 – 29' to 'Female 20 – 29' and that of 'Male – 19, 30 –' to 'Female – 19, 30 –' show that both of male estimates are larger especially for 'Male 20 – 29'. Ratio of 'Male 20 – 29' to 'Male – 19, 30 –' and that of 'Female 20 – 29' to 'Female – 19, 30 –' show that 'Male 20 – 29' has larger or the same values, and that 'Female 20 – 29' smaller values, suggesting that the motorcycles are less attractive for younger females. Although the age categories are set differently compared to car ownership, the age and gender differences in motorcycle ownership are relatively stable over time as motorization proceeds.

A positively estimated correlation suggests the existence of common factors related both to car and motorcycle ownership such as a propensity to own both cars and motorcycles (cars and motorcycles increase together or decrease together, which is counter-intuitive from Figure 5), and/or the common transportation environmental factors that are not completely captured by the accessibility measures, and/or desire for personal convenience, and personal mobility by both transportation modes.

Next, models using all four accessibility measures presented in Table 7 are compared. All models have the same explanatory variables as shown in Table 6 except for accessibility measures, but only estimates of accessibility and correlation are given in the table.

Comparing non-weighted and weighted accessibility models, adjusted goodness-of-fit values indicate that no clear findings are obtained. Comparing accessibility by transit and additional accessibility of car and motorcycle availability models, adjusted goodness-of-fit values indicate that additional accessibility models capture vehicle ownership behavior more efficiently with weighted accessibility measures but accessibility by transit models trap vehicle ownership more effectively with non-weighted accessibility measures. (Comparing the adjusted goodness-of-fit of models (c) with that of models (d), models (d) are better. Comparing the adjusted goodness-of-fit of models (a) with that of models (b), models (a) are better.)

Compared with models estimating neither correlation nor interaction, likelihood ratio test (L1 in the table) indicates that these two kinds of models are not always significantly different. Compared with models with both correlation and interaction, the likelihood ratio test (L2 in the table) indicates that inclusion of an interaction term does not lead to model improvement. Here the number of motorcycles owned is included in the function of car ownership, since this has given a better result than including number of cars owned in the motorcycle ownership function. This suggests that the number of motorcycles does not directly affect car ownership.

To sum up, there is no direct relationship (interaction) between car and motorcycle ownership. This is an interesting finding in Nagoya since households do not consider the number of cars when the household intends

Table 7 Summary of estimation results of bivariate ordered probit model

	NGO81		NGO91		NGO01	
	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.
(a) Non-weighted accessibility by transit model						
AT (C)†	−0.0005	−3.7	−0.0011	−7.7	−0.0007	−6.0
AT (MC)†	−0.0003	−1.3	−0.0006	−2.9	−0.0004	−2.3
Correlation	0.16	3.3	0.08	1.7	0.11	2.0
Adjusted ρ^2	0.0857		0.1697		0.1749	
L1*	11.24		2.90		3.82	
L2**	0.46		0.40		0.08	
(b) Non-weighted additional accessibility of car and motorcycle availability model						
AAC (C)†	0.0006	3.6	0.0009	4.6	0.0008	6.1
AAMC (MC)†	0.0001	0.2	0.0007	1.6	0.0006	2.0
Correlation	0.17	3.5	0.10	2.0	0.13	2.3
Adjusted ρ^2	0.0848		0.1626		0.1748	
L1*	12.18		4.06		4.88	
L2**	0.46		0.22		0.40	
(c) Weighted accessibility by transit model						
WAT (C)†	−0.38	−3.5	−0.53	−5.3	−0.68	−8.5
WAT (MC)†	−0.20	−1.3	−0.27	−2.4	−0.20	−1.8
Correlation	0.24	5.4	0.08	1.8	0.04	0.8
Adjusted ρ^2	0.0909		0.1888		0.1509	
L1*	26.72		2.84		0.58	
L2**	1.42		0.26		0.60	
(d) Weighted additional accessibility of car and motorcycle availability model						
WAAC (C)†	0.44	4.3	0.59	7.1	0.48	9.2
WAAMC (MC)†	1.13	2.7	0.92	2.0	0.26	0.6
Correlation	0.25	5.7	0.08	1.8	0.04	0.9
Adjusted ρ^2	0.0945		0.1950		0.1565	
L1*	28.66		2.88		0.62	
L2**	0.56		0.50		0.82	

* Likelihood ratio test compared to models estimating neither correlation nor interaction.
$\chi^2(.05) = 3.84$. (d.f. = 1).
** Likelihood ratio test compared to models estimating both correlation and interaction.
$\chi^2(.05) = 3.84$. (d.f. = 1).
† C and MC in parentheses denote a inclusion in car and motorcycle propensity functions respectively.

to own a motorcycle, and since households do not consider the number of motorcycles when the household intends to own cars. This can be caused by the much cheaper price of motorcycles in Japan compared to cars. People do not consider the number of motorcycles when they intend to own cars since motorcycles are so cheap. People do not consider the number of cars when they intend to own motorcycles since motorcycles are so cheap. Another interpretation is that the car is so prevalent in Japan, and some of the motorcycles are owned by fiends for motorcycles. For them the number of motorcycles is not important when they intend to own cars, and vice versa. Significant error correlation is interpreted as a complementary relationship between car and motorcycle ownership. The fact can mean that the error correlation suggests that unobserved factors that influence car ownership are positively correlated with unobserved factors that influence motorcycle ownership. An interpretation is that the existence of common factors related both to car and motorcycle ownership such as a propensity to own both cars and motorcycles (cars and motorcycles increase together or decrease together), and/or the common transportation environmental factors that are not completely captured by the accessibility measures, and/or desire for personal convenience, and personal mobility. It can be suspicious that cars and motorcycles increase together or decrease together from Figure 5. Accordingly, the common transportation environmental factors that are not completely captured by the accessibility measures, desire for personal convenience, and personal mobility can be the main reason.

Here the reason why the models shown in Table 6 are the best for the comparison is given. Although no clear findings were obtained concerning the relationships between the accessibility measures and the model fit, weighted additional accessibility of the car and motorcycle availability model was used for comparison since models with this accessibility provide the highest model fit in NGO81 and NGO91. Estimating the correlation but not interaction models were used since inclusion of correlation term leads to substantial model improvement in NGO81 and not significant but slight improvement in NGO91 (t-statistics for correlation is not significant at 5% level but significant at 10% level in model *(d)*). (Six of twelve L1 values are significant in Table 7, in total, suggesting that inclusion of the correlation has some meaning.) An additional inclusion of interaction term has not led to model improvement at all.

Again, estimates of accessibility measures are discussed in Table 7. Accessibility by transit is estimated negatively and additional accessibility of car and motorcycle availability was positively estimated, as expected. More significant accessibility estimates are obtained in the car ownership function than in the motorcycle ownership function.

5.3 Assessment of temporal transferability

Temporal transferability was examined. NGO91 and NGO01 vehicle ownership were predicted using NGO81, and NGO81 and NGO91 models respectively.

Measures to evaluate model transferability can be divided into: 1) tests of model parameter equality, 2) tests of disaggregate prediction, and 3) tests of aggregate – zonal level – prediction[24]. The measures used in this subsection consist of tests of aggregate prediction, since prediction at aggregate level is of a primary interest for policy planners. The measures considered are absolute error (*AE*) of the share, weighted share difference between expected and actual car ownership (*DIFC*), and weighted share difference between expected and actual motorcycle ownership (*DIFMC*). For the calculation of *DIFC* and *DIFMC*, 3+ cars and 2+ motorcycles are dealt with as 3 cars and 2 motorcycles respectively. The weight in the weighted accessibility models is the weight in the application context rather than in the estimation context.

$$AE = \sum_{c,mc} \left| S_{c,mc}(\theta_{t1}) - S_{c,mc}(C_{t2}) \right| \tag{9}$$

$$DIFC = \sum_{c,mc} c \times \left| S_{c,mc}(\theta_{t1}) - S_{c,mc}(C_{t2}) \right| \tag{10}$$

$$DIFMC = \sum_{c,mc} mc \times \left| S_{c,mc}(\theta_{t1}) - S_{c,mc}(C_{t2}) \right| \tag{11}$$

where, $S_{c,mc}(\theta_{t1})$ denotes the predicted share of the household owning c cars and mc motorcycles in $t2$ context using parameter θ_{t1} estimated in the context $t1$. $S_{c,mc}(C_{t2})$ denotes the observed share in the context $t2$.

The results are shown in Table 8. Models used for transferability analysis are estimating correlation but not interaction. However, different accessibility indexes are used. Table 8 (a), (b), (c), and (d) correspond to Table 5 A2, B2, C2, and D2 respectively. Comparison between weighted and non-weighted models (comparison between (a) and (c), and (b) and (d) in Table 8), suggests that many indexes show better transferability in the weighted models. Although in the previous subsection no clear differences were obtained concerning the relationships between accessibility measures and model fit (weighted or non-weighted), the insight that weighted accessibility brings better transferability is obtained except for 01/91 transit. The finding that the NGO91 model predicts NGO01

Table 8 Temporal transferability of vehicle ownership models

t2 / t1 *		(a) non-weighted, transit	(b) non-weighted, additional	(c) weighted, transit	(d) weighted, additional
91 / 81	*AE*	0.367	0.356	0.316	0.316
	DIFC	0.497	0.484	0.451	0.452
	DIFMC	0.124	0.122	0.090	0.088
01 / 81	*AE*	0.735	0.729	0.676	0.643
	DIFC	0.988	0.983	0.939	0.899
	DIFMC	0.120	0.121	0.109	0.093
01 / 91	*AE*	0.524	0.528	0.540	0.507
	DIFC	0.752	0.756	0.770	0.729
	DIFMC	0.111	0.112	0.099	0.092

* *t2*: the year predicted; *t1*: the year model developed.

ownership better than NGO81 model suggests that the model close to the target year can bring better transferability. This is naturally expected since the contexts (population, incomes, behaviors, tastes, and so on) are likely to be more similar in the two closer periods.

6. CONCLUSIONS

This study has built and analyzed BOP models to describe and to predict household car and motorcycle ownership behaviors in NGO. More specifically, the following investigations were conducted: 1) transportation convenience in residential areas on vehicle ownership; 2) interrelationships between car and motorcycle ownership; and 3) inter-temporal comparison of ownership behaviors.

Estimation results of mode choice models developed to calculate accessibility measures suggest that age and gender differences are less important for the modal choice as motorization increases. In other words, anyone can use any transportation mode.

BOP results obtained in this study provided considerable insight into the vehicle ownership behaviors. Both car and motorcycle ownership was affected by the traffic convenience in residential areas. However, accessibility is more significantly estimated in the function of car ownership. This suggests that motorcycle ownership is less affected by accessibility than car ownership, or that the area considered in this study was too large to capture the accessibility of motorcycles. Another accessibility measure to capture motorcycle ownership would be a further research topic. (This paragraph is related to Hypothesis 1 in section 1.)

Concerning the correlation estimates, it was positive but not always significantly estimated. This suggests that in NGO basically there is a complementary relationship between car and motorcycle ownership. An interpretation is that existence of common factors related both to car and motorcycle ownership such as a propensity to own both cars and motorcycles (cars and motorcycles increase together or decrease together), and/or the common transportation environmental factors that are not completely captured by the accessibility measures, and/or desire for personal convenience, and personal mobility. It can be suspicious that cars and motorcycles increase together or decrease together as noted in Figure 5. Accordingly, the common transportation environmental factors that are not completely captured by the accessibility measures, desire for personal convenience, and personal mobility can be the main reason. Including interaction (number of motorcycles in the car ownership function) has not led to model improvement, suggesting that motorcycle ownership does not affect car ownership. (This paragraph is related to Hypothesis 2 in section 1.)

Based on the discussion on temporal transferability, the advantage of weighted accessibility was obtained. The finding that NGO91 model predicts NGO01 ownership better than NGO81 model suggests that the model close to the target year can bring better transferability as expected.

Parameter comparison of the car ownership propensity function suggests that gender and age differences of the ownership are generally becoming less important as motorization proceeds. Parameter comparison of the motorcycle ownership propensity function suggests that males tend to own more motorcycles than females. Higher license ownership of males for motorcycles can also explain this[3]. The age and gender differences for motorcycle ownership were relatively stable over time, although the age categories were set differently. (This paragraph is related to Hypothesis 3 in section 1.)

From the political viewpoint, some implications are suggested. From the BOP models, both car and motorcycle ownership are affected by the traffic convenience in residential areas. Accordingly, investment into the public transportation may have some value to decrease vehicle ownership. Positive correlation suggests that desire for personal convenience or personal mobility can be common in car and motorcycle ownership. Transportation measures which meet personal convenience or personal mobility will be important. Based on the discussion on temporal transferability, weighted accessibility and the model close to the target year can bring better forecasting.

Finally, a future study is recommended by pooling the data of all time points, so as to incorporate the idea of parameter change in the model estimation. Explanatory variables explaining economic conditions can also be included in the model. This can improve model transferability when the model estimated in the developed countries is applied to developing countries. Estimating the model in developing countries is also of interest. (Some of key findings such as complementary relationship can be checked in a different context.) Search for better accessibility measures is required, and some ideas are expected maximum utility of mode and destination choice models, accessibility to work location only, and so on. A simulation study can be a further research topic when the household characteristics are changed and the accessibility measures are changed. Estimating discrete car and motorcycle ownership models and comparing them to ordered models can also be proposed as potential research themes.

REFERENCES

1. AIRIA (Automobile Inspection & Registration Information Association). http://www.airia.or.jp/number/index.html (accessed in June, 2008).
2. PSOSJ (Portal Site of Official Statistics of Japan). http://www.e-stat.go.jp/SG1/estat/List.do?lid=000001010879 (accessed in June, 2008).
3. NPA (National Police Agency). http://www.npa.go.jp/toukei/menkyo/menkyo10/h18_main.pdf (accessed in June, 2008).
4. AIRIA (Automobile Inspection & Registration Information Association). http://www.airia.or.jp/publish/pdf/happyou/2006_08setai.pdf (accessed in June, 2008).
5. PSOSJ (Portal Site of Official Statistics of Japan). http://www.e-stat.go.jp/SG1/estat/List.do?bid=000000090004&cycode=0 (accessed in June, 2008).
6. Button, K., Ngoe, N. and Hine, J. Modeling vehicle ownership and use in low income countries. "Journal of Transport Economics and Policy" 27: pp. 51-67. (1993).
7. Said, G. M. Modeling household car ownership in the Gulf States. "Journal of Transport Economics and Policy" 26: pp. 121-138. (1992).
8. Stanovnik, T. Automobile ownership in Yugoslavia. "Transportation Research" 24A: pp. 113-119. (1990).
9. Vasconcellos, E. A. The demand for cars in developing countries. "Transportation Research" 31A (3): pp. 245-258. (1997).
10. Ben-Akiva, M. and Lerman, S. R. Discrete Choice Analysis. MIT Press, Cambridge. (1985).
11. Bhat, C. R. and Pulugurta, V. A comparison of two alternative behavioral choice mechanisms for household auto ownership decisions. "Transportation Research" 32B (1): pp. 61-75. (1998).
12. Chu, Y. L. Automobile ownership analysis using ordered probit models. "Transportation Research Record" 1805: pp. 60-67. (2002).
13. Dissanayake, D. and Morikawa, T. Household travel behavior in developing countries: nested logit model of vehicle ownership, mode choice, and trip chaining. "Transportation Research Record" 1805: pp. 45-52. (2002).
14. Pendyala, R. M., Kostyniuk, L. P. and Goulias, K. G. A repeated cross-sectional evaluation of car ownership. "Transportation" 22: pp. 165-184. (1995).
15. Zhao, Y. and Kockelman, K. M. Household vehicle ownership by vehicle types: application of a multivariate negative binomial model. Compendium CD-ROM of the 81st Annual Meeting of Transportation Research Board. (2002).
16. Lee, C-K. and Shiaw, M-S. Constrained diffusion models for the prediction of multi-class motor vehicle ownership. Presented at the 7th WCTR, Sydney. (1995).
17. Senbil, M., Zhang, J. and Fujiwara, A. Motorization in Asia – 14 countries and three metropolitan areas –. "IATSS Research" 31(1): pp. 46-58. (2007).
18. Scott, D. M. and Axhausen, K. W. Household mobility ownership: modeling interactions between cars and season tickets. "Transportation" 33: pp. 311-328. (2006).
19. Sánchez-Silva, M., Daniels, M., Lleras, G. and Patiño, D. A transport network reliability model for the efficient assignment of resources. "Transportation Research" 39B (1): pp. 47-63. (2005).
20. CTSTKK (Chuukyou Toshiken Sougou Toshi Koutsuu Kyougikai). http://www.chukyo-pt.gr.jp/persontrip/pdf/h15_pt.pdf (2003) (accessed in June, 2008).
21. TBCN (Transportation Bureau City of Nagoya). http://www.kotsu.city.nagoya.jp/dbps_data/_material_/localhost/_res/about/environment/sibusutikatetu19/P10.pdf (accessed in June, 2008).
22. TBCN (Transportation Bureau City of Nagoya). http://www.kotsu.city.nagoya.jp/dbps_data/_material_/localhost/_res/about/environment/sibusutikatetu19/p18-19.pdf (accessed in June, 2008).
23. CTSTKK (Chuukyou Toshiken Sougou Toshi Koutsuu Kyougikai) Dai 4 kai Chuukyou toshiken pason torippu chousa houkokusho 2-1. (2003).
24. Koppelman, F. S. and Wilmot, C. G. Transferability analysis of disaggregate choice models. "Transportation Research Record" 895: pp. 18-24. (1982).

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