Travel Behavior Analysis
and its Implication to Urban Transport Planning for Asian Cities: Case Studies of Bangkok, Kuala Lumpur, Manila, and Nagoya

ICRA Project Report

Research Project Funded by International Cooperative Research Activity (ICRA)
for the period of two years commencing from November 2001.

Principal Researcher: Takayuki Morikawa (Professor, Nagoya University)

Co-researchers:
Toshiyuki Yamamoto (Assoc. Professor, Nagoya University)
Dilum Dissanayake (Postdoctoral Fellow, Nagoya University)
Nobuhiro Sanko (Graduate Student, Nagoya University)
Shinya Kurauchi (Research Associate, Nagoya University)
Hiroaki Maesoba (Graduate Student, Nagoya University)
Satoko Ohashi (Graduate Student, Nagoya University)
Noriel Tiglao (Uni. Ext. Specialist, University of the Philippines)
Caesar Rubite (Assistant Professor, University of the Philippines)
Michael Rivera (Graduate Student, University of the Philippines)

Graduate School Environmental Studies
Nagoya University
Japan

November 2003

ABSTRACT

Increasing vehicle ownership is becoming a great threat to the urban environment in Southeast Asian Metropolises. Economic growth and its related effects such as increasing income and mobility motivate travelers to own private vehicles. Also, insufficient supply and inferior quality of public transportation may encourage travelers to own and use private vehicles. Even though public transport facilities are getting improvements in most Asian cities with growing economy such as increasing supply and improving quality, there is a considerable gap between demand and supply of transport facilities.

There is a direct relationship between vehicle ownership and ridership on public transport. In a vehicle-based society, public transport services tend to decline in quality. Therefore, investigation of travel demand is very important to understand the future transportation system including expediency and role on public transport.

By considering the mobility crisis in Asia, this study attempts to investigate travel demand, vehicle ownership, and transport policies for Southeast Asian cities of Bangkok, Kuala Lumpur, Manila, and Nagoya. At first, Multinomial Logit Models (MNL) were developed to analyze the travel demand in the cities concerned. Then, the estimation results of the developed travel demand models were successfully used in computing accessibility information for modeling vehicle ownership in Asian cities. In addition to the accessibility inputs, household related vehicle ownership and socio economic data were incorporated for analyzing vehicle ownership in a comprehensive modeling framework. Since car and motorcycle ownership are very high in Asian cities, vehicle ownership models for each city were developed as Bivariate Ordered Response Probit Models (BOPM). Estimation results of the travel demand models and the vehicle ownership models were successfully incorporated to compare the trends of travel demand and vehicle ownership in different Asian cities.

Furthermore, household travel decisions such as vehicle ownership, trip sharing and mode choice in Bangkok Metropolitan Region were modeled as a Nested Logit Model (NL) with two levels to investigate the household travel behavior on mode selection. The upper level of the nesting structure indicates household choices for vehicle ownership decisions and the lower level shows the corresponding mode choice combinations for household travel. Household trip sharing is also included as one of the mode choice options in the NL model. The developed NL model was then applied for integrated transport policies of road pricing, telecommuting and relocation of residences. Policy related impacts were estimated in the reductions of vehicle kilometers of travel and air pollution.

1. INTRODUCTION

1.1 Background

Most of the Asian cities are experiencing severe transport problems resulting from rapidly increasing vehicle ownership and usage. One of the reasons for increasing vehicle ownership and usage 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, travelers' 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 vehicle-based society, public transport services decline in quality. Therefore, investigations of travel demand and vehicle ownership are found as important to understand the future transportation system including expediency and role on public transport.

On the other hand, travelers in Asian countries often create complex travel patterns using private vehicles since the public transportation facilities operate with inefficient and unproductive phase. Accordingly, household members make a joint decision regarding their daily travel by utilizing the household vehicles aiming to cover all travel needs in the household. Therefore, this research investigates individual travel behavior in four Asian cities of Bangkok, Kuala Lumpur, Manila, and Nagoya and household travel behavior in Bangkok Metropolitan Region (BMR) considering the recent variations of travel patterns.

1.2 Objectives of the Research

Considering the severe traffic condition in Asian cities, this study investigates travel demand and vehicle ownership with a comprehensive modeling framework for Bangkok, Kuala Lumpur, Manila, and Nagoya. Accordingly, principal objectives of this study can be stated as follows:

1. Analyzing travel demand in several Asian cities such as Bangkok, Kuala Lumpur, manila, and Nagoya
2. Comparison of travel demand trends in different Asian cities towards a sustainable transport system
3. Analyzing vehicle ownership in Asian cities of Bangkok, Kuala Lumpur, manila, and Nagoya
4. Comparison of vehicle ownership in different Asian cities
5. Analyzing Revealed preference (RP) and Stated Preference (SP) data to investigate travel behavior in Metro Manila
6. Transport policy analysis in Bangkok Metropolitan Region considering road pricing, telecommuting and relocation of residences

1.3 Methodology in Brief

By considering the mobility crisis in Asia, this study attempts to investigate travel demand, vehicle ownership, and transport policies for Southeast Asian cities of Bangkok, Kuala Lumpur, Manila, and Nagoya. At first, Multinomial Logit Models (MNL) were developed to analyze the travel demand in the cities concerned. Then, the estimation results of the developed travel demand models were successfully used in computing accessibility information for modeling vehicle ownership in Asian cities. In addition to the accessibility inputs, household related vehicle ownership and socio economic data were used for analyzing vehicle ownership in a comprehensive modeling framework. Since car and motorcycle ownership are very high in Asian cities, vehicle ownership model for each city was developed as Bivariate Ordered Response Probit Model (BOPM). Estimation results of travel demand models and vehicle ownership models were successfully incorporated to compare the trends of travel demand and vehicle ownership in different Asian cities. Figure 1 explains the framework of this study.

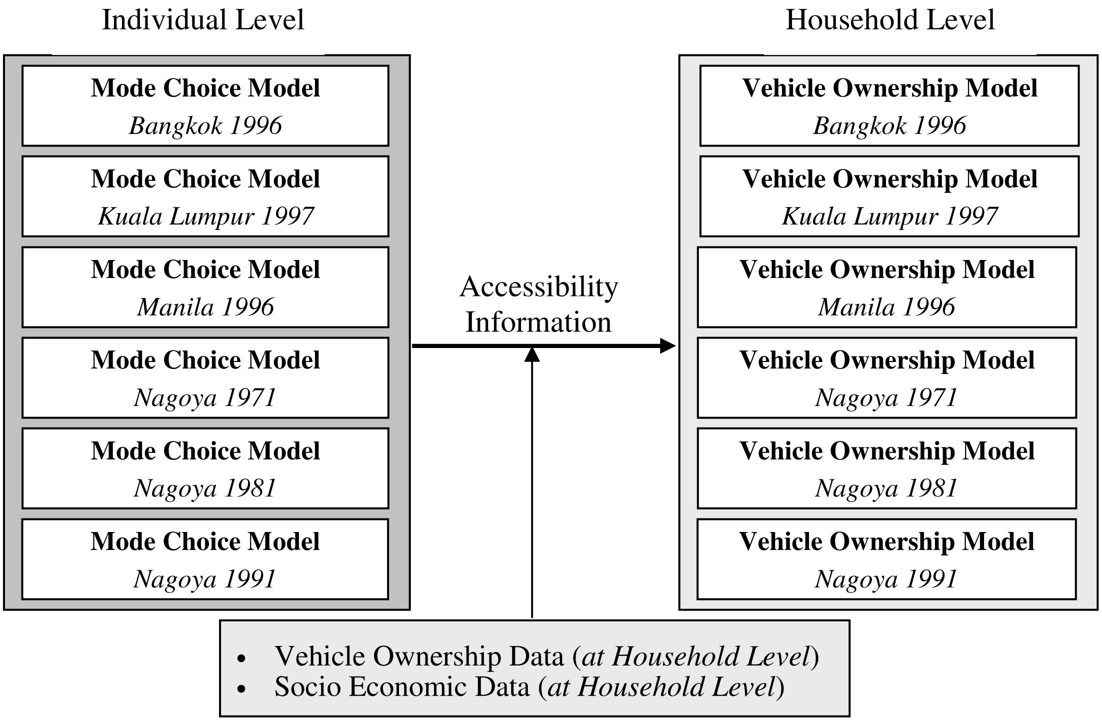

Figure 1: Framework of the study

Furthermore, household travel decisions such as vehicle ownership, trip sharing and mode choice in Bangkok Metropolitan Region were modeled as a Nested Logit Model (NL) with two levels to investigate the household travel behavior on mode selection. The upper level of the nesting structure indicates household choices for vehicle ownership decisions and the lower level shows the corresponding mode choice combinations for household travel. Household trip sharing is also included as one of the mode choice options in the NL model. The developed NL model was then applied for integrated transport policies of road pricing, telecommuting and relocation of residences. Policy related impacts were estimated in the reductions of vehicle kilometers of travel and air pollution.

2. LITERATURE REVIEW

Travel demand modeling has been receiving substantial attention from several decades but the research effort has tended to accelerate in size and scope in recent years. Transport planners, researchers and practitioners are searching reasonable solutions for ever-growing travel demand and its related adverse effects on local and global environments.

Travel demand for different transport services are extremely qualitative due to its dependence on time of day, day of week, journey purpose, frequency, speed and route of travel etc., and therefore, modeling travel demand is identified as a difficult task (*1*). It is clear that travel demand modeling is a potentially important aspect in finding effective solutions for urban transport problems. Considering the situation prevailing in Asian countries, suitable modeling techniques are very important to accommodate the recent variations of travel demand such as aging population, increasing vehicle ownership, varying income levels and growing information technology, which collectively dominate the travel demand at particular point of time. Moreover, modeling urban travel demand is important not only for planning and managing the transportation system but also for investigating the impacts of traffic congestion and environmental pollution due to increasing vehicle usage.

Disaggregate demand modeling is an appropriate tool, which can be successfully adopted for micro-level considerations over individual or household perspectives by describing the travel behavior with discrete variables. In general, disaggregate demand modeling has been closely related with discrete choice analysis (DCA), which is based on the principle of utility maximization (*2*). Among the vast variety of modeling techniques in transportation planning, binomial and multinomial logit (MNL) models are found as the original applications of DCA that have been undertaken with the assumption of the independence from irrelevant alternatives (IIA). Vovsha (*3*) mentioned that there exists an absolute dominance of Multinomial and Nested Logit Models over other mode choice models due to the simple analytical framework.

Dissanayake and Morikawa (*4*) investigated the travel behavior using a MNL model, and conducted several market segmentation analysis based on travel modes and income groups. Hayashi et al. (*5*) developed a MNL model to examine the possibilities of easing traffic congestion in Bangkok with a MRT proposal. According to the results, MRT was found as a positive contribution to the transport system in Bangkok and will earn 41% of the total share in the year 2010. However, 75% of diverted demand to MRT was found to come from previous bus users and the rest is from car users. As proposed by Hayashi et al. (*5*), improving access services to MRT stations would be a great support to attract travelers to MRT.

Vehicle ownership modeling is one of the major areas in transport planning context in developed as well as developing countries due to its uncontrollable effects on the environment. Discrete choice analysis is an appropriate technique for modeling vehicle ownership. Pendyala et al. (*6*) 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. Since mode choice and vehicle ownership are inextricably linked, development of integrated model is important for future investigations on travel demand.

Car ownership and public transport usage is widely investigated topic in transport planning from decades (Dissanayake and Morikawa (*7*); Goodwin, (*8*); Kitamura, (*9*). More recently, Dissanayake and Morikawa (2001) investigated transport policies for developing countries emphasizing *push and pull* concept by implementing vehicle tax for car and motorcycle travel in city centers together with reduction of public transport fares. However, resultant reduction of vehicle travel was reported to be inadequate due to travelers' great preference of using private vehicles use. As mentioned by Goodwin (*8*), the quality of public transport services depends not only on the level of car ownership but also on both the level of car ownership and the relation between changes in the level of car ownership and changes in public transport use. Also, Goodwin (*8*) proposed that longitudinal survey data would be more helpful to investigate such changes than using cross section surveys or aggregate time series data. Kitamura (*9*) also discussed about the importance of analyzing car ownership using the longitudinal data sources rather than accepting the results from cross section based analysis, and conducted an investigation to observe the causal analysis of car ownership and transit use. According to the reported results explains that car use determines transit use but not transit use determines car use.

3. STUDY AREAS

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 Southeast Asia and therefore, investigation of travel demand is found as important for such cities. In addition, Asian city like Nagoya that has efficient transportation system is also considered in the analysis to fulfill the task of comparing cities with different transportation settings. Following sections explain the area based information and brief introduction of the data surveys that have been incorporated in this study.

3.1 Bangkok Metropolitan Region (BMR)

Bangkok Metropolitan Region (BMR) located in the gulf of Thailand serves as a development center to the whole country (Figure 2). Bangkok has developed substantially for several decades providing successful outcomes on infrastructure, industry and business sectors. Especially, the construction industry has flourished, with plenty of residences, commercial and business premises, hotels and department stores, to face for the economic development. Additionally, employment opportunities have increased and many people from other areas of Thailand gathered to Bangkok continuously to search suitable jobs. Finally, Bangkok has turned into a mixed society with different origins and cultures. A variety of occupations create remarkably varied income levels, and life patterns there are quite different among each other as a result. In contrast, people who live in Bangkok have comparatively higher incomes than that in other parts of the country, although incomes are fluctuating with time, according to the uncertainties in the economy.

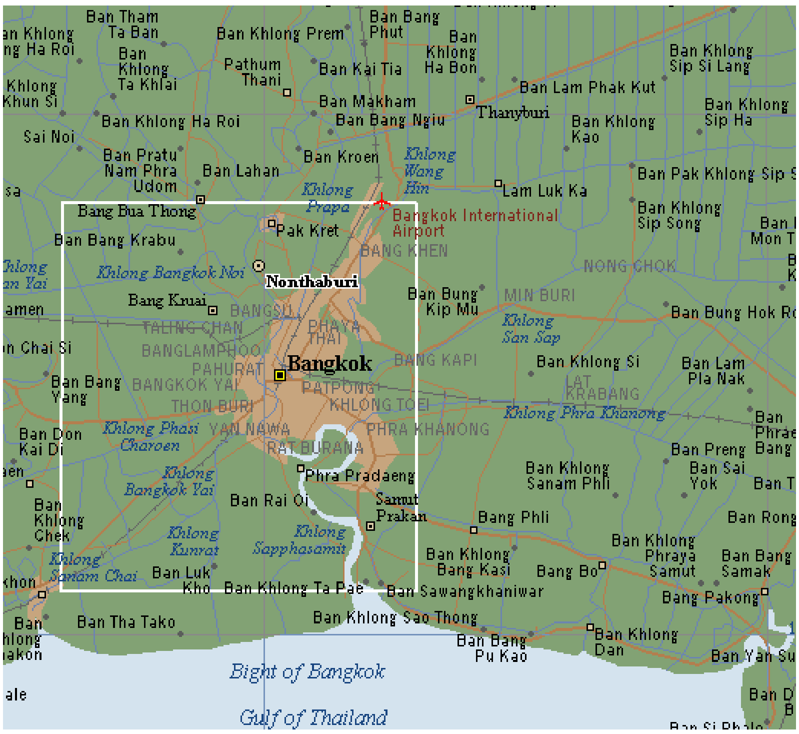

Figure 2 Bangkok Metropolitan Region

Bangkok has numerous rivers and canals, and several decades ago, it was completely a water-based city. During that time, ferry was an effective transportation mode for the travelers, and therefore, it had only a little attention for the development of road infrastructure. In conjunction with the industrial revolution, the city has considerably expanded, and it has been finally changed into a road-based city.

Although, the network of main roads in BMR has been widely spread all over the area, there is still some insufficiency of road infrastructure to meet the demand. Considering the area-wide basis, 80% of land in BMR is privately owned and the possibility of expanding the road infrastructure cannot be expected. Additionally, the insufficient number of bridges spanning over rivers and canals contributes more to the bottleneck effect of the transport network (Kubota, *10*).

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.

The income based vehicle ownership for Bangkok households in year 1995/1996 is shown in Figure 3. 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.

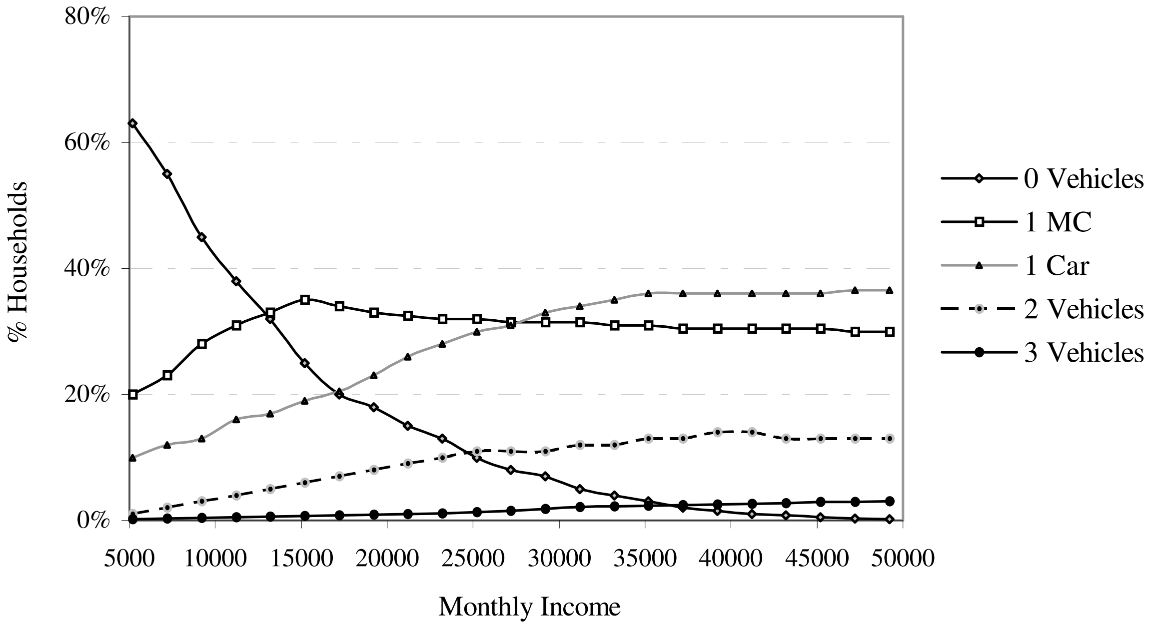

Figure 3 Households Distribution by Income & Vehicle Ownership in Bangkok in 1995/1996
Source: Urban Transport Database and Model Development Project, Final Report (*11*)

The study area covers Bangkok Metropolitan Area[1] (BMA) and five adjacent provinces of Pathum Thani[2], Nonthaburi[3], Nakorn Pathom[4], Samut Sakorn[5] and Samut Prakan[6] (Figure 4).

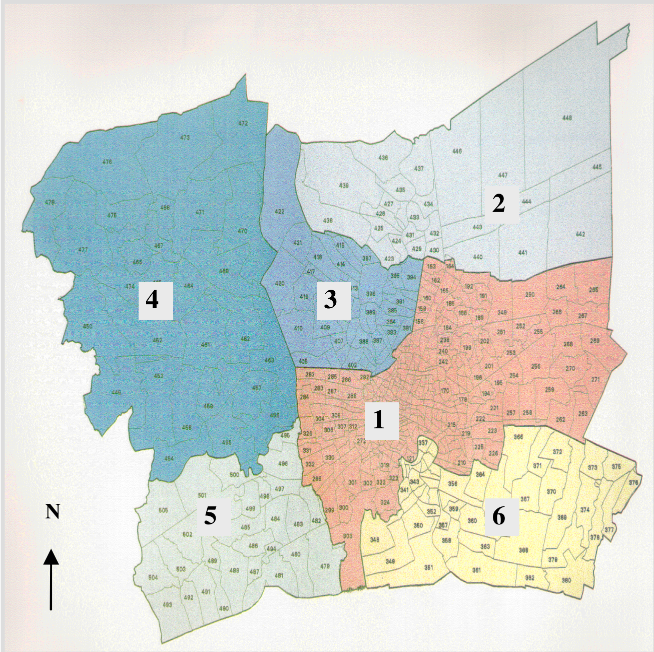

Figure 4 Study Area (BMR)

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. In conjunction with the industrial revolution, city has been expanded considerably. Although the network of main roads in BMR has been widely spread all over the area, there is still some insufficiency of road infrastructure to meet the demand. Due to extremely severe traffic condition in BMR, the average travel speed has been drastically dropped down to 10.9 km/h. In the year 2001, peak hour speed in CBD was estimated to be 5.9 km/h and commuters often caused difficulties to access Bangkok.

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 (*11*). Additional database for home interview survey conducted by Bangkok Environmental Improvement Project (BEIP) was used to strengthen the overall database (*12*).

The survey collected household travel data covering most of the areas in BMR. The database consists of all attributes of the trips that were made on the date of the survey and the information of household members. In the database, each trip was described by the characteristics of mode (unlinked) trips. Location-based information such as trip length was calculated using an Arc-View software, which was helpful for easy reference and meaningful comparison whenever necessary.

3.2 Kuala Lumpur Metropolitan (KLMP)

The study area, Klang Vally Region, covers the Federal Territory of Kuala Lumpur and its conurbation about 10 km from the boundary (Figure 5). Klang Vally area consists of Kuala Lumpur Metropolitan and Selangor state that includes four districts such as Gombak, Klang, Petaling and Ulu Langat. 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%.

Figure 5 Kuala Lumpur Metropolitan

The Malaysian economy has been rapidly expanding since 1987. The expansion of the economy has encouraged rapid urbanisation and motorization. The highest growth of urbanisation and motorisation was observed in Kuala Lumpur and the Klang Valley Region. 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%. Table 1 shows the Vehicle Ownership in Klang Valley region. According to the results of Home Interview Survey, car ownership in the Klang Valley area is estimated at 209 vehicles per 1,000 person, which is approximately 50% higher than the average national level.

Table 1 Vehicle Ownership in Klang Valley Region

	Number of Automobile			Ownership per 1000 person		
District	Motorcycle	Car	Total	Motorcycle	Car	Total
Kuala Lumpu	225,031	289,521	514,552	164	211	375
Gombak	83,143	88,818	171,961	174	186	360
Hulu Langat	110,466	109,829	220,295	194	193	388
Petaling	140,891	192,222	333,113	169	231	400
Klang	99,056	107,356	206,412	190	206	396
Total	658,587	787,746	1,446,333	175	209	383

Source: Home Interview Survey by SMURT-KL (1997)

Change in modal composition in the Klang Vally Region is shown in table 2. 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, as shown in Table 2.

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 %.

Table 2 Change in Modal Composition : 1985 and 1997

	Person Trip (.000)		Composition (%)	
	1985	1997	1985	1997
Private Mode	3,054.2	5,047.4	65.7	80.3
Motor Cycle	*884.2*	*1,492.2*	*19.0*	*23.7*
Car	*2,170.0*	*3,555.2*	*46.7*	*56.6*
Public Mode	1,595.8	1,235.8	34.3	19.7
Stage Bus/Mini Bus	*1,129.9*	*493.9*	*24.3*	*7.9*
Factory Bus/School Bus	*465.9*	*638.7*	*10.0*	*10.2*
Rail	*0.0*	*103.2*	*0.0*	*1.6*
Total	4,650.0	6,283.2	100.0	100.0

Source: 1) SMURT-KL Home Interview Survey, 1997
2) Klang Valley Transportation Study, JICA, 1987

The rapid growth of urbanisation has resulted in a deterioration of the environment in major urban areas, especially in Kuala Lumpur. Traffic congestion, frequent traffic accidents and air pollution in Kuala Lumpur and in its conurbation is a crucial issue, which has been given national priority. Traffic congestion appears mainly in the CBD and on the radial roads surrounding the CBD. Travel speeds on the major roads were observed to be less than 10 km per hour. The existing road network in the CBD is basically poor. Many arterial roads in the area have only four lanes for both directions. Thus, additional roads should be constructed to complement the existing arterial road network, and also to establish an efficient road network. 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. Therefore, traffic management needs to be practical in the short term to alleviate traffic congestion, although continuous efforts should be made for the construction new roads and improvement of the existing roads. Several countermeasures have been proposed such as the introduction of new public transport modes, encouragement of car-pooling, improvement of the bus system, and strict enforcement of traffic regulations.

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" (*13*). The database provides useful information related to households, individual members and person trips.

3.3 Metro Manila

The study area consists of Metro Manila and the adjacent municipalities in the adjoining provinces of Cavite, Laguna, Rizal and Bulacan as shown in figure 6. Metro Manila covers an area of 636 km^2, and metropolitan area is expanding rapidly towards the outer areas covering 3,670 km^2.

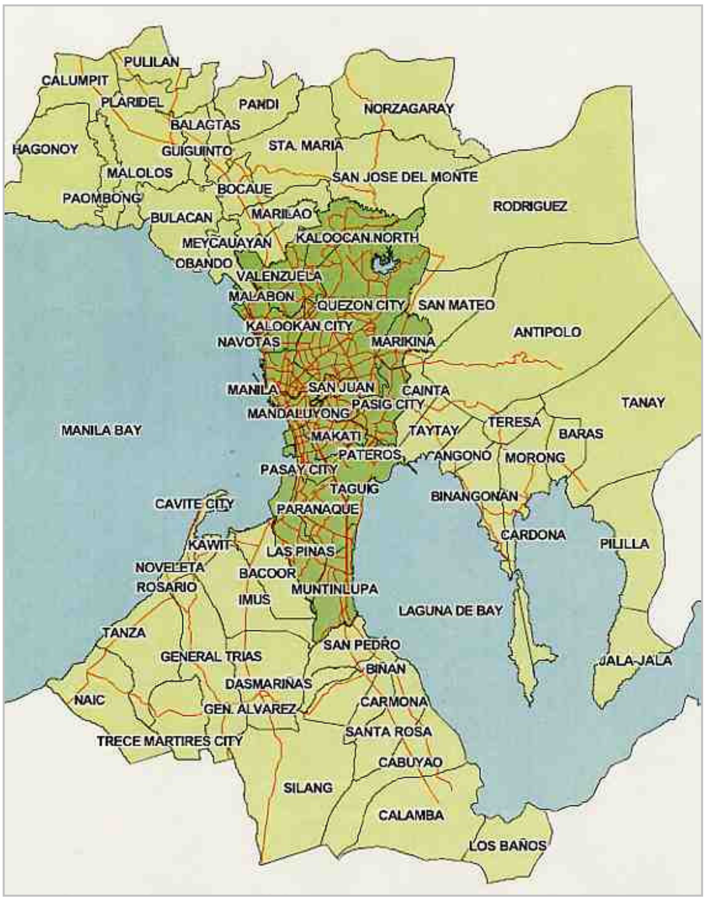

Figure 6 Metro Manila.

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%. Motorization in Metro Manila has been increasing very rapidly with a 6% yearly rate of vehicle registration. More than 40% of the registered vehicles in the Philippines are concentrated in Metro manila. 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) (*14*). 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)

The study area, Chukyo Metropolitan Region (CMR), is a large urban area centering Nagoya City. CMR consists of Nagoya city and the surrounding areas from Aichi, Gifu and Mie prefectures in Japan (Figure 7).

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 and 1991, and the survey peripheries are as shown in figure 8. In the databases for 1971, 1981 and 1991, survey areas considered were found as different such as 5173 km^2, 5656 km^2, 4096 km^2 respectively. There are 396 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.

Figure 7 Chukyo Metropolitan Region.

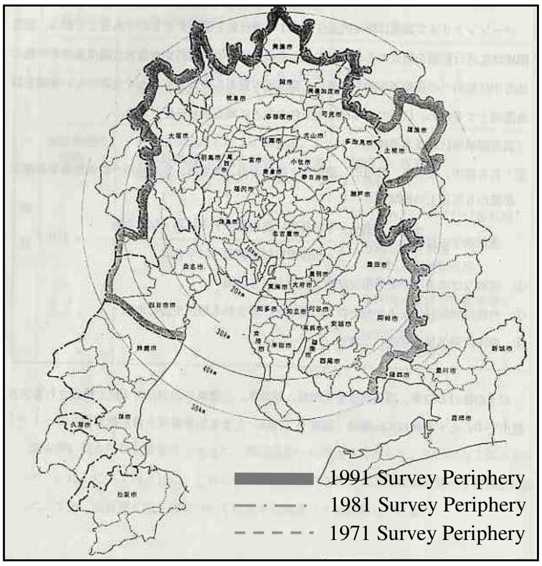

Figure 8 Survey Peripheries

4. DATA DESCRIPTION

4.1 Data Availability

Table 3 describes the available information in the Bangkok, Kuala Lumpur and Nagoya databases. Most of the informations in the databases are explicitly used in the analysis.

Table 3 Data Availability in the Databases from Bangkok, Kuala Lumpur and Nagoya

Data Types	Bangkok 1996	Kuala Lumpur 1997	Nagoya 1971	Nagoya 1981	Nagoya 1991
Area based information					
Area (km^2)	7758	500	4096	5656	5173
No of Traffic Zones	505	244	396	396	396
GDP (US$ billion)	157.1	100.2	-	-	5113.2
Population (million)	13	4	6.2	7.8	8
No of households	-	0.73	1.6	2.3	2.6
Person Trip Information					
Origin zone	O	O	O	O	O
Destination zone	O	O	O	O	O
Journey number	O	O	O	O	O
Trip purpose	O	O	O	O	O
Mode of travel	O	O	Δ	Δ	Δ
Trip start time	O	O	O	O	O
Trip finish time	O	O	O	O	O
Travel time	O	O	O	O	O
Travel cost	O	X	X	X	O
Accompanying persons	O	O	X	X	X
Expressway cost	O	X	X	X	X
Public transport fare	O	X	X	X	X
Parking cost	O	Δ	X	X	X
Income	O	X	X	X	X
Gender	O	O	O	O	O
Age	O	O	O	O	O
Driving license	O	O	O	O	O
Education level	O	X	X	X	X
Occupation	O	O	O	O	O
Work Zone	O	O	O	O	O
Work start time	O	X	X	X	X
Individual’s income	O	X	X	X	X
Household Information					
House type	O	O	Δ	Δ	Δ
No of zones	O	O	O	O	O
No of children	O	O	X	X	X
No of employees	O	O	Δ	Δ	Δ
Income	O	Δ	X	X	X
No of cars owned	O	O	O	O	O
No of motorcycles owned	O	O	X	O	O
Parking	O	X	X	X	X

O Complete Information Δ Partial Information X No information

4.2 Modal Shares

Respective modal shares for all databases are shown in figure 9.

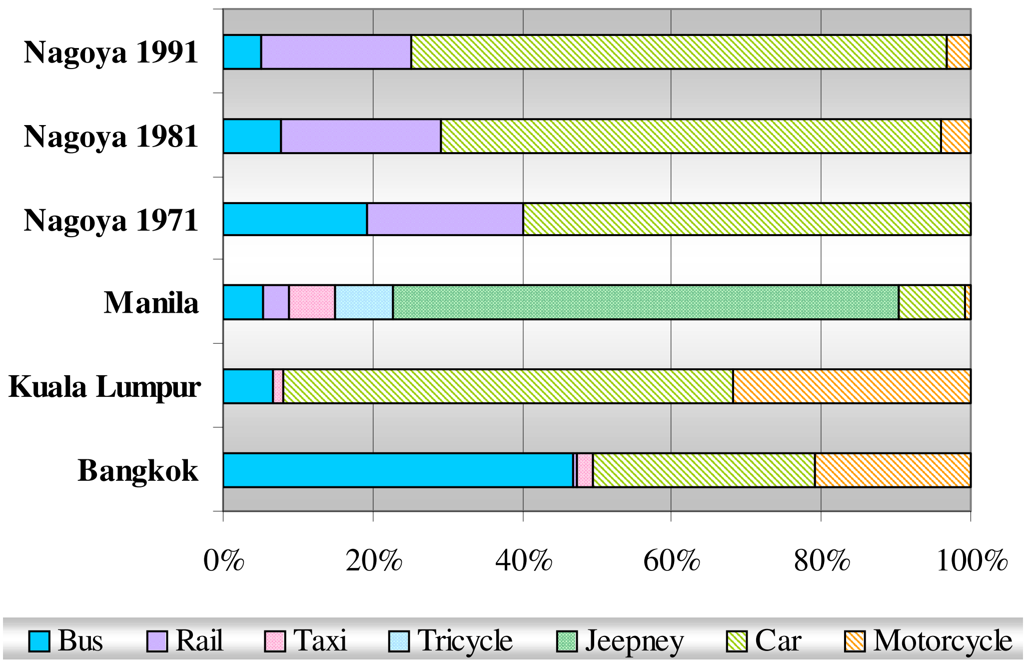

Figure 9 Modal Share Distribution in Southeast Asian Cities

In BMR, available transport modes are bus, taxi, car and motorcycle. Among them, modal share for rail is very low and it may be due to limited accessibility and poor serviceability of rail service. Bus is the most popular transport mode with 46% share. Modal share for car and motorcycle are also very high in the area as observed

The modes available in KLMP are reported as bus, taxi, car and motorcycle. Modal share for car and motorcycle is very high in the region and total share for private vehicle usage is more than 90%. Usage of public transport is observed as very low in the region.

In Manila, there are wide variety of modes such as bus, car, motorcycle, taxi, rail, tricycle and Jeepney, and about 70% of the total shares are made for Jeepney.

In Nagoya 1991 and 1981, modes available are bus, rail, car and motorcycle. But in Nagoya 1971, there are only three modes in the system as bus, rail and car. By observing Nagoya data, it is clear that car usage increases from 60% to 72% during the period of 20 years from 1971 to 1991.

5. MODELING TRAVEL DEMAND

5.1 Model Formulation

In MNL model, utility functions for transport alternatives can be formulated as equation 1.

$$U_{in} = \beta' x_{in} + \varepsilon_i \qquad \text{for all } i \in C_n \tag{1}$$

Where, U_{in} is the utility of transport alternative i for individual n in the database, x_{in} is the vector of attributes in data, β_i' is the vector of unknown parameters, ε_i is the random error, and C_n is the choice set for individual n.

The related MNL model can be written as follows:

$$P_n(i) = exp^{\mu(\beta' x_{in})} \Big/ \sum_{j \in C_n} exp^{\mu(\beta' x_{jn})} \tag{2}$$

Where, $P_n(i)$ is the probability that the individual n chooses alternative i, and μ is a scale parameter.

For the estimation of MNL model, log-likelihood function can be written as equation 3.

$$L = \sum_{n=1}^{N} \sum_{i \in C_n} \left(\beta' \mathbf{x}_{in} - \ln \sum_{j \in C_n} \exp^{\beta' \mathbf{x}_{jn}} \right)_i \tag{3}$$

5.2 Model Estimation and Results

In this study, MNL models are developed for Bangkok, Kuala Lumpur, Manila, and Nagoya. The attributes such as travel time, gender, age, income and occupation are appropriately included in the choice models. Parameter estimation results for the MNL models for Bangkok, Kuala Lumpur, and Manila are shown in table 4. Table 5 presents the estimation results for Nagoya.

In the estimated models for Bangkok, Kuala Lumpur, Manila, and Nagoya, the alternative specific constants for all modes are significantly estimated. Positive significant parameters for bus constant in Bangkok, Kuala Lumpur, and Manila models indicate travelers' attraction for bus mode. In addition, the alternative specific constants for tricycle and jeepney in Manila model are positively significant indicating that those modes are with great attraction.

In Nagoya model, the alternative specific constants for bus, car and motorcycle are significant and negative. Since Nagoya is well facilitated with transit systems such as subway and three main railways of JR (Japan Railway), Meitetsu and Kintetsu that provide customers with efficient transport services, traveler attraction for other modes such as bus, car and motorcycle might be comparatively low.

Table 4. Parameter Estimation Results for Bangkok, Kuala Lumpur, and Manila.

Variables	Parameter Estimates (t-statistics in parenthesis)					
	Bangkok (1996)		**Kuala Lumpur** (1997)		**Manila** (1996)	
Alternative specific constants						
Bus constant	**0.46**	(2.87)	**1.41**	(16.55)	**2.74**	(19.61)
Car constant	**-1.54**	(-9.16)	**-0.39**	(-8.45)	**1.62**	(15.34)
Motorcycle constant	**-0.87**	(-5.13)	-		-	
Rail constant	-		-		**4.24**	(27.53)
Tricycle constant	-		-		**4.09**	(29.88)
Jeepney constant	-		-		**5.22**	(38.62)
Level-of-service variables						
Travel time (hours)	**-0.13**	(-2.93)	**-0.41**	(-3.24)	**-0.12**	(-1.97)
Alternative specific dummies						
Male (*car, motorcycle*)	**0.50**	(12.49)	**0.78**	(7.88)	**1.14**	(18.97)
Age ≥18 (*car, motorcycle*)	**0.69**	(13.76)	**3.89**	(36.43)	**1.21**	(18.97)
Age ≥ 45 (*bus*)	**-0.17**	(-2.84)	**-0.82**	(-2.69)	**-0.51**	(-4.68)
Student (*rail*)	-		-		**-0.45**	(-3.73)
Female (*rail*)	-		-		**-0.42**	(-4.17)
license (*car, motorcycle*)	**1.98**	(42.11)	**1.55**	(34.45)	-	
Number of observations	13691		1530		15000	
$L(\hat{\beta})$	-10315.9		-8420.69		-11741.9	
$L(0)$	-18979.7		-13765.6		-26876.4	
ρ^2	0.46		0.39		0.56	

Table 5. Parameter Estimation Results for Nagoya.

Variables	Parameter Estimates (t-statistics in parenthesis)					
	Nagoya (1971)		**Nagoya** (1981)		**Nagoya** (1991)	
Alternative specific constants						
Bus constant	**-0.21**	(-4.72)	**-1.21**	(-18.22)	**-1.55**	(-17.78)
Car constant	**-1.04**	(-15.38)	**-1.59**	(-18.36)	**-1.67**	(-14.11)
Motorcycle constant	-		**-4.08**	(-16.97)	**-6.58**	(-6.52)
Level-of-service variables						
Travel time (hours)	**-0.55**	(-6.46)	**-1.55**	(-15.97)	**-2.03**	(-21.85)
Alternative specific dummies						
Male (*car*)	**0.64**	(10.42)	-		-	
Male (*car, motorcycle*)	-		**0.87**	(11.31)	**0.99**	(10.08)
Student (*rail*)	**0.65**	(9.69)	**0.56**	(8.30)	**1.11**	(13.59)
Female (*rail*)	**-0.58**	(-9.43)	**-0.84**	(-10.29)	**-0.70**	(-6.57)
Age ≥16 (car, *motorcycle*)	-		-		**2.15**	(2.14)
Age ≥18 (car, *motorcycle*)	-		**1.76**	(7.68)	-	
Age ≥ 65 (*bus*)	**0.36**	(2.49)	**1.07**	(7.91)	**0.89**	(5.82)
License (*car, motorcycle*)	**4.14**	(57.24)	**3.25**	(59.66)	**1.82**	(28.79)
Nagoya residence (*car*)	**-0.59**	(-11.67)	**-0.53**	(-10.59)	**-0.67**	(-13.30)
Number of observations	15000		15000		15000	
$L(\hat{\beta})$	-7822.46		-8327.69		-6956.07	
$L(0)$	-13606.5		-15721.1		-12084.8	
ρ^2	0.42		0.46		0.42	

For all models, coefficients for the travel time are significantly negative as expected. Several dummy variables are considered in the models to understand the travel behavior for different modes.

Estimations for Bangkok, Kuala Lumpur, and Manila reveal that male travelers attraction for car and motorcycle since the corresponding dummy variables were estimated with positive significance. Nagoya model (1971) explains that male travelers' attraction for car use. In addition, estimations of Nagoya models (1981 and 1991) show male travelers' preference for car and motorcycle use. Rail is found as a preferred mode choice among the school children in Nagoya since the related dummy is positive and significant in all estimated models for Nagoya. However female in Nagoya have negative preference on rail.

Travelers' age is also tested as dummies in the models, and when travelers are more than 18 years old, they prefer to use car and motorcycle, as the related parameters are significantly positive for all models. For the travelers in Nagoya who are in or above 65 years old, prefer bus travel. Aged people in Nagoya are offered free transit passes for their daily travel by Nagoya city and this can be the reason for their preference for bus use. In contrast with Nagoya models, Bangkok, Kuala Lumpur, and Manila travelers who are in or above 45 years dislike bus transport, and they may prefer taxi or other paratransit modes for their travel

Driver's license is also analyzed as a dummy variable in Bangkok, Kuala Lumpur and Nagoya models. Having driver's license encourage travelers to use car and motorcycles as the estimated parameters are significantly positive for all cases.

Residing in Nagoya city is also included as a dummy in all Nagoya models and found that travelers who reside in Nagoya city have negative preference to make car trips. Since Nagoya city has a very efficient subway system, it might be very convenient to use subway for city travel instead of using car.

The models estimated are with large number of observations and the goodness of fit measures for all models are found as considerably high.

6. MODELING VEHICLE OWNERSHIP

6.1 Model Formulation

In this study, vehicle ownership was developed as Bivariate Ordered Probit Model (BOPM) and following formulation explains the formulation of the model.

$$y^*_{id,CAR} = \boldsymbol{\lambda}'\mathbf{s}_{id,CAR} + \varepsilon_{id,CAR} = V_{id,CAR} + \varepsilon_{id,CAR}$$

$$y^*_{id,MC} = \boldsymbol{\theta}'\mathbf{r}_{id,MC} + \varepsilon_{id,MC} = V_{id,MC} + \varepsilon_{id,MC}$$

$$\begin{aligned} y_{id,CAR} &= 0 \quad if \;\; y^*_{id,CAR} \le 0, \\ &= 1 \quad if \;\; 0 < y^*_{id,CAR} \le \mu_{d1,CAR}, \\ &\vdots \\ &= J \quad if \;\; \mu_{d(J-1),CAR} < y^*_{id,CAR} \end{aligned}$$

$$\begin{aligned} y_{id,MC} &= 0 \quad if \;\; y^*_{id,MC} \le 0, \\ &= 1 \quad if \;\; 0 < y^*_{id,MC} \le \mu_{d1,MC}, \\ &\vdots \\ &= J \quad if \;\; \mu_{d(J-1),MC} < y^*_{id,MC} \end{aligned}$$

$y^*_{id,CAR}$: Intention for Car Ownership for household i in Dataset d

$y^*_{id,MC}$: Intention for Motorcycle Ownership for household i in Dataset d

$\mathbf{s}, \mathbf{r}$: Vectors of attributes

$\boldsymbol{\lambda}, \boldsymbol{\theta}$: Vectors of unknown parameters

ε : Random error

V : Systematic component

$y_{id,CAR}$: Actual/reported car ownership for household i in Dataset d

$y_{id,MC}$: Actual/reported motorcycle ownership for household i in Dataset d

μ : Unknown parameter to be estimated

Considering that household own "n" cars and "m" motorcycles, probability can be written as:

$$\begin{aligned} &\Pr\left(y_{id,CAR} = n_{id}, y_{id,MC} = m_{id}\right) \\ &= \Pr\left(\mu_{d(n_{id}-1),CAR} < y^*_{id,CAR} \le \mu_{dn_{id},CAR}, \mu_{d(m_{id}-1),MC} < y^*_{id,MC} \le \mu_{dm_{id},MC}\right) \\ &= \int_{\mu_{d(n_{id}-1),CAR}-V_{id,CAR}}^{\mu_{dn_{id},CAR}-V_{id,CAR}} \int_{\mu_{d(m_{id}-1),MC}-V_{id,MC}}^{\mu_{dm_{id},MC}-V_{id,MC}} \phi_2\left(\varepsilon_{id,CAR}, \varepsilon_{id,MC}, \rho\right) d\varepsilon_{id,CAR} d\varepsilon_{id,MC} \\ &= \Phi_2\left(\mu_{dn_{id},CAR} - V_{id,CAR}, \mu_{dm_{id},MC} - V_{id,MC}, \rho\right) - \Phi_2\left(\mu_{dn_{id},CAR} - V_{id,CAR}, \mu_{d(m_{id}-1),MC} - V_{id,MC}, \rho\right) \\ &\quad - \Phi_2\left(\mu_{d(n_{id}-1),CAR} - V_{id,CAR}, \mu_{dm_{id},MC} - V_{id,MC}, \rho\right) + \Phi_2\left(\mu_{d(n_{id}-1),CAR} - V_{id,CAR}, \mu_{d(m_{id}-1),MC} - V_{id,MC}, \rho\right) \end{aligned}$$

where,

$\phi_2(\cdot)$: PDFof standard bivariate normal distribution

$\Phi_2(\cdot)$: CDF of standard bivariate normal distribution

ρ : correlation coefficient between $\varepsilon_{id,CAR} and \varepsilon_{id,MC}$

and set $\mu_{d(-1)} = -\infty$, $\mu_{d0} = 0$, $\mu_{dJ} = \infty$

6.2 Model Estimation and Results

The estimation results for the vehicle ownership models are in the Appendix 1.

REFERENCES

1. Ortuzar, J. D. and L. G. Willumsen. Modeling Transport, 1990 John Wiley & sons Ltd.
2. Ben -Akiva, M. and S. Lerman. Discrete Choice Analysis, 1985, MIT Press, Cambridge, Massachusetts.
3. Vovsha, P. Application of Cross-Nested Logit Model to Mode Choice in Tel Aviv, Israel, Metropolitan Area, Transportation Research Record 1607, 1997, 6-15.
4. Dissanayake, D. and T. Morikawa. Travel Demand Models with the RP/SP Combining Technique for the Developing Countries. Presented at the International Conference CODATU IX, Mexico, 2000.
5. Hayashi, Y., Anurakamonkul, K., Okuda, T., Osman, O. and H. Nakamura. Examining the Effects of a Mass Rapid Transit System on Easing Traffic Congestion in Auto-dependent Bangkok, Regional Development Studies: UNCRD, Vol. 4, 1998, 65-85.
6. Pendyala R. M., Kostyniuk L.P., and Goulias K.G., A repeated cross-sectional evaluation of car ownership, Transportation, 22, 165-184, 1995
7. Dissanayake, D. and T. Morikawa. Modeling Vehicle Usage, Mode Choice, and Trip Chaining for Multiple Household Members in Developing Countries. Journal of Infrastructure Planning and Management, JSCE, No. 688/IV-53, 125-133, 2001.
9. Kitamura, R., A Causal Analysis of Car Ownership and Transit Use**,** Transportation 16. 1989.
10. Kubota H. (1996), World's Worst Traffic jams and Their Causes, The Wheel Extended: Toyota Quarterly Review, Toyota Motor Corporation, No. 96, 5-13.
11. Urban Transport Database and Model Development Project (UTDM) Office of the Commission for the Management of Land Traffic (OCMLT), Final Report Vol. 1 & 2. 1998, Bangkok, Thailand.
12. Environmental Atlas: Bangkok Metropolitan Area, Final Report of the Study on Urban Environmental Improvement Program in Bangkok Metropolitan Area (BEIP Study). Pacific Consultants International, and Suuri-Keikaku Co. Ltd., 1997.
13. Strategies for Managing Urban Transport in Kuala Lumpur (SMURT), Japan International Cooperation Agency, SMURT-KL Summary, 1999, Kuala Lumpur, Malaysia.
14. Metro Manila Urban Transportation Integration Study (MMUTIS), Japan International Cooperation Agency, Final Report, 1999, Manila, Philippines.