
NU TREND
Nagoya University TRansportation and ENvironment Dynamics

WATCH

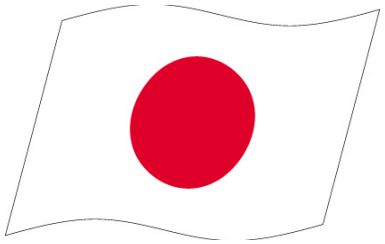
+

SAKURA

＝花見

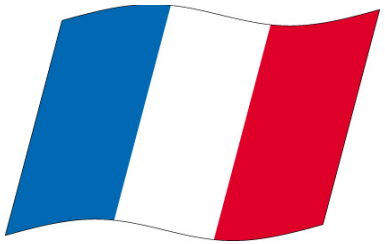
(Party under cherry blossom)

Inter-Temporal and Inter-Regional Analysis of Household Car and Motorcycle Ownership Behaviours in Asian Big Cities



***SAKURA* Project**

July 2004



Nagoya University

Nobuhiro Sanko, Hiroaki Maesoba, Dilum Dissanayake

Toshiyuki Yamamoto, and Takayuki Morikawa

INTRODUCTION

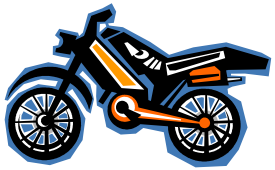
Economic Growth

↓

Income Increase

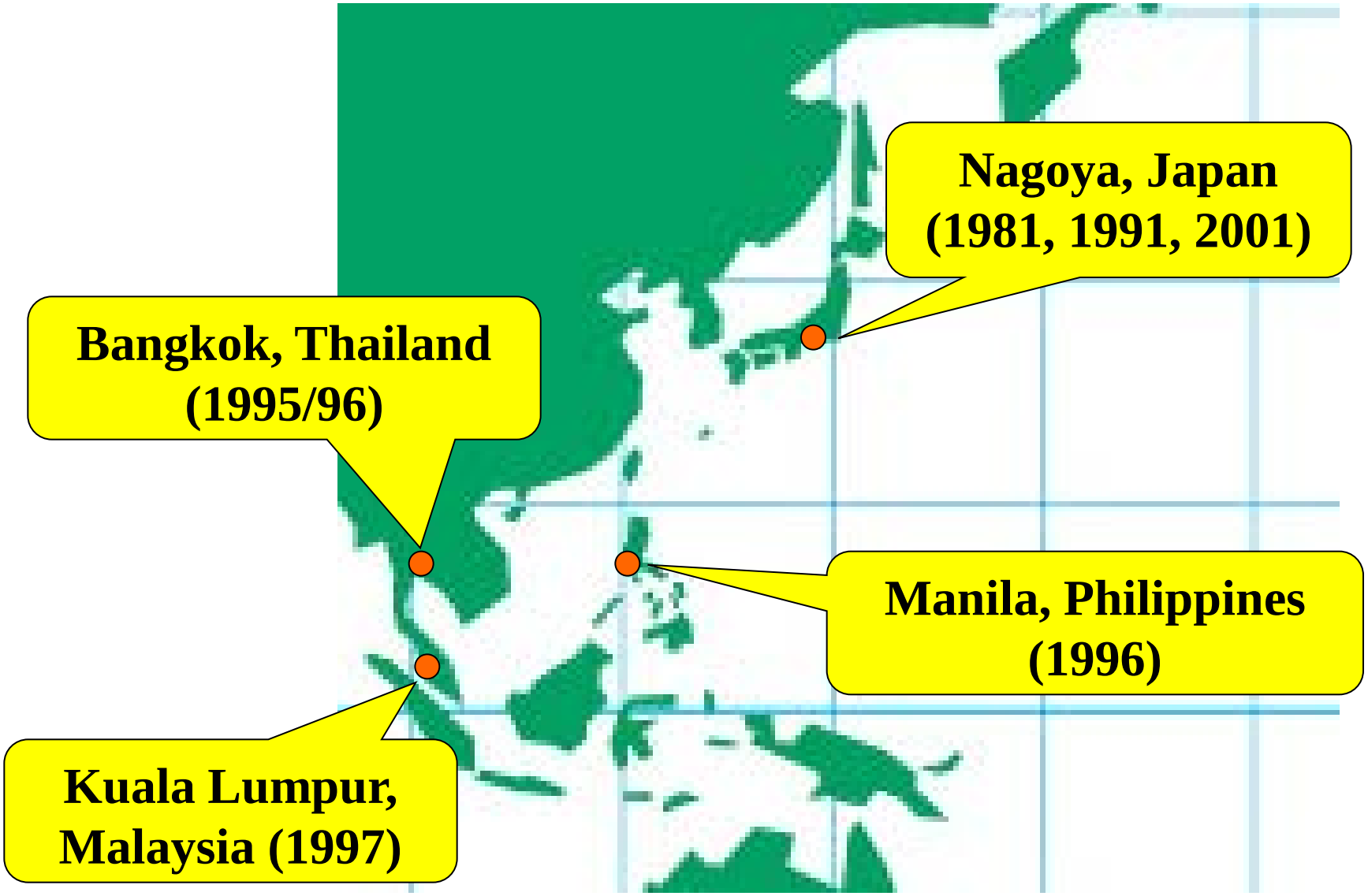
↓

Vehicle Ownership Increase



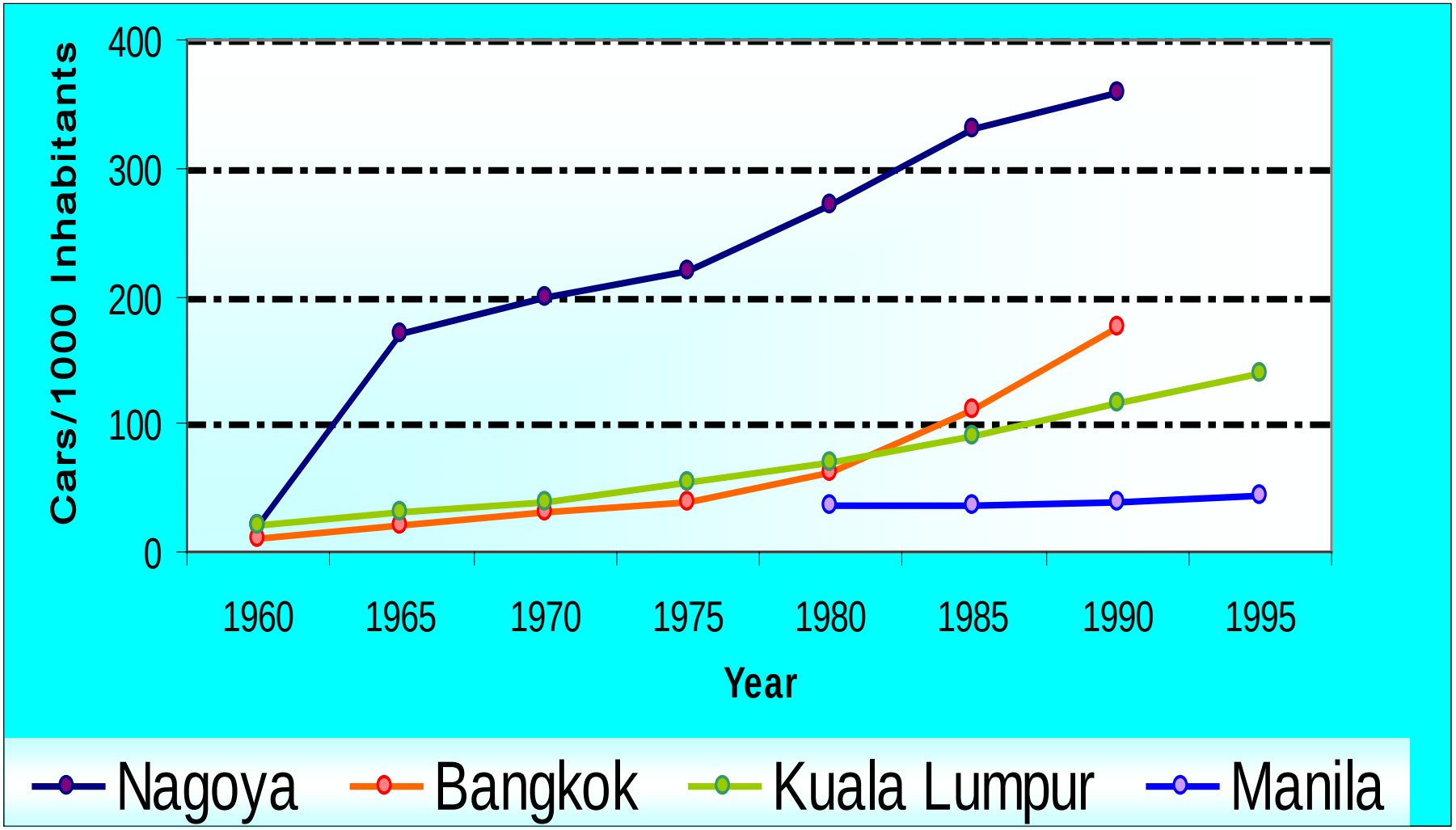
CASE STUDY CITIES

CASE STUDY CITIES

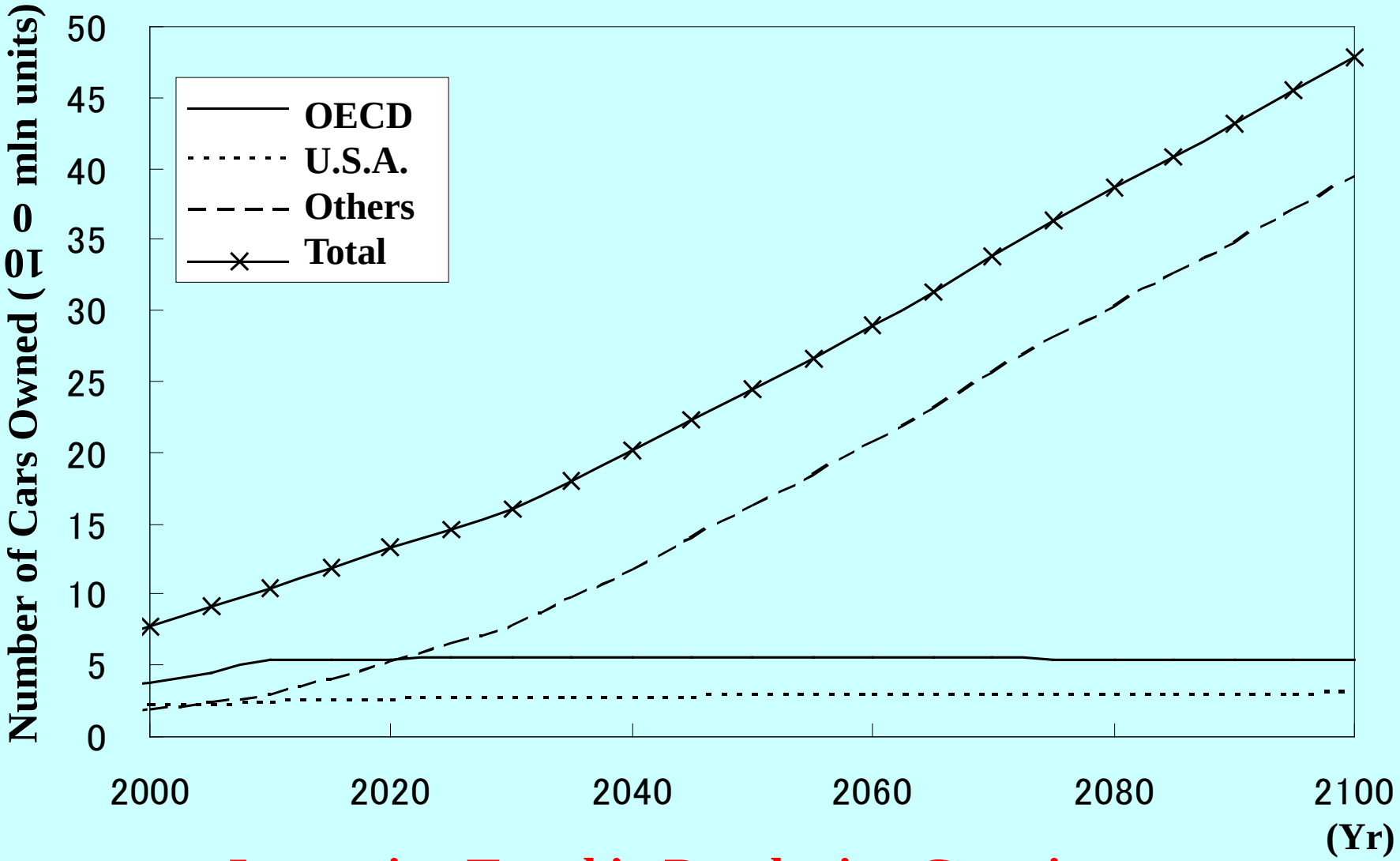


Car Ownership in Case Study Cities

(1960 ~ 1995)



Car Ownership Forecast around the World



Increasing Trend in Developing Courtiers

INTRODUCTION

Vehicle Ownership Increase

→ can cause traffic congestions and environmental problems

Some Countermeasures Considered

- Investment in road infrastructure and public transit systems
- Regulations against vehicle ownership and usage
- Technical innovation in vehicle performance

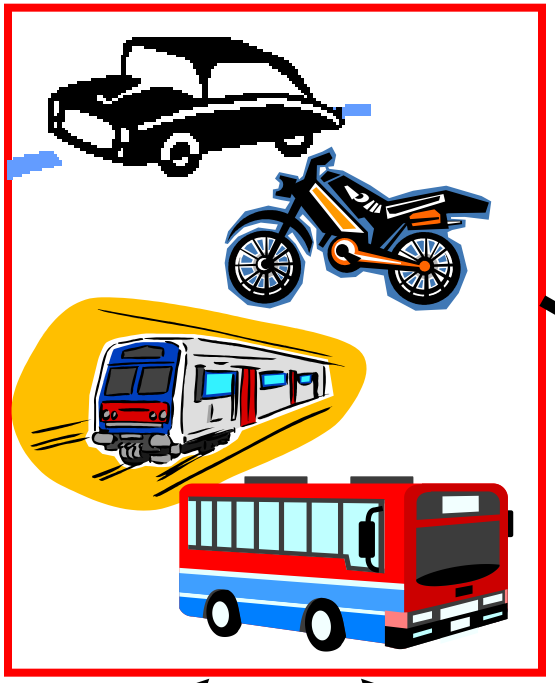
However, understanding vehicle ownership behaviours is the key and prerequisite.

OBJECTIVES

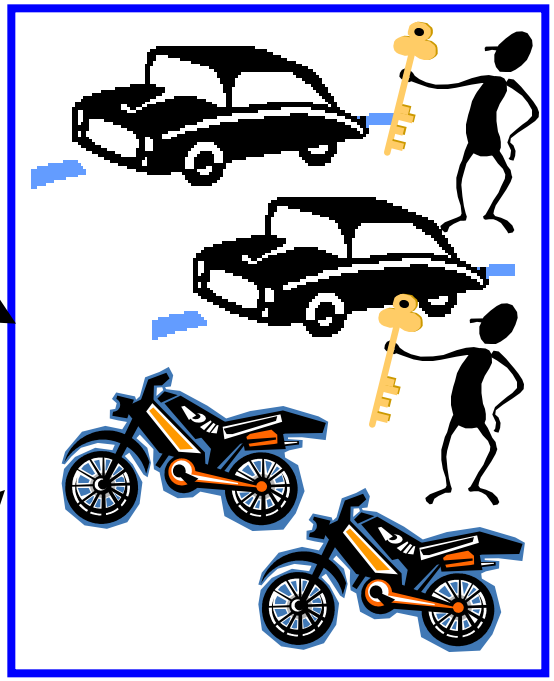
- Modelling and comparing vehicle ownership behaviours in the case study cities (Nagoya, Bangkok, Kuala Lumpur and Manila)
- Obtaining insights into the effects of accessibility on vehicle ownership behaviours
- Evaluating temporal and spatial transferability of vehicle ownership models

MODELLING FRAMEWORK

Mode Choice Model
Multinomial Logit Model
(Trip Level)



Vehicle Ownership Model
Bivariate Ordered Probit Model
(Household Level)



Accessibility Measures

Household members' SE

Trip makers' SE

LOS

MODELLING FRAMEWORK

Comparing Vehicle Ownership Models and Evaluating their Transferability

NGO81

NGO91

NGO01

BKK95

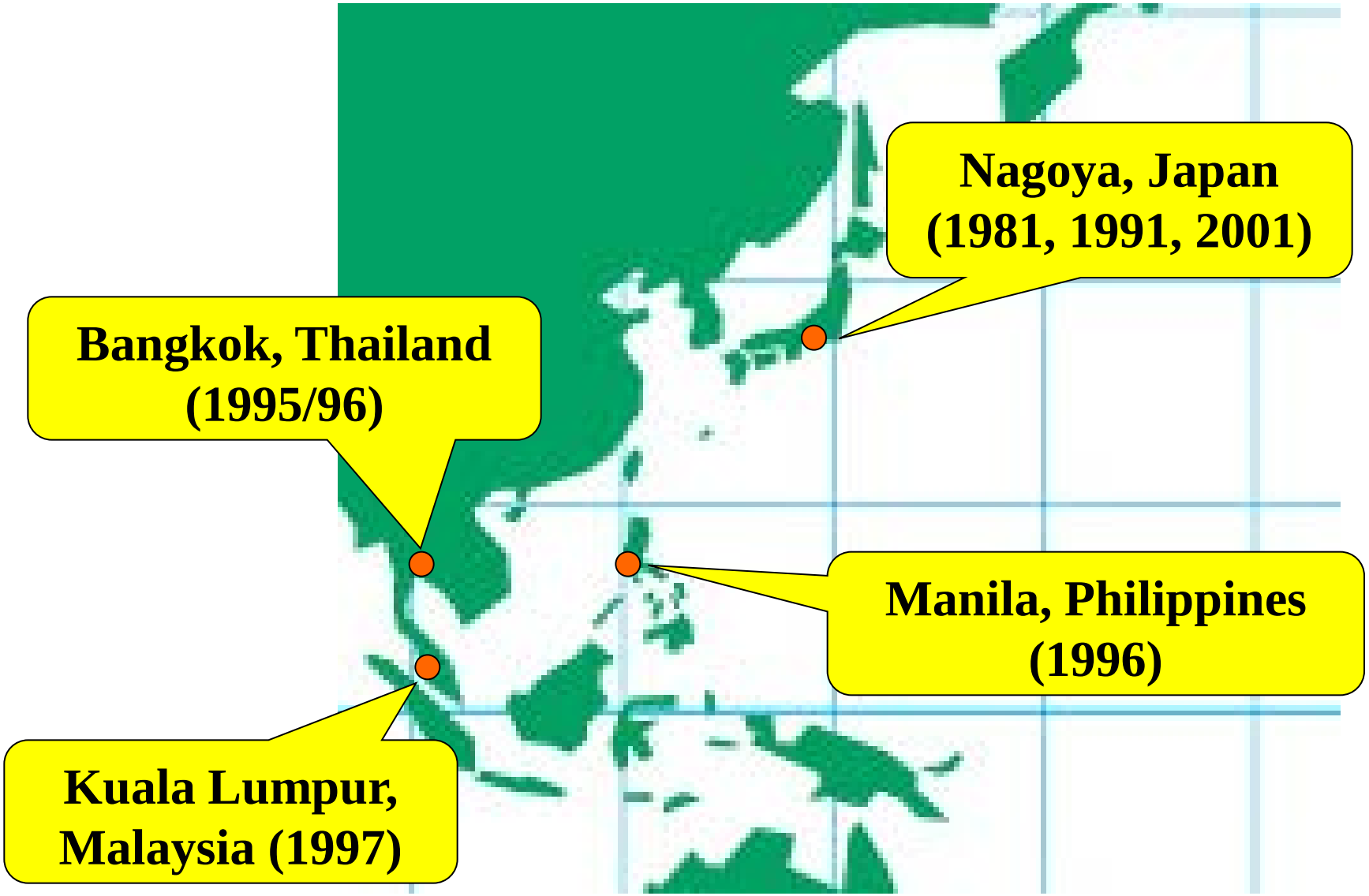
KL97

MNL96

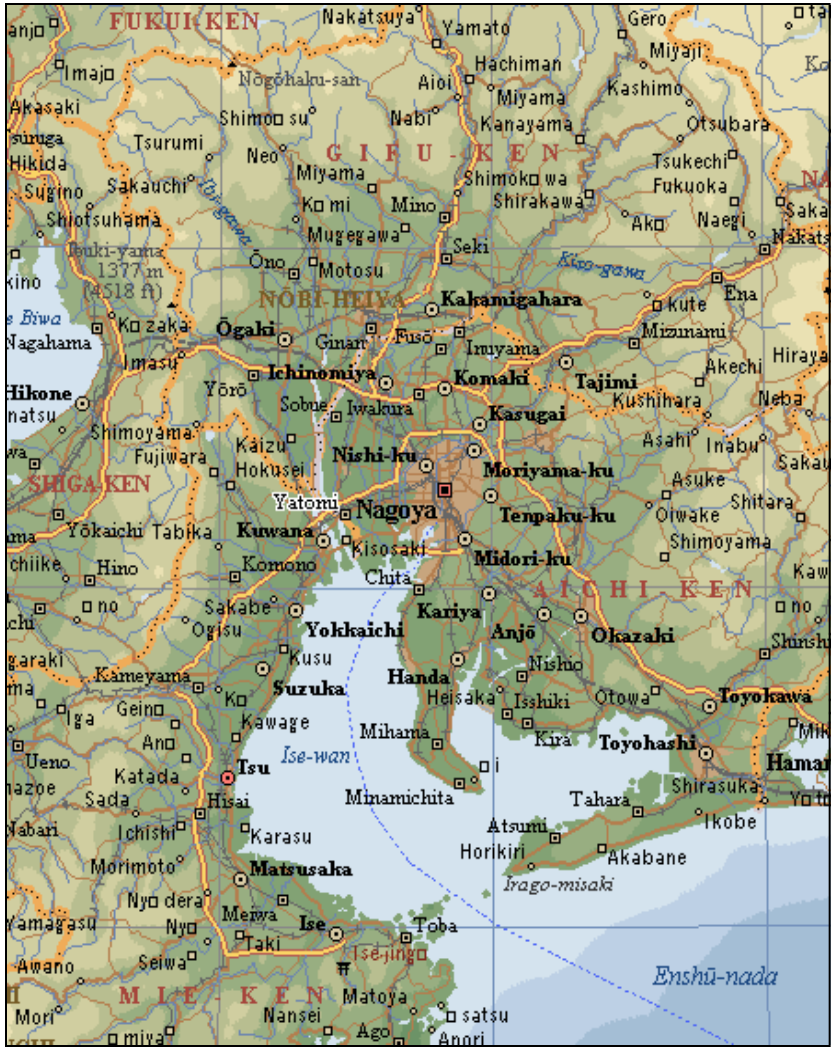
Inter-temporal comparison and temporal transferability

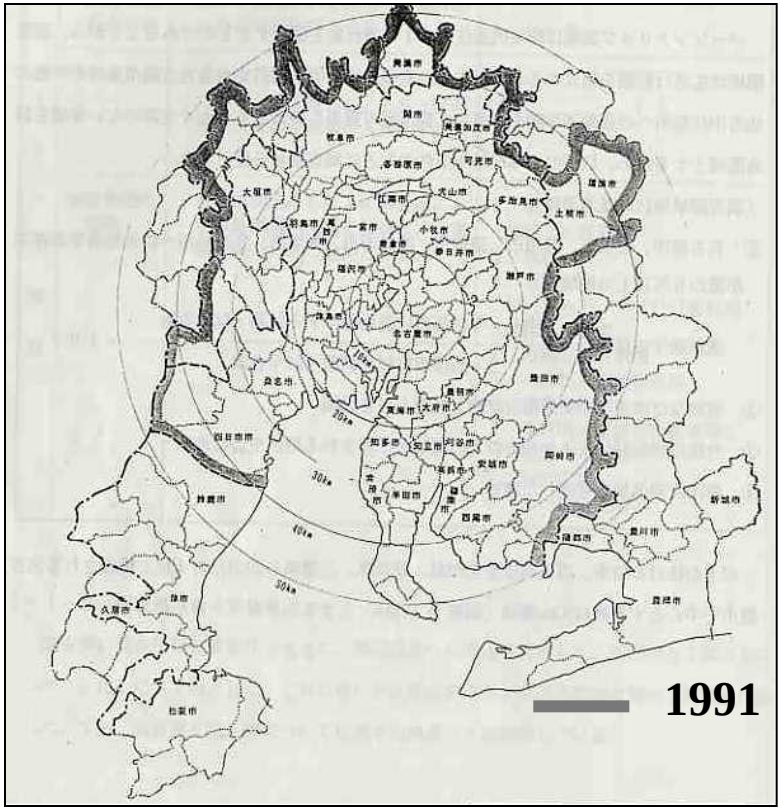
Inter-regional comparison and spatial transferability

CASE STUDY CITIES AND THE DATA



Chukyo Metropolitan Area (Nagoya and Surrounding Areas)



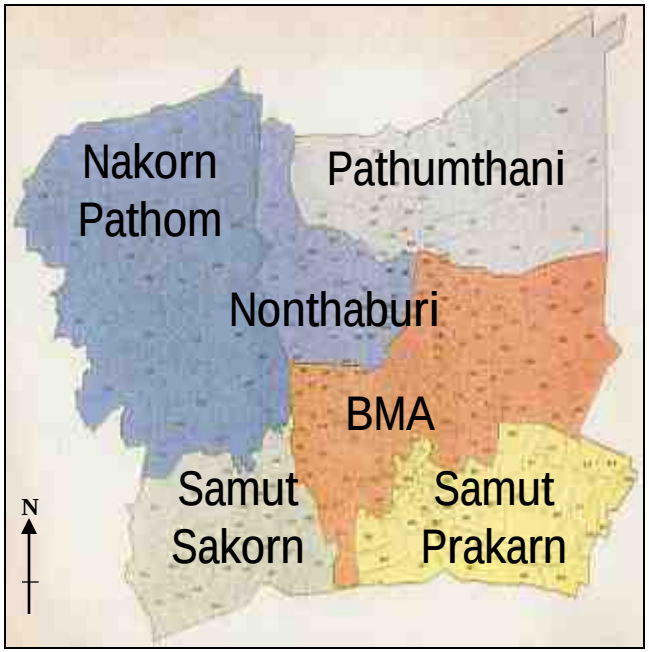


Area: 5656, 5173, 6696km^2
(1981, 1991, 2001)

Population: 7.8, 8.1, 9.0 million
(1981, 1991, 2001)

Nagoya

Bangkok Metropolitan Region (BMR)



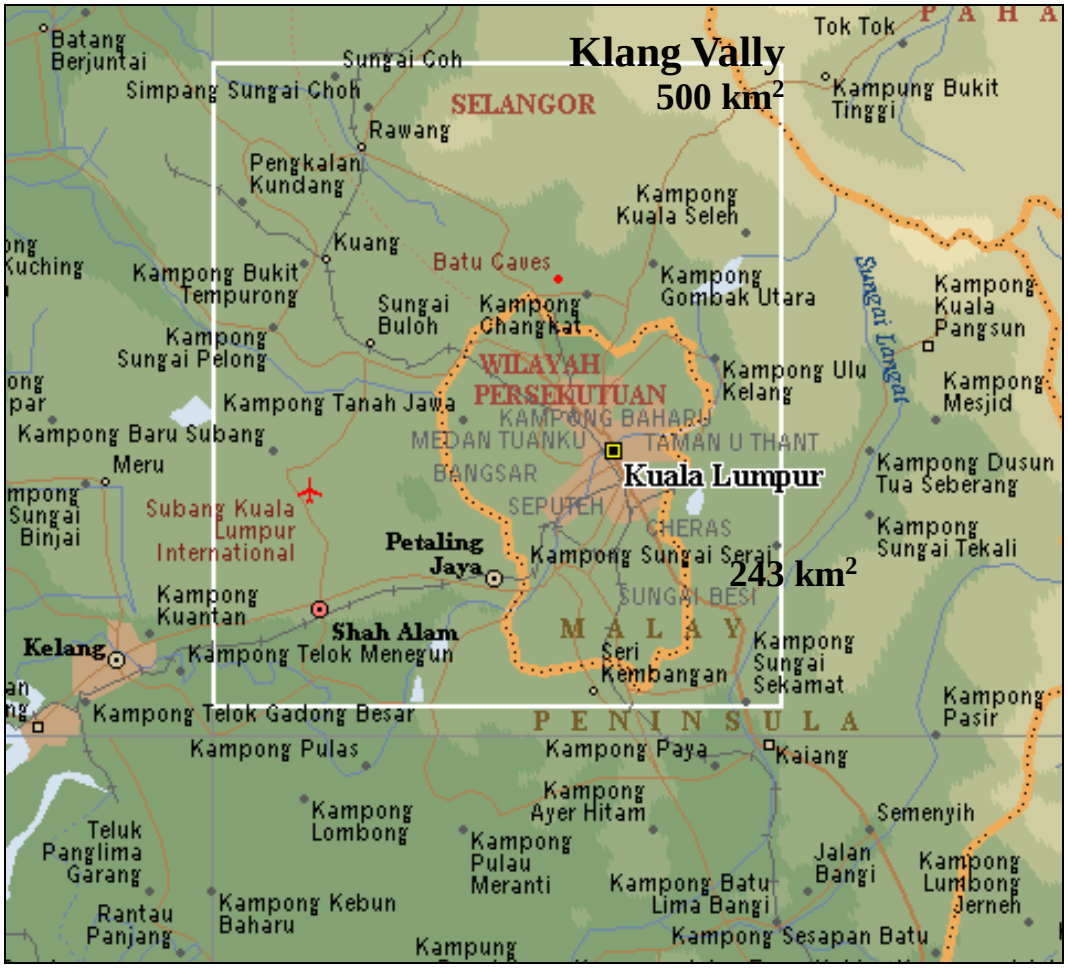
Area: 7758 km^2

Population: 13 million

Data Source: UTDM survey in 1995/96.

Bangkok

Kuala Lumpur Metropolitan (KLMP)



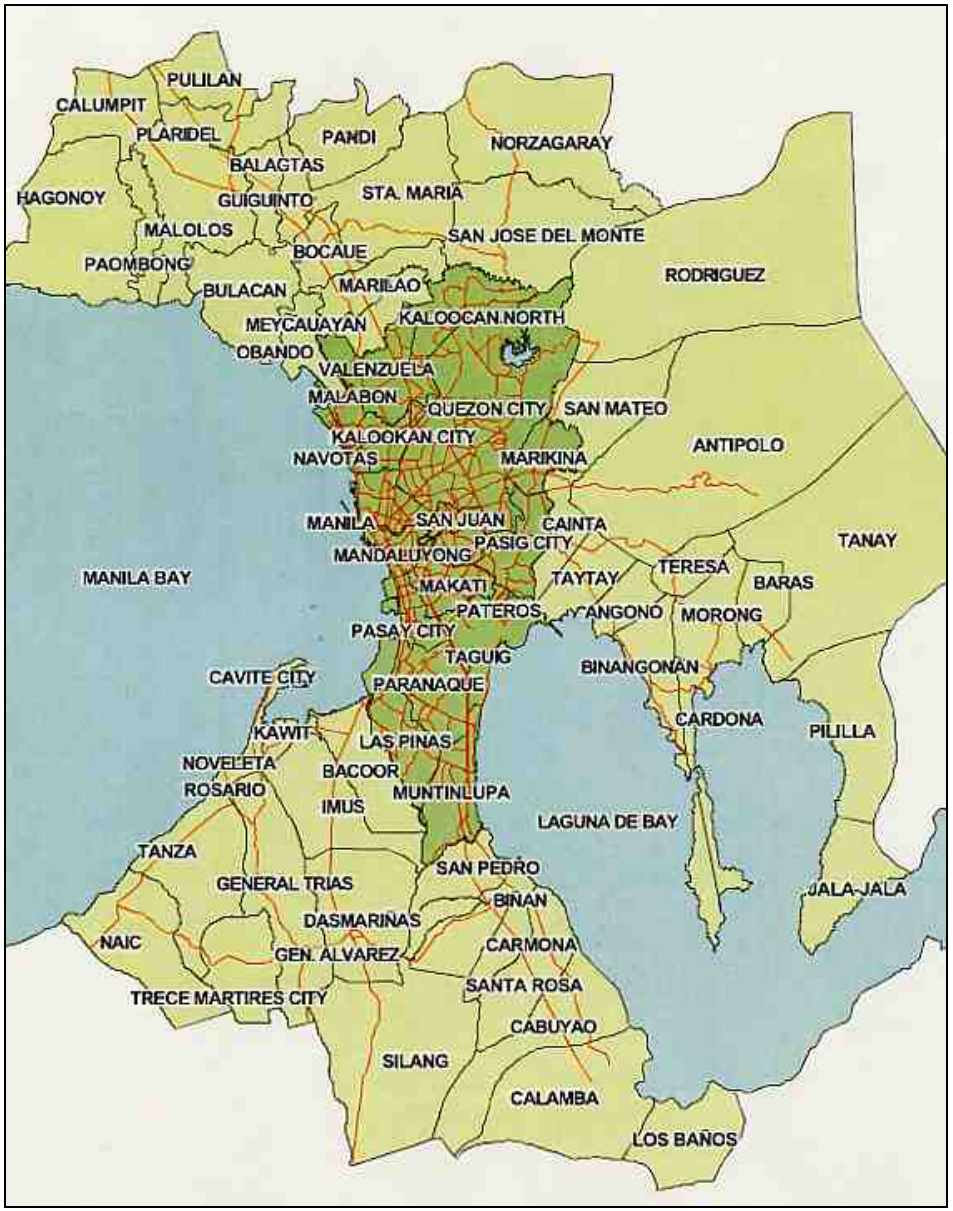
Area: 500 km²

Population: 4.1 million

Data source: JICA survey in 1997.

(JICA: Japan International Cooperation Agency)

Kuala Lumpur

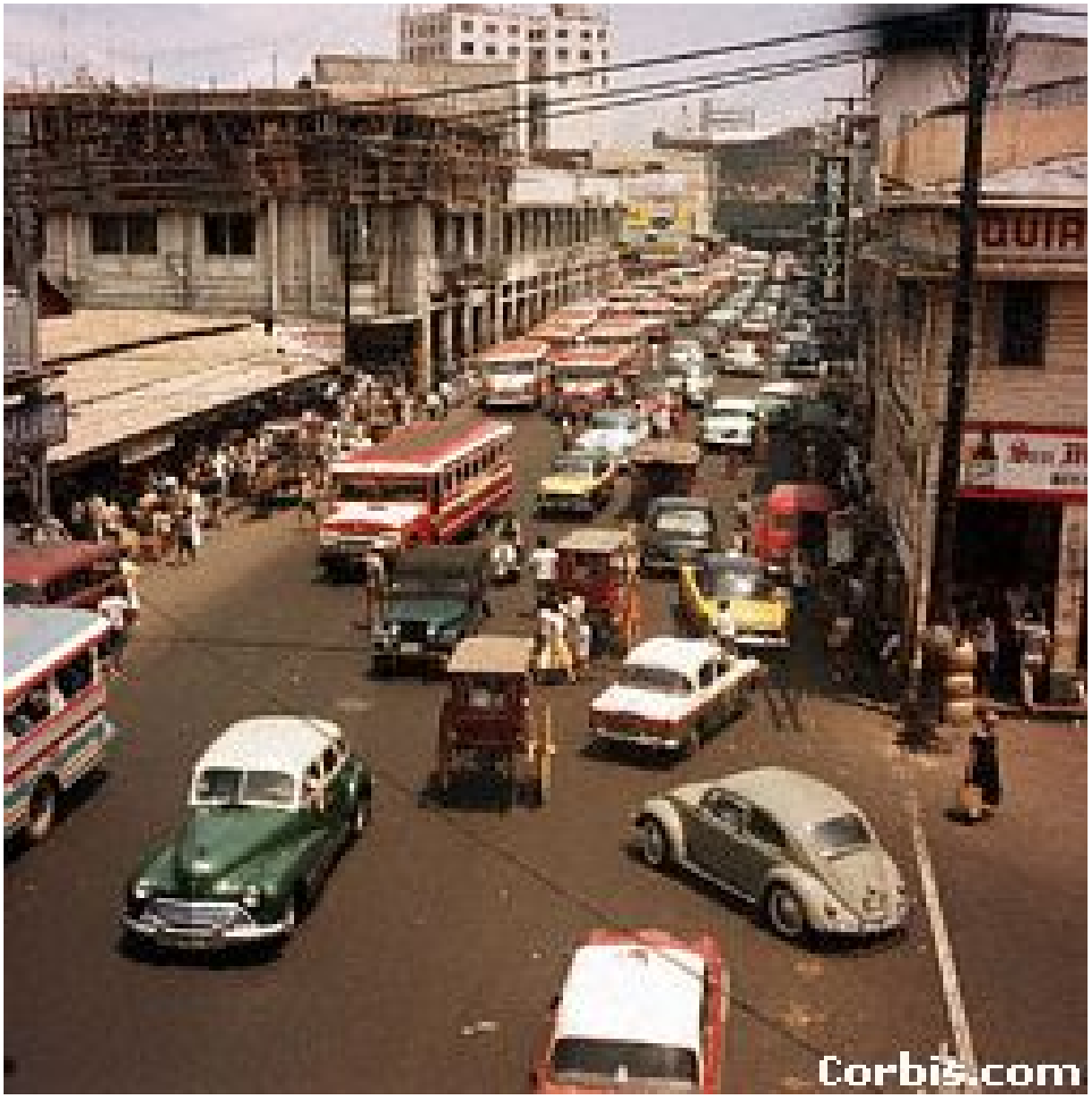


Metro Manila

Area: 636 km^2

Population: 14.4 million

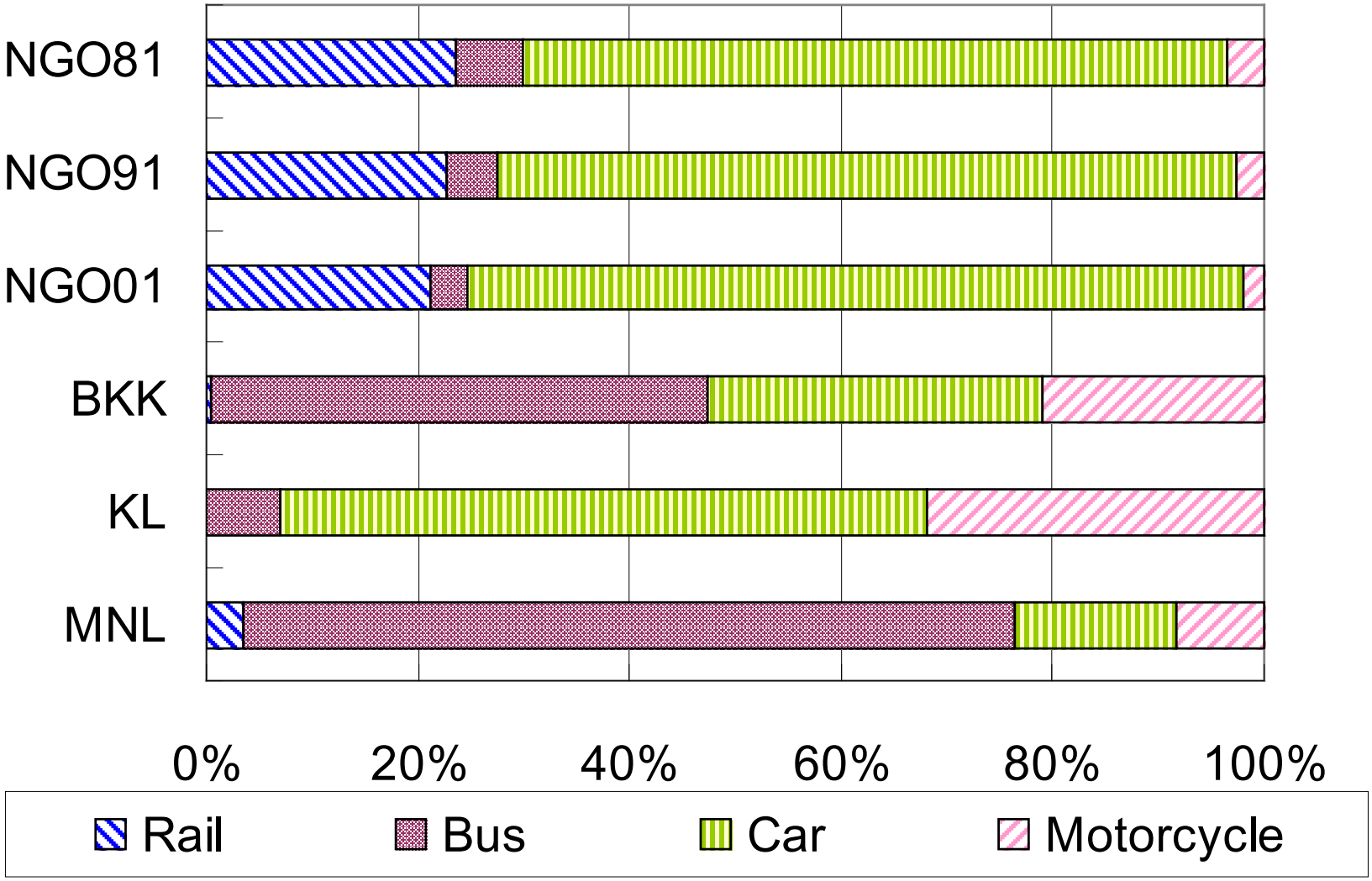
Data source:
JICA survey in 1996.



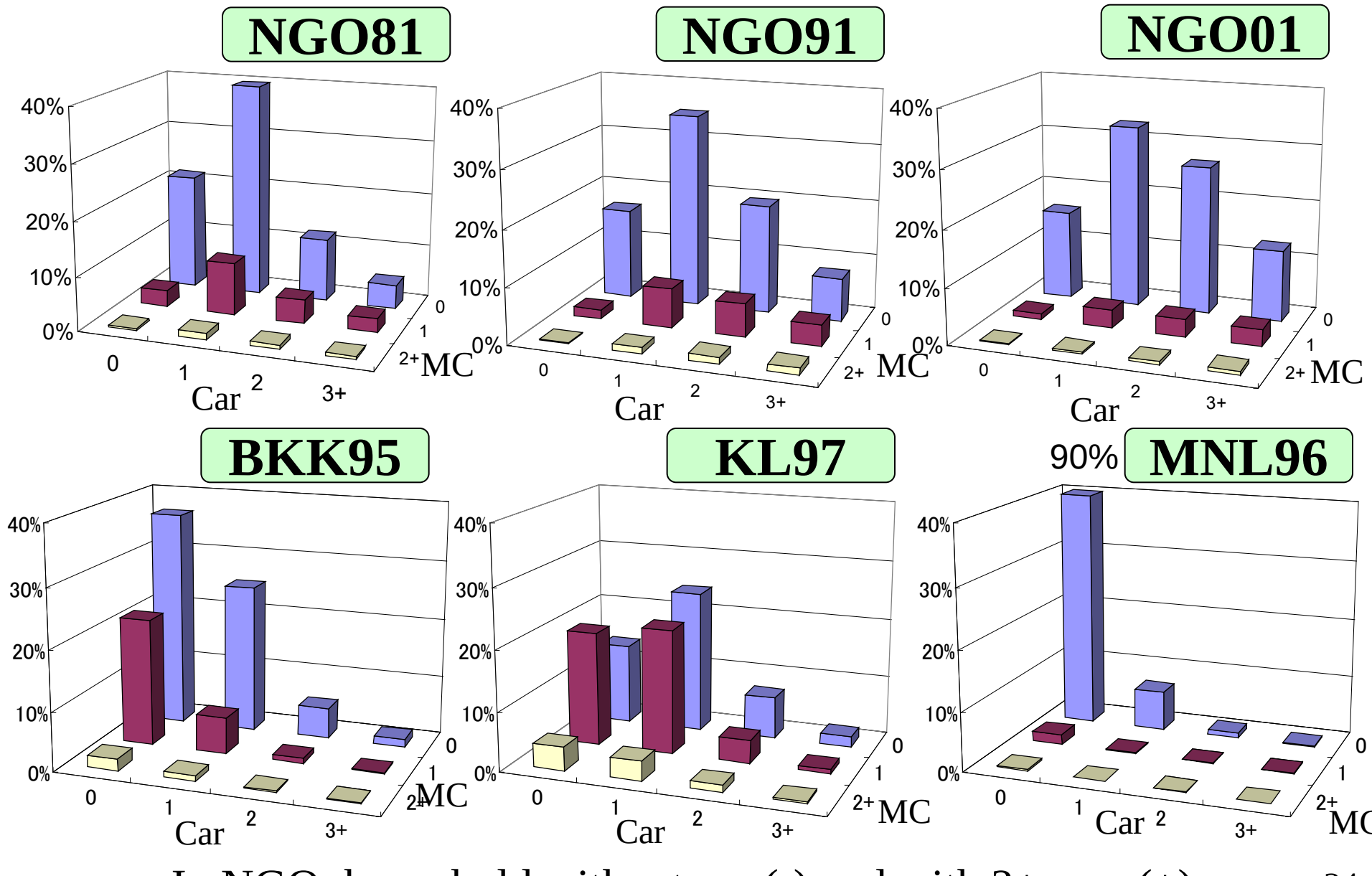
Manila


TRICYCLE
NO ENTRY

Modal Splits in Case Study Cities



Vehicle Ownership Characteristics in Case Study Cities



In NGO, household without car (-) and with 2+ cars (+)

LOS DATA

Survey area is divided into zones

Travel time: Average travel time reported by respondents
(if no trip is made, larger zones are considered)

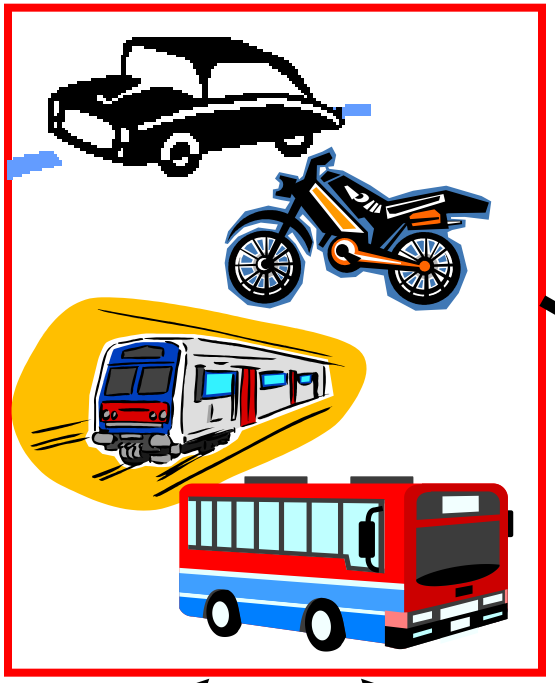
Cost: Not available in all case study cities, thus not included in the model

SOCIO-ECONOMIC DATA

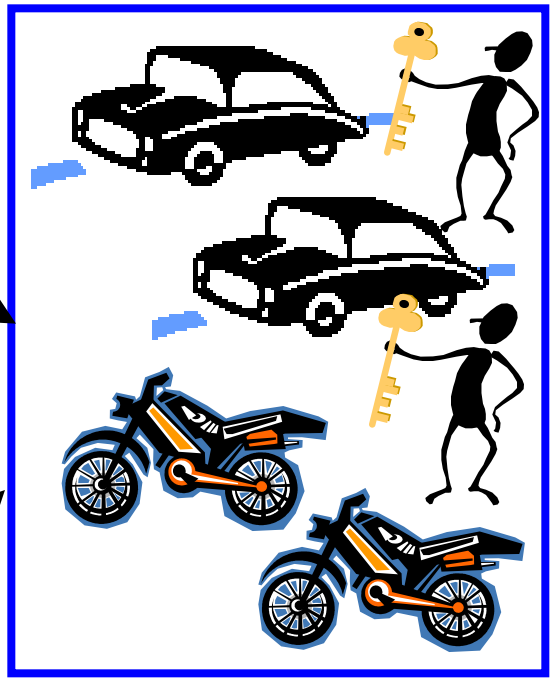
Driving license holding: Difficult to forecast and highly endogenous, thus not included in the model

MODELLING FRAMEWORK

Mode Choice Model
Multinomial Logit Model
(Trip Level)



Vehicle Ownership Model
Bivariate Ordered Probit Model
(Household Level)



Accessibility Measures

Household members' SE

Trip makers' SE

LOS

Estimation Results (Summary statistics)

	NGO81	NGO91	NGO01	BKK	KL	MNL
N	15,000	15,000	15,000	13,882	12,667	15,000
L ($\boldsymbol{\beta}$)	-10,834.2	-9,254.1	-8,223.8	-9,433.7	-9,212.4	-9,513.2
L ($\mathbf{0}$)	-15,702.5	-15,140.8	-14,787.2	-12,249.1	-13,434.0	-12,948.8
$\bar{\rho}^2$	0.309	0.388	0.443	0.229	0.313	0.265

- 15,000 samples are drawn randomly in NGO and MNL
- Goodness of fit indexes are satisfactory

Estimation Results (alternative-specific constants and LOS)

Variable	NGO81	NGO91	NGO01	BKK	KL	MNL
Constant (R)	0	0	0	0	--	0
Constant (B)	-1.30	-1.54	-1.69	0.04	0	1.03
Constant (C)	-1.95	-1.27	-0.66	-1.54	-0.72	-0.52
Constant (MC)	-4.46	-4.15	-3.90	-1.75	-1.62	-0.82
Time (60 min.)	-1.92	-1.95	-2.53	-0.17	-0.14*	-0.30

*Not significant at 5% level

- Four alternatives except for KL (Rail, Bus, Car, MotorCycle)
- Travel time is negatively estimated (not significant in KL)

Estimation Results (SE: Socio-Economic variables)

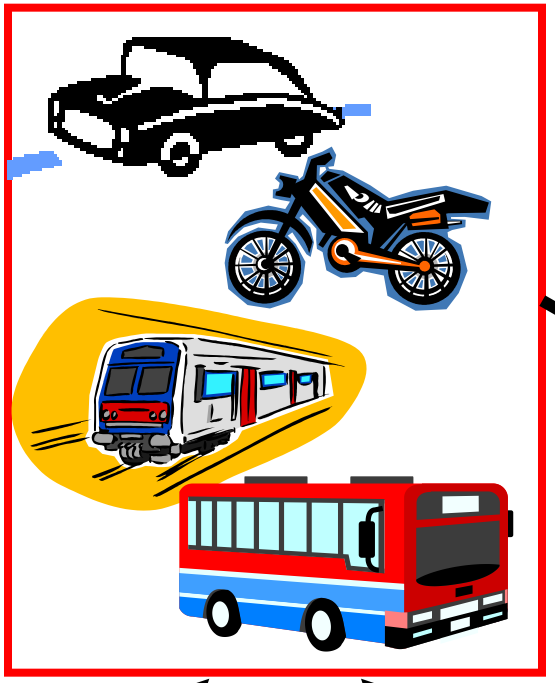
Variable	NGO81	NGO91	NGO01	BKK	KL	MNL
Male (C, MC)	1.74	1.49	1.02	0.72	0.95	0.40
Age ≥ 20 (C, MC)	1.36	1.23	1.02	1.17	4.30	0.79
In City (C)	-0.75	-0.81	-1.02	-0.01*	-0.27	-0.91
Age ≥ 65 (B)	1.78	1.83	1.29	--	--	--
Female (R)	-0.75	-0.77	-0.54	-0.57	--	-0.43
Student (R)	0.64	0.97	1.04	-0.35	--	-0.64

*Not significant at 5% level

- Three SE variables have effects on car and motorcycle usage
  - Male and age ≥ 20 (+)
  - In City (–), not significant in BKK
- Three SE variables have effects on transit usage
  - Age ≥ 65 (+, bus)
  - Female (–, rail)
  - Student (+, in NGO; –, in BKK and MNL, rail)

MODELLING FRAMEWORK

Mode Choice Model
Multinomial Logit Model
(Trip Level)



Vehicle Ownership Model
Bivariate Ordered Probit Model
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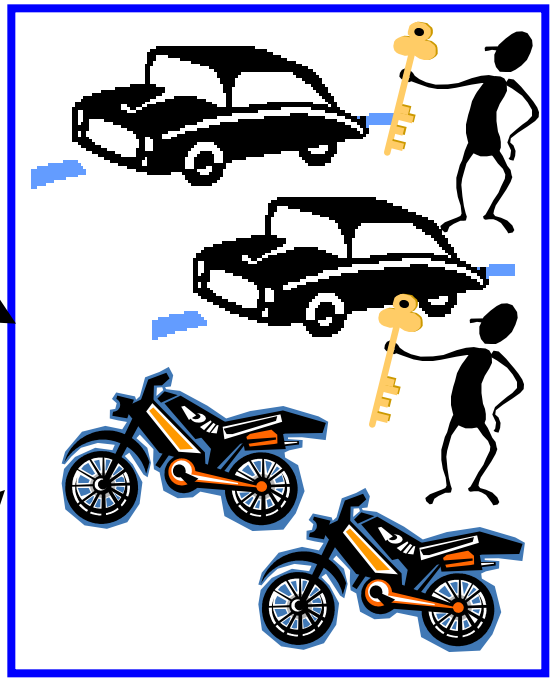


Accessibility Measures

Household members' SE

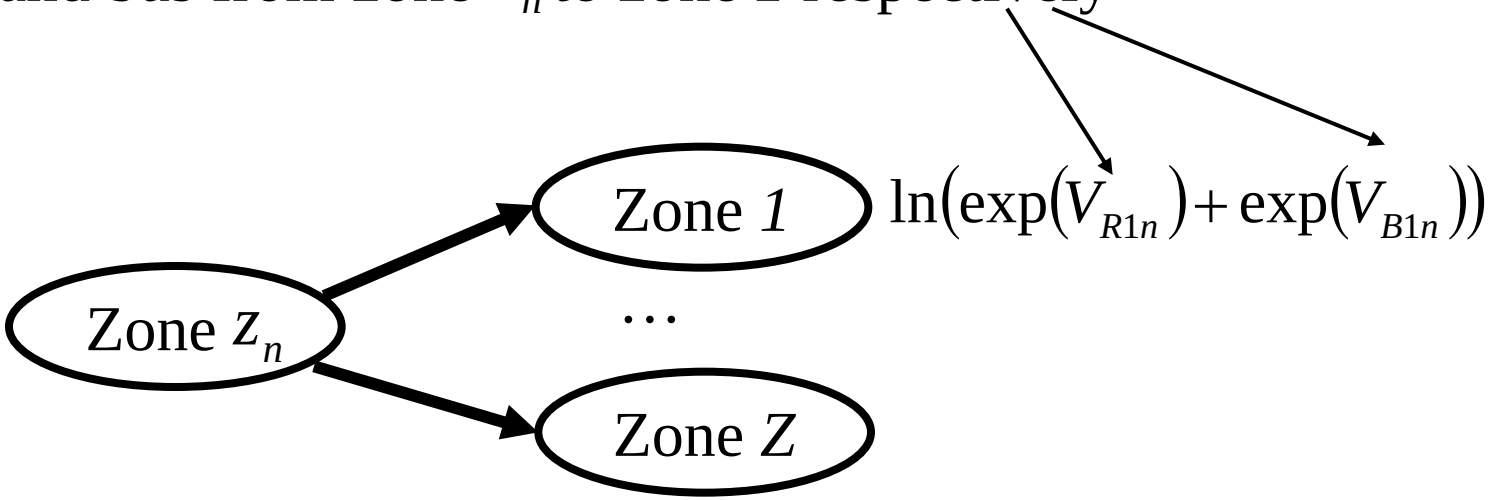
Trip makers' SE

LOS

ACCESSIBILITY

For individual n residing in zone z_n ($z_n = 1, \ldots, Z$)

Systematic component of the utility when individual n uses rail and bus from zone z_n to zone *1* respectively



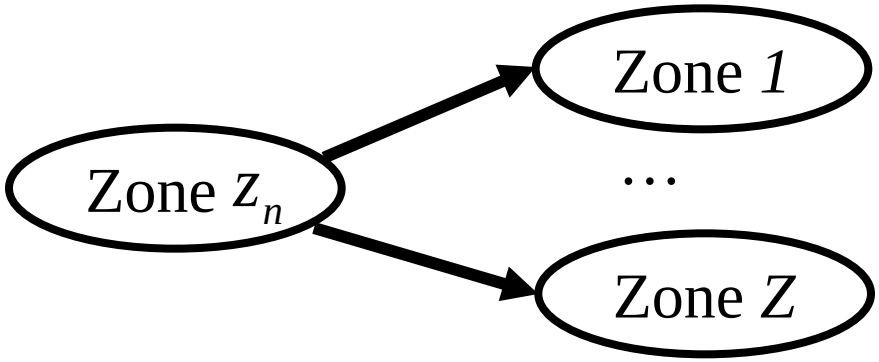
Accessibility to Transit

(Convenience of transit for those reside in zone z_n)

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

ACCESSIBILITY

For individual n residing in zone z_n ($z_n = 1, \ldots, Z$)



$$\ln\left(\exp\left(V_{R1n}\right)+\exp\left(V_{B1n}\right)+\exp\left(V_{C1n}\right)\right)$$
$$-\ln\left(\exp\left(V_{R1n}\right)+\exp\left(V_{B1n}\right)\right)$$

$$\ln\left(\exp\left(V_{R1n}\right)+\exp\left(V_{B1n}\right)+\exp\left(V_{MC1n}\right)\right)$$
$$-\ln\left(\exp\left(V_{R1n}\right)+\exp\left(V_{B1n}\right)\right)$$

Additional Accessibility of Car and Motorcycle Availability

(Convenience of car and motorcycle if the individual can use these alternatives in addition to transit which is usually available to all citizens)

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

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

ACCESSIBILITY

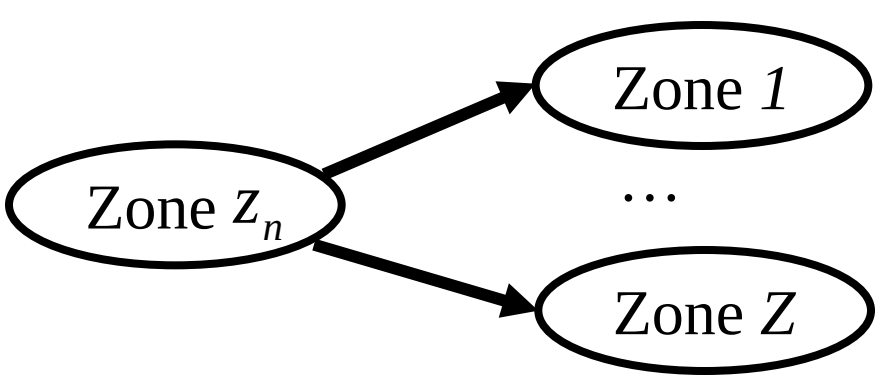
A potential drawback of "accessibility to transit" and "Additional accessibility of car and motorcycle availability"

When the survey area is large, considering accessibility to all zones is questionable

Weighted accessibility measures based on # of trips are considered.

ACCESSIBILITY

For individual n residing in zone z_n ($z_n = 1, \ldots, Z$)



$w_{RB1} \ln\left(\exp\left(V_{R1n}\right) + \exp\left(V_{B1n}\right)\right)$

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

Traffic volume from zone z_n to zone z by rail and bus respectively

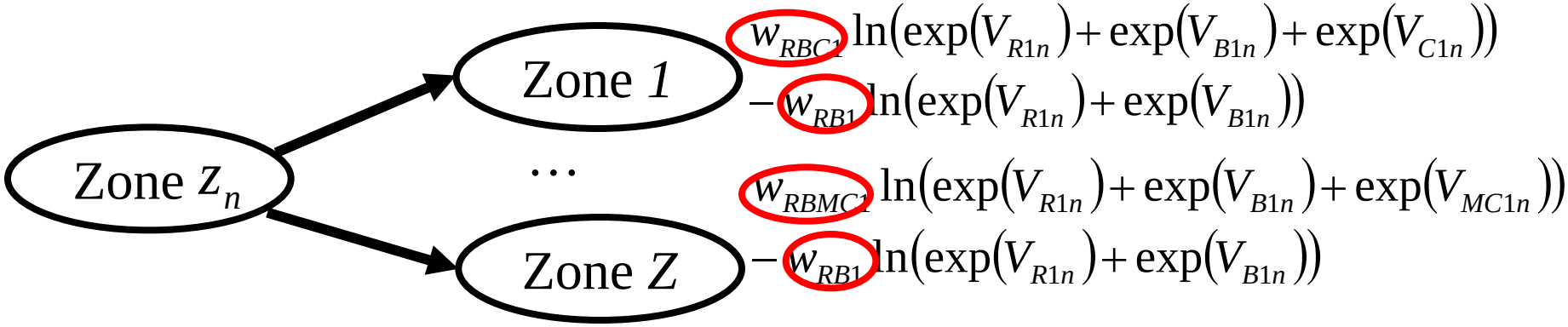
: importance of zone z for those reside in zone z_n

Weighted Accessibility to Transit

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

ACCESSIBILITY

For individual n residing in zone z_n $(z_n = 1, \ldots, Z)$



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

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

Weighted Additional Accessibility of Car and Motorcycle Availability

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

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

ACCESSIBILITY

A potential drawback of weighted accessibility

If people may travel to close and convenient zones only, then inconvenient but attractive zones may be excluded from the evaluation

Anyway, we expect that the lower accessibility to transit and higher additional accessibility lead to car and motorcycle ownership intentions

Accessibility measures considered

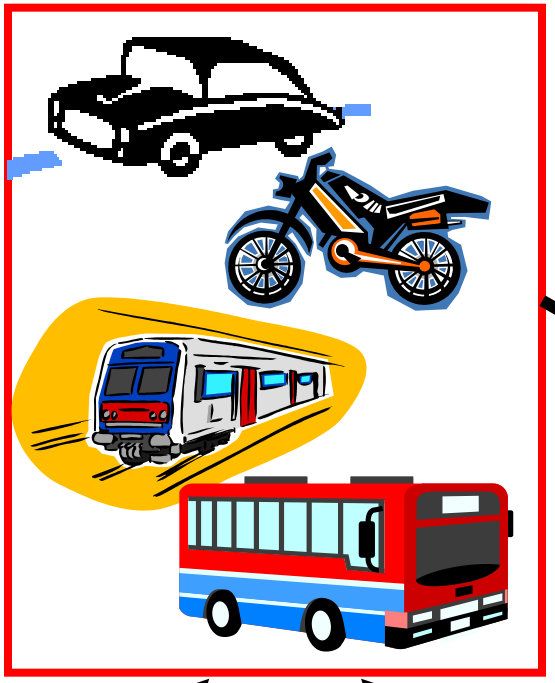
		NGO81	NGO91	NGO01	BKK	KL
Without weights	Transit					
	Addition					
With weights	Transit					
	Addition					

(Not available due to the lack of zoning information)

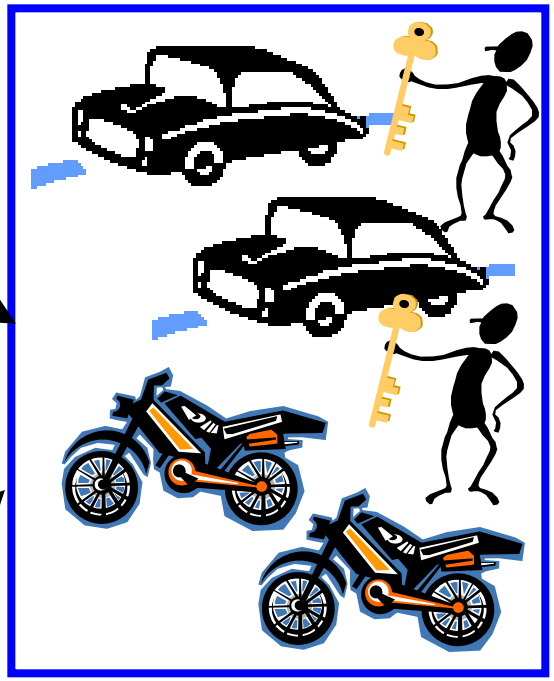
Manila is excluded since the model has not been estimated successfully.

MODELLING FRAMEWORK

Mode Choice Model
Multinomial Logit Model
(Trip Level)



Vehicle Ownership Model
Bivariate Ordered Probit Model
(Household Level)



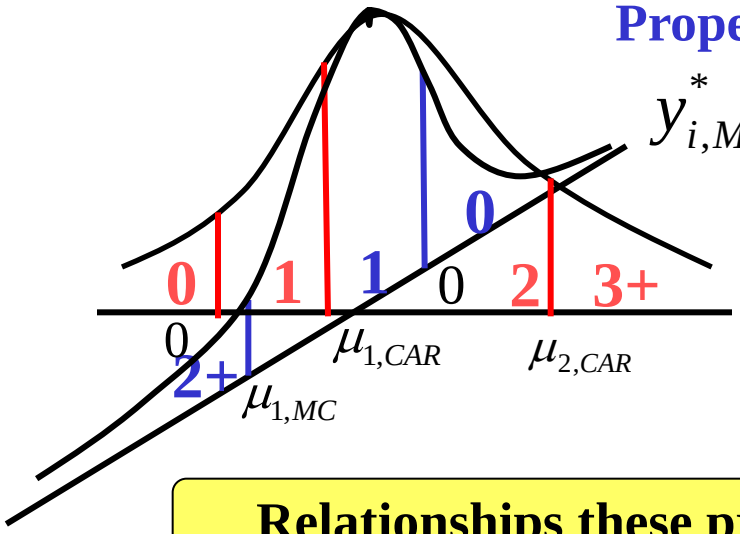
Accessibility Measures

Household members' SE

Trip makers' SE

LOS

VEHICLE OWNERSHIP MODEL



Propensity for Motorcycle Ownership

$$y^*_{i,MC} = \boldsymbol{\gamma}\mathbf{x}_{i,MC} + \varepsilon_{i,MC}$$

Propensity for Car Ownership

$$y^*_{i,CAR} = \boldsymbol{\beta}\mathbf{x}_{i,CAR} + \varepsilon_{i,CAR}$$

Relationships these propensity functions with observations

$$y_{i,CAR} = \begin{cases} 0 & \text{if } y^*_{i,CAR} \le 0, \\ 1 & \text{if } 0 < y^*_{i,CAR} \le \mu_{1,CAR}, \\ \cdots & \\ J & \text{if } \mu_{J-1,CAR} < y^*_{i,CAR} \end{cases}$$

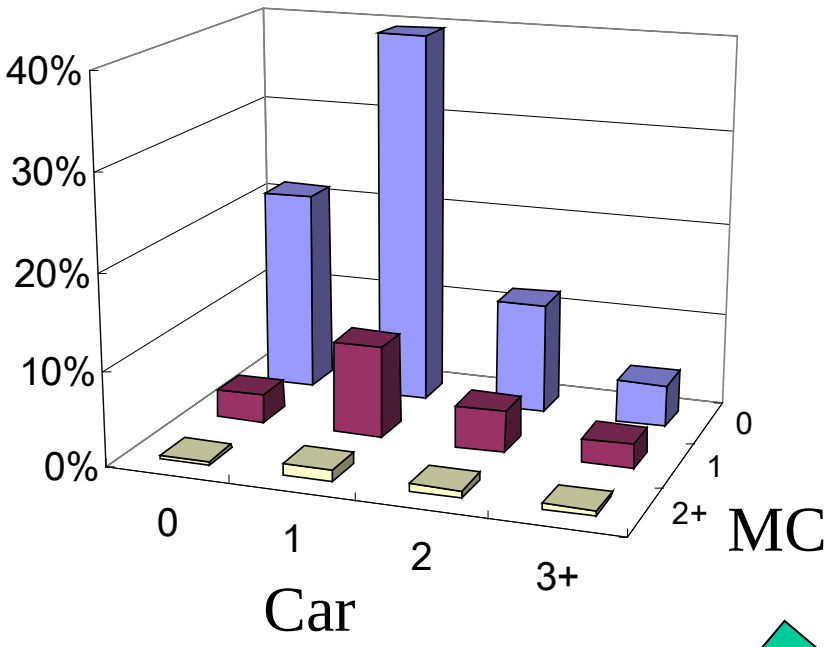
$$y_{i,MC} = \begin{cases} 0 & \text{if } y^*_{i,MC} \le 0, \\ 1 & \text{if } 0 < y^*_{i,MC} \le \mu_{1,MC}, \\ \cdots & \\ K & \text{if } \mu_{K-1,MC} < y^*_{i,MC} \end{cases}$$

$y_{i,CAR}$, $y_{i,MC}$: observed # of car and motorcycle owned by household i

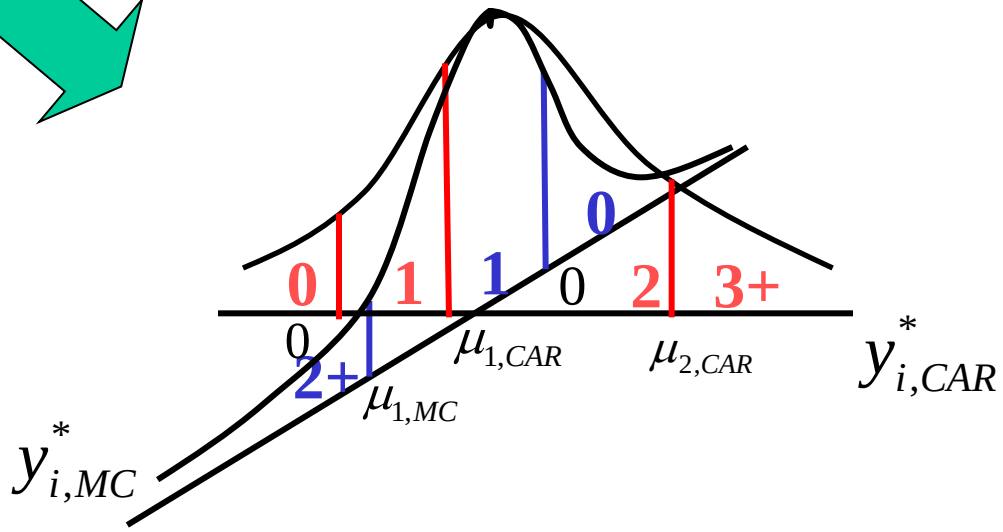
$\boldsymbol{\beta}$, $\boldsymbol{\gamma}$, $\boldsymbol{\mu}$: unknown parameter and threshold vectors to be estimated

$\varepsilon_{i,CAR}$, $\varepsilon_{i,MC}$: error components standard bivariate normally distributed with correlation ρ to be estimated

VEHICLE OWNERSHIP MODEL

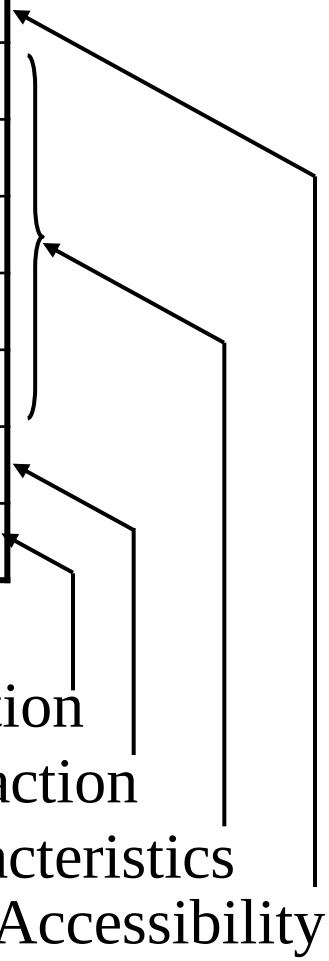


Cars : 0, 1, 2 and 3+
MC's : 0, 1 and 2+



EXPLANATORY VARIABLES USED

Car Ownership	Motorcycle Ownership
Accessibility	Accessibility
# of males aged 20–65	# of males aged 20–29
# of males aged –19, 66–	# of males aged –19, 30–
# of females aged 20–65	# of females aged 20–29
# of females aged –19, 66–	# of females aged –19, 30–
# of workers	# of workers
# of motorcycles owned	
Correlation	



License info. is not used: difficult to forecast in developing countries

CORRELATION AND INTERACTION

<Chi-square test: with/ without correlation models> $\chi^2_1(.05)=3.84$

		NGO81	NGO91	NGO01	BKK	KL
Without weights	Transit	11.24	2.90	3.88		
	Addition	12.18	4.06	4.88		
With weights	Transit	26.72	2.84	0.56	24.32	36.74
	Addition	0.58	2.88	0.58	16.66	37.3

<Chi-square test: with/ without interaction models> $\chi^2_1(.05)=3.84$

		NGO81	NGO91	NGO01	BKK	KL
Without weights	Transit	0.46	0.02	0.14		
	Addition	0.46	0.12	0.50		
With weights	Transit	1.42	0.26	0.48	1.92	20.88
	Addition	0.56	0.5	0.68	0.8	20.66

We have confirmed that generally:

- Including error correlation significantly improves model fits
- Including interaction terms does not significantly improve model fits

Models with error correlation (not interaction) are presented hereafter

ESTIMATION RESULTS

Accessibility measures considered
($\bar{\rho}^2$ based on L(**0**) and L(**c**) is reported)

		NGO81	NGO91	NGO01	BKK	KL
Without weights	Transit	0.0857	0.1697	0.1744		
	Addition	0.0848	0.1626	0.1744		
With weights	Transit	0.0909	0.1888	0.1513	0.0478	0.0487
	Addition	0.0945	0.1950	0.1568	0.0535	0.0487

Not available

As an example, the results using weighted additional accessibility of car and motorcycle availability are presented (the best fit to the data except for NGO 01)

Estimation Results (summary statistics)

	NGO81	NGO91	NGO01	BKK	KL
N	1,000	1,000	1,000	1,000	1,000
L(**β**)	-1,600.6	-1,584.3	-1,419.7	-1,531.0	-1,896.4
L(**c**)	-1,782.0	-1,984.3	-1,699.1	-1,631.3	-2,007.1
$\bar{\rho}^2$	0.0945	0.1950	0.1568	0.0535	0.0487

- 1,000 samples are drawn randomly

Estimation Results (car ownership)

	NGO81		NGO91		NGO01		BKK		KL	
Variable	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.
M20-65	0.38	6.0	0.64	8.8	0.57	7.4	0.29	14.6	0.20	3.5
M-19,66-	0.06	1.6	0.29	6.2	0.41	4.4	0.10	1.8	0.09	1.7
F20-65	0.03	0.6	0.50	7.6	0.66	9.7	0.14	2.4	0.18	3.5
F-19,66-	0.11	2.5	0.32	6.0	0.54	5.9	0.23	4.4	-0.01	-0.1
Worker	0.21	4.0	0.40	7.7	0.34	4.9	0.10	1.9	0.11	2.2

- Generally, household with more members has more cars
- # of workers have significant positive effects except for BKK
- Males aged 20-65 have greater effects than females aged 20-65 in developing countries and used to have in NGO
- Aged between 20-65 have greater effects than aged -19,66- except for NGO81 females and BKK females

Estimation Results (motorcycle ownership)

	NGO81		NGO91		NGO01		BKK		KL	
Variable	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.
M20-29	0.22	2.0	0.54	4.9	0.36	2.9	0.45	5.6	0.36	6.0
M-19,30-	0.06	1.1	0.29	5.5	0.25	2.4	0.22	4.1	0.16	3.4
F20-29	0.02	0.2	0.04	0.4	0.11	0.9	-0.12	-1.5	-0.17	-2.6
F-19,30-	0.03	0.6	0.07	1.2	0.18	2.2	-0.03	-0.6	-0.11	-2.7
Worker	0.20	3.4	0.15	2.6	0.03	0.3	0.11	2.2	0.14	3.2

- Household members' characteristics estimated positively significantly or insignificantly except for females in KL
  - More members, more motorcycles, generally
- # of workers have positive effects
- Males have greater effects
- Aged between 20-29 have greater effects than aged -19,30- except for females in NGO01 and females in KL

Estimation Results (accessibility measures)

	NGO81		NGO91		NGO01		BKK		KL	
Variable	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.
WAAC	0.44	4.3	0.59	7.1	0.48	9.2	0.54	3.1	0.12	0.1
WAAMC	1.13	2.7	0.92	2.0	0.27	0.6	0.89	3.3	-0.30	-0.3

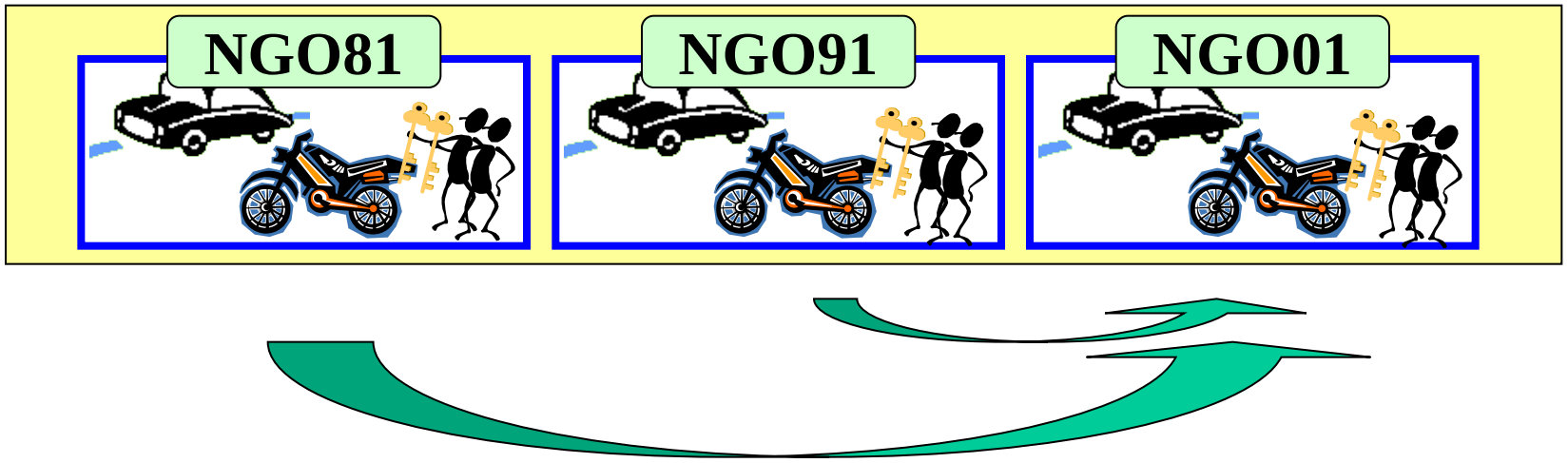
- WAAC estimated positively and significantly in NGO and BKK
- WAAMC estimated positively and significantly in BKK and used to be in NGO
- WAAC is estimated more significantly than WAAMC in NGO, suggesting that some own motorcycles for pleasure

Estimation Results (correlation)

	NGO81		NGO91		NGO01		BKK		KL	
Variable	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.
Cor.	0.25	5.7	0.08	1.8	0.04	0.9	-0.21	-4.0	-0.25	-6.5

- Positively estimated in NGO
  - Positive unobserved interaction between car and motorcycle ownership
  - Those who intend to own cars intend to own motorcycles, and vice versa
  - Tend to become insignificant, that is, independent
- Negatively and significantly estimated in BKK and KL
  - Negative unobserved interaction between car and motorcycle ownership
  - Those who intend to own cars DO NOT intend to own motorcycles, and vice versa (substitution effect)

TEMPORAL TRANSFERABILITY

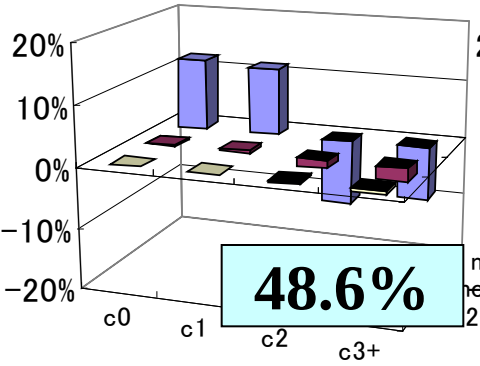
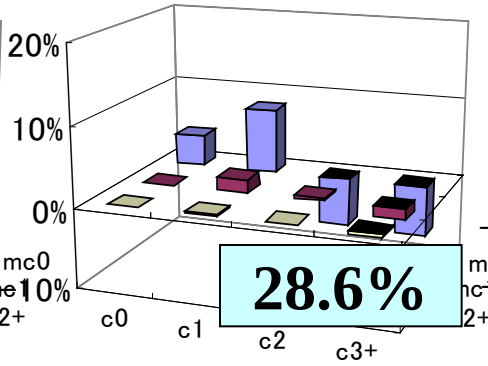
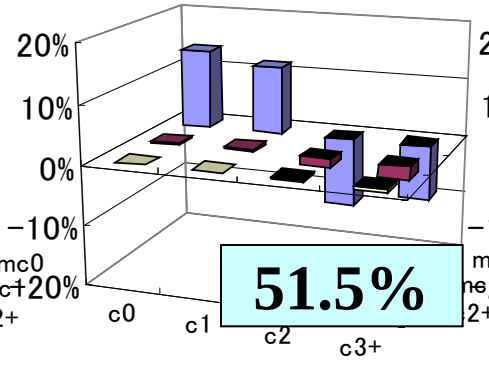
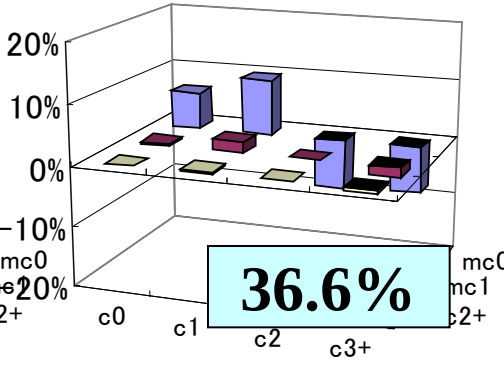
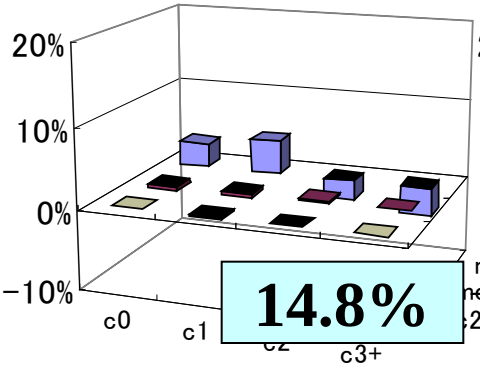
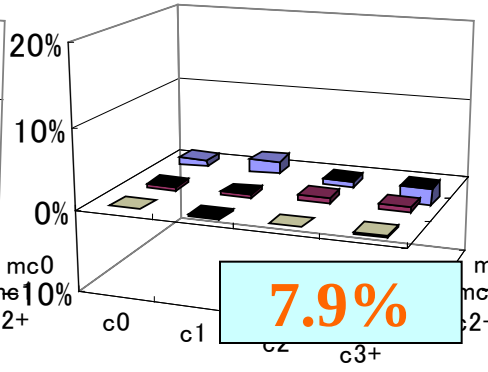
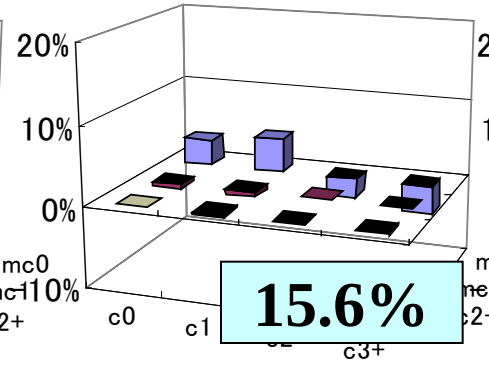
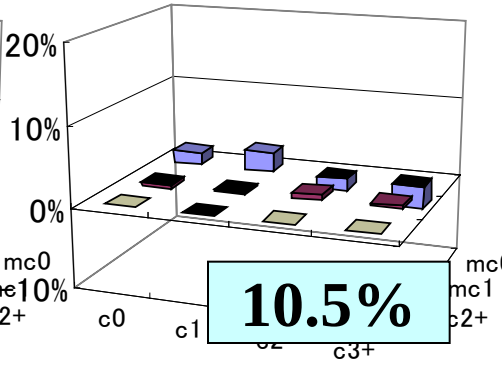


NGO01 vehicle ownership is predicted using NGO81 and NGO91 models

TEMPORAL TRANSFERABILITY

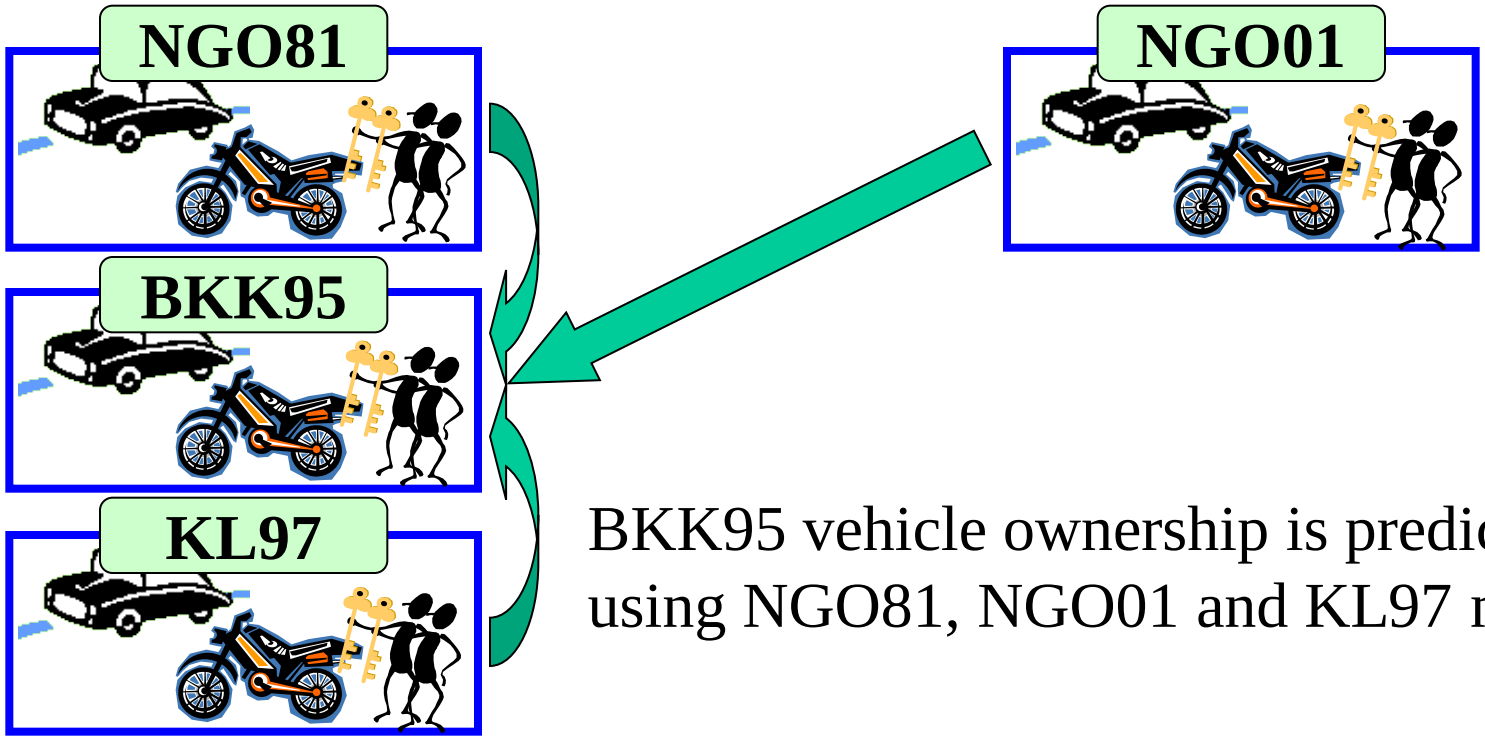
(Forecast value – Actual value) is presented

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

Without weights		With weights	
Transit	Addition	Transit	Addition
NGO81(T)	**NGO81(A)**	**NGO81(W-T)**	**NGO81(W-A)**
			
48.6%	**28.6%**	**51.5%**	**36.6%**
NGO91(T)	**NGO91(A)**	**NGO91(W-T)**	**NGO91(W-A)**
			
14.8%	**7.9%**	**15.6%**	**10.5%**

91, without weights, additional is the best

SPATIAL TRANSFERABILITY



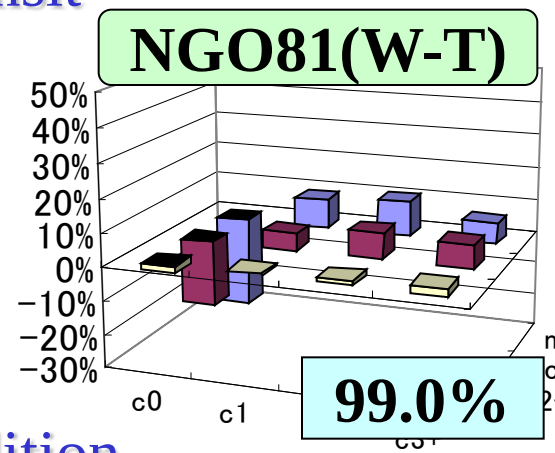
BKK95 vehicle ownership is predicted using NGO81, NGO01 and KL97 models

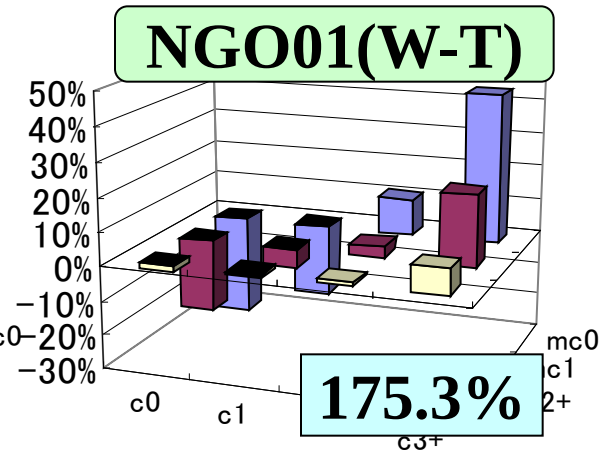
SPATIAL TRANSFERABILITY

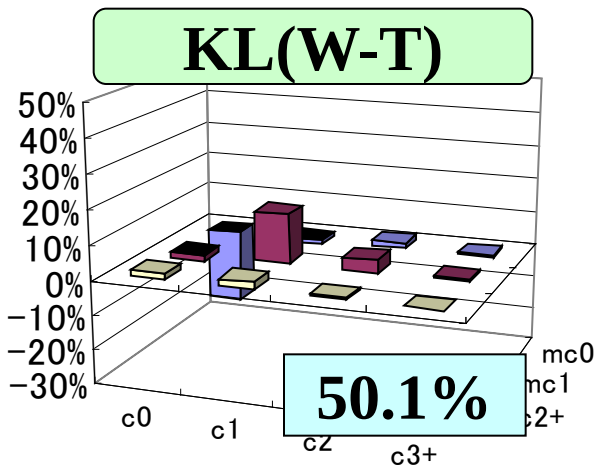
(Forecast value – Actual value) is presented

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

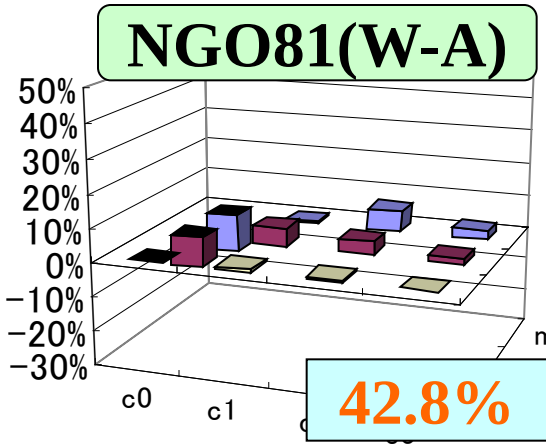
Transit

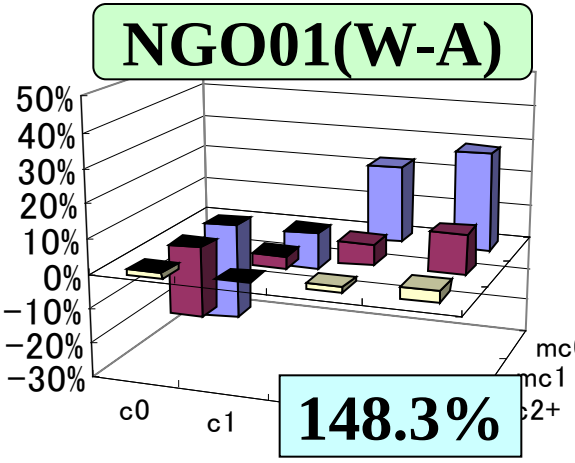


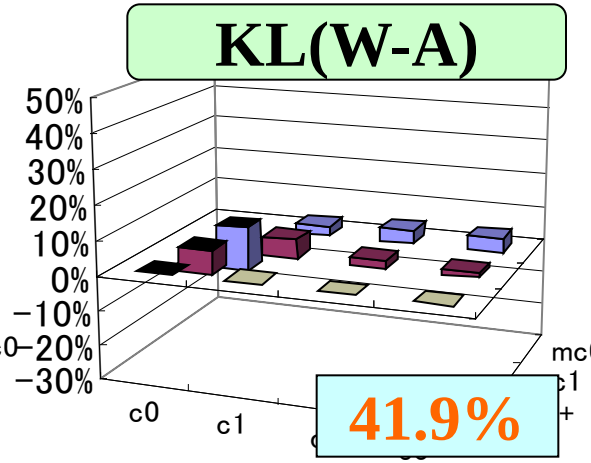




Addition







NGO81 and KL additional are better

CONCLUSIONS

- This study analysed car and motorcycle ownership behaviours in Asian cities incorporating accessibility measures obtained through mode choice models.
- Findings from the bivariate ordered probit models
  - More members, more vehicles
  - More workers, more vehicles
  - Males generally have greater effects on vehicle ownership
  - Aged between 20-65 (car) and 20-29 (motorcycle) have greater effects on vehicle ownership
  - Accessibility generally has significant impacts on vehicle ownership and has greater effects on car ownership
  - Correlation is estimated positively in NGO and negatively in developing countries

CONCLUSIONS

- Findings from transferability analysis
  - Additional accessibility models have better transferability
  - Without weights accessibility models have better temporal transferability
  - Models estimated at the year closer to the target year have better temporal transferability
  - Models estimated at the area or time point that have similar characteristics to the target area have better spatial transferability

Merci de votre attention!