# Time-Series Comparison of Auto/Motorcycle Ownership and Joint Mode and Destination Choice Models Based on Two Large-Scale Surveys in Jakarta

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**Abstract**: This paper presents the results of household auto/motorcycle ownership and joint mode and destination choice models that were developed based on the two large-scale travel surveys conducted eight years apart from each other. It also compares the models and discusses implications of the changes that have been made in the Jakarta Metropolitan Area in the last decade. So long as the context of the society will not change, both models should remain unchanged with fixed parameters over a period of time. However, the models that were estimated based on the surveys conducted nearly a decade apart have indicated quite different parameters with different degrees of significance. Such implications may also be important and hence worth studying for other urban areas of the developing world though similarities may be restricted to regions that share modal and cultural norms in common.

*Keywords*: Time-Series Comparison, Auto Ownership, Motorcycle Ownership, Joint Mode and Destination Choice, Travel Survey, Jakarta

## 1. INTRODUCTION

Activity-based travel demand models developed in practical applications have several major modules including daily activity patterns and tours, time of day choices, and mode and destination choices. While developing individual components of such framework has its own difficulties, developing a valid and useful joint mode and destination choice model seems to be one of the critical and challenging elements of such framework. This is mainly due to the fact that mode and destination choice are tied to exact household and activity locations that in most cases are not available to the analyst, making it difficult to develop such models.

The data obtained from a large household travel survey provided dataset explaining travel patterns and preferences as well as detailed information on household socio-demographic characteristics. The survey was sponsored by Japan International Cooperation Agency (JICA) that conducted “The Study on Integrated Transportation Master Plan (SITRAMP)” (BAPPENAS and JICA, 2004) in the Jakarta Metropolitan Area, Indonesia from November 2001 to March 2004. The overall objective was to identify possible policy measures and solutions to develop a sustainable transportation system in the Jakarta Metropolitan Area with a focus on encouraging public transport usage and improving mobility of people. As such, detailed transportation surveys and analyses were undertaken to prepare a comprehensive long-term transportation plan with the objective to develop and calibrate disaggregate travel demand models to simulate present and future interactions between socio-economic distribution and transportation in the region.

The Household Travel Survey (HTS), among a variety of the surveys conducted in 2002, provided the largest and most comprehensive travel data in the region. The dataset covered as many as 166,000 households which correspond to 3% of the entire population, and provided daily travel patterns and detailed information on household socio-demographic characteristics.

Furthermore, from July 2009 to September 2011, a Japan-Indonesia joint technical cooperation project called "JABODETABEK Urban Transportation Policy Integration (JUTPI)" was also conducted by JICA in order to update the transportation survey database and revise the SITRAMP master plan. In this project, another large-scale survey, Commuter Travel Survey (CTS), was conducted in 2010 to understand the characteristics of commuting trips (e.g., destination, mode, travel time, cost) of worker(s) and student(s) of each household and to collect the socioeconomic information of the household and household members in the Jakarta Metropolitan Area. This survey dataset covers as many as 179,000 households which correspond to 3% of the entire population, and provides daily commuting (i.e., home-based work and school) travel patterns and, again, detailed information on household socio-demographic characteristics.

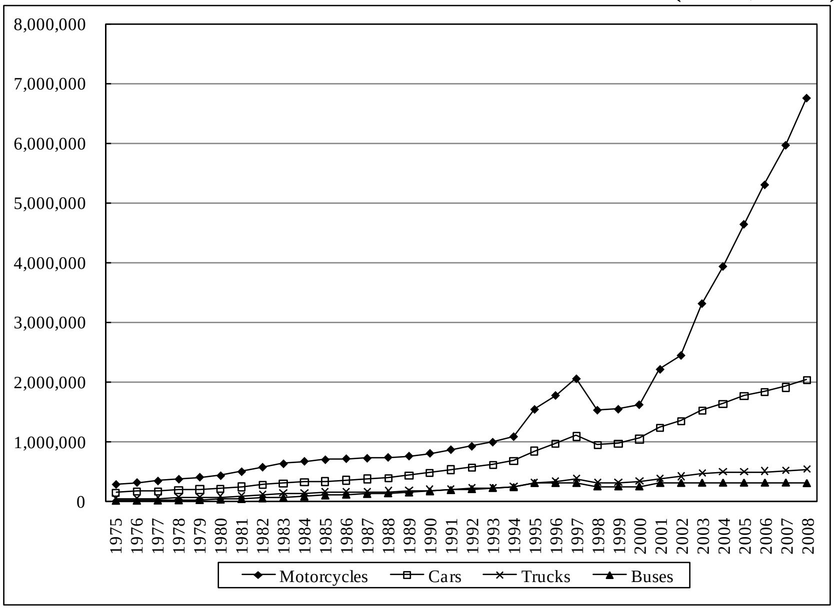
In SITRAMP and JUTPI, travel characteristics as well as socioeconomic features were analyzed in detail based on the HTS and the CTS datasets, respectively. Above all, in the Jakarta Metropolitan Area, last decade has seen an unprecedented growth in auto and motorcycle ownership and a drastic change in mode shares as well as people's travel behavior. Thus, this paper presents time series comparison of household auto ownership and joint mode and destination choice models in a changing transportation environment in Jakarta.

## 2. CHANGE IN TRANSPORTATION ENVIRONMENT OF JAKARTA

The Jakarta Metropolitan Area, called Jabodetabek, is a large-scale metropolitan region with a population of 28 million, and consists of DKI (Special Capital District) Jakarta and eight local municipalities (Kabupaten and Kota Bogor, Kota Depok, Kabupaten and Kota Tangerang, Kota South Tangerang, and Kabupaten and Kota Bekasi). Its gross regional domestic product (GRDP) is estimated at Rp. 1,056,000 billion (US$ 118.7billion) or 19 percent of the national gross domestic product (GDP) (as of 2010) (Statistics Indonesia, 2010a; Statistics Indonesia, 2010b), showing that the Jakarta Metropolitan Area is strategically the most important region of the nation.

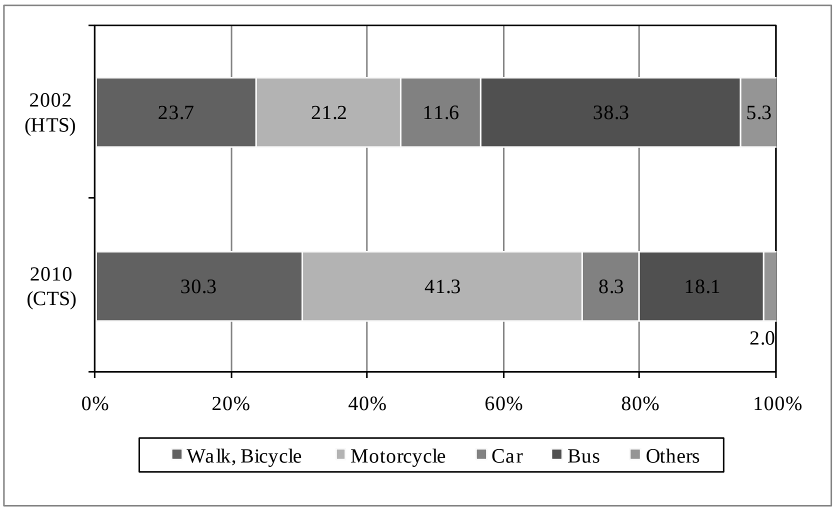
In the Jakarta Metropolitan Area, last decade has seen an unprecedented growth in auto and motorcycle ownership as well as a drastic change in mode shares. The number of the registered autos in Jakarta has increased twice in the period from 2000 to 2010 while the number of the registered motorcycles has increased 4.6 times in the same period as indicated in Figure 1. It may be because motorcycle has become more easily affordable with a simple loan scheme. Furthermore, as motorcycle is a virtually "congestion-free" mode of transport by running through the narrow space between autos, about half of motorcycle users value its swiftness as a reason for the mode choice (Kawaguchi *et al.*, 2010). Such an increase of motorcycles has brought about rapid growth of trips made by motorcycles.

As for mode shares, results of HTS and CTS indicate drastic changes in the commuting trip mode shares in the region between 2002 and 2010, as shown in Figure 2. In 2002, as many as 40% of trips were made by buses while nearly 50% of trips were made by motorcycles in 2010. Such dramatic changes in the transportation environment may also occur in other urban areas of the developing world. For example, in Vietnam, which used to be famous for the enormous mode share of bicycles in urban areas, the mode share of motorcycles increased from 21% in 1995 to 64% in 2005 in Hanoi (JICA, 2005).




Source: (Statistics Indonesia, 2010c)

Figure 1. Number of registered vehicles in DKI Jakarta.




Source: (BAPPENAS and JICA, 2004; CMEA and JICA, 2011)

Figure 2. Change in mode shares of commuting trips: 2002 - 2010.

The change in mode shares in Jakarta implies that public transportation represented by bus transportation is losing passengers and it needs urgent solution. Furthermore, major shift from bus transportation to motorcycle implies that in future those who are accustomed to using private mode of transport would shift to private autos when their income increases. Consequently it may cause serious traffic congestion on the road network in the region.

## 3. DATA SOURCE

In SITRAMP (BAPPENAS and JICA, 2004), detailed transportation surveys such as Household Travel Survey (HTS) were conducted in 2002, and analyses were undertaken to prepare a comprehensive long-term transportation plan. The primary objective of these surveys was to develop and calibrate disaggregate travel demand models to simulate present and future interactions between socioeconomic distribution and transportation demand. Among a variety of the surveys conducted, HTS, which is a large scale home interview survey of household daily travel, provides the largest and most comprehensive travel data in the region. Furthermore, along with the Activity Diary Survey which provided a detailed four-day diary covering around 4,000 individuals in Jakarta, activity-based travel demand models were developed with several major modules including daily activity patterns and tours, time of day choices, and mode and destination choices (Yagi, 2006).

Thus, the large datasets obtained for SITRAMP provided a unique opportunity to conduct numerous other research work. In addition, latest dataset obtained from the Commuter Travel Survey (CTS), which was conducted within the scope of JUTPI in 2010, provides a further opportunity for an in-depth study such as a time-series comparison of travel behavior that has been drastically changing in the Jakarta Metropolitan Area as mentioned earlier.

## 3.1 Household Travel Survey (HTS)

HTS in 2002 covered the Jakarta Metropolitan Area with a targeted sampling rate of 3%, which led to the sample size of some 166,600 households as shown in Table 1. Average household size is different in DKI (special capital district) Jakarta and Bodetabek (suburban municipalities); hence, numbers of samples were calculated respectively. A random sampling method was adopted for HTS sampling rather than a stratified sampling method. The survey method was a home interview followed by a questionnaire. Interviewers were visiting homes for initial interview, leaving questionnaires, and collecting them by a re-visit usually one week later. The questionnaires include household, household member, and travel information as explained below.

1) Household Information: This survey component covers the socio-economic background of the household including residential address, telephone availability, auto/motorcycle ownership, income level, length of residency, household composition, opinions on transport issues, and related items.
2) Household Member Information: This survey component provides information on the socio-demographic background of the household members including age, gender, occupation, work/school address, industry, workplace type, working field, monthly income, vehicle availability, transport cost, transport cost subsidy from company, and related items.
3) Travel Information: This survey component covers the characteristics of the trips made by the household members on a weekday (Tuesday, Wednesday, or Thursday) including origin and destination, travel purpose, transport mode, transfer, departure and arrival times, and related items.

## 3.2 Commuter Travel Survey (CTS)

CTS in 2010 also covered the Jakarta Metropolitan Area with a targeted sampling rate of 3%, which led to the sample size of some 179,000 households as shown in Table 1. A random sampling method was also adopted for CTS sampling. The survey method was also a home interview followed by a questionnaire; however, interviewers were visiting homes for interview only once. Survey form consisted of socioeconomic conditions of household and household members (similar to the above-mentioned Forms 1 and 2), polling of opinion, and detailed information (similar to the above-mentioned Form 3) of work or school trips made by household members who regularly go to work or school. The above-mentioned income-related bias was also revealed in the CTS dataset, and hence the weight factors have also been adjusted so that it would reflect the current regional vehicle registration data.

In JUTPI, the analysis results obtained from the CTS dataset were first compared with those from the previous HTS dataset. That is, distributions of household socio-demographic attributes as well as travel characteristics (e.g., trip rates) were compared to analyze the change in the society as well as the transportation environment in the Jakarta Metropolitan Area.

Table 1. Sample size of HTS and CTS.

a) HTS (2002)

| | DKI Jakarta[1/] | Bodetabek[2/] | Total |
|---|---|---|---|
| Population[3/] | 8,447,000 | 13,127,000 | 21,574,000 |
| No. of households | 2,253,700 | 3,300,800 | 5,554,500 |
| Average household size[4/] | 3.75 | 3.98 | 3.88 |
| No. of HTS zones (villages) | 261 | 1,224 | 1,485 |
| No. of sampled households[5/] | 67,600 | 99,000 | 166,600 |

Notes: 1/ Capital District
2/ Suburban Municipalities
3/ Estimated based on census (as of 2002)
4/ Based on population census
5/ Calculated at a sampling rate of 3%.

b) CTS (2010)

| | DKI Jakarta[1/] | Bodetabek[2/] | Total |
|---|---|---|---|
| Population[3/] | 10,225,000 | 17,686,000 | 27,911,000 |
| No. of households | 2,353,000 | 4,953,000 | 7,306,000 |
| Average household size[4/] | 4.35 | 3.57 | 3.82 |
| No. of HTS zones (villages) | 386 | 1,273 | 1,659 |
| No. of sampled households | 50,200 | 128,800 | 179,000 |

Notes: 1/ Capital District
2/ Suburban Municipalities
3/ Estimated based on census (as of 2010)
4/ Based on population census

## 4. MODELING AUTO/MOTORCYCLE OWNERSHIP AND JOINT MODE AND DESTINATION CHOICE MODELS

### 4.1 Model Description

A “trip” is defined as a travel between two activities representing the trip purpose (home to work, home to school, etc). The term “purpose” is used to present the activity performed at the trip end. Furthermore, each trip record is coded with travel mode (walk, bus, motorcycle, etc.). A “tour”, on the other hand, is defined as a chain of trips which start from a base and return to the same base. In this study, a tour has been considered a home-based tour if it starts from home and ends at home.

The main purpose of the study is to estimate models of household auto/motorcycle ownership choice and models of joint choice of mode and destination for home-based *work* and *work* tours based on the latest CTS dataset in 2010 and to compare them with the models that were developed earlier based on the HTS dataset in 2002 (Yagi, 2006; Yagi and Mohammadian, 2008). The modeling approach is a discrete choice model based on the random utility maximizing principles. It has been shown that the multinomial logit model is the most popular form of discrete choice model in practical applications (Mohammadian and Doherty, 2005). Nested logit model, which has been utilized in this study, is a model that has been developed in order to overcome the so-called independence of irrelevant alternatives (IIA) limitation in the multinomial model by modifying the choice structure into multiple tiers. Nested logit models are very commonly used for modeling mode choice, permitting covariance in random components among nests of alternatives. Alternatives in a nest exhibit an identical degree of increased sensitivity relative to alternatives in the nest (Williams, 1977; McFadden, 1978; Daly and Zachary, 1978). A nested logit model has a log-sum or expected maximum utility associated with the lower-tier decision process. The parameter of the log-sum determines the correlation in unobserved components among alternatives in the nest (Daganzo and Kusnic, 1993). The range of this parameter should be between 0 and 1 for all nests if the nested logit model is to remain globally consistent with the random utility maximizing principle.

### 4.1.1 Household auto/motorcycle ownership choice model

Activity-based travel demand models that were developed based on HTS needed input about the number of autos and motorcycles owned by each household of different attributes; hence, a household auto/motorcycle ownership choice model was developed (Yagi, 2006). When HTS was conducted in the Jakarta Metropolitan Area in 2002, it was revealed that 56% of households owned neither autos nor motorcycles; meanwhile, 34% owned motorcycle(s), and 17% owned auto(s). A household auto/motorcycle ownership choice model was developed with major combinations of numbers of autos and motorcycles owned by the household (i.e. 1% at the minimum) as choice alternatives as shown in Table 2. In order to create representative alternatives for modeling, households were classified into those with 0, 1, and 2 or more autos; then, households with 0 auto were subdivided into those with 0, 1, and 2 or more motorcycles while households with 1 auto were subdivided into those with 0 and 1 or more motorcycles. It was a simple multinomial logit model with six alternatives.

Table 2. Compositions of households owning autos/motorcycles.

a) HTS (2002)

| No. of Motorcycles | No. of Autos | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4+ | Total |
| 0 | 55.7% | 8.4% | 1.4% | 0.2% | 0.1% | 65.9% |
| 1 | 25.1% | 5.2% | 0.6% | 0.1% | 0.1% | 31.1% |
| 2 | 1.7% | 0.7% | 0.1% | 0.0% | 0.0% | 2.6% |
| 3 | 0.2% | 0.1% | 0.0% | 0.0% | 0.0% | 0.3% |
| 4+ | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% |
| Total | 82.8% | 14.5% | 2.2% | 0.4% | 0.1% | 100.0% |

b) CTS (2010)

| No. of Motorcycles | No. of Autos | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4+ | Total |
| 0 | 24.1% | 3.3% | 0.6% | 0.1% | 0.0% | 28.1% |
| 1 | 39.0% | 10.1% | 1.0% | 0.2% | 0.1% | 50.4% |
| 2 | 9.9% | 6.0% | 0.6% | 0.1% | 0.1% | 16.6% |
| 3 | 2.0% | 1.6% | 0.3% | 0.1% | 0.0% | 3.9% |
| 4+ | 0.5% | 0.4% | 0.1% | 0.0% | 0.0% | 1.0% |
| Total | 75.4% | 21.4% | 2.6% | 0.5% | 0.2% | 100.0% |

Notes: Shaded cells indicate compositions of over 1%.

Meanwhile, in the CTS dataset, more than 70% of households own at least one motorcycle, as of 2010. Another household auto/motorcycle ownership choice model from the CTS dataset was developed with more major combinations of numbers of autos and motorcycles owned by the household defined in the same manner. In order to create representative alternatives for modeling, households were classified into those with 0, 1, and 2 or more autos; then, households with 0 auto were subdivided into those with 0, 1, 2, and 3 or more motorcycles while households with 1 auto were subdivided into those with 0 and 1, and 2 or more motorcycles. It is now a simple multinomial logit model with nine alternatives.

Over 160,000 samples were taken from the HTS and CTS databases, and different models were estimated based on those two datasets and compared.

### 4.1.2 Joint mode and destination choice model

For joint mode and destination choice, the results of both HTS and CTS show that at least over 90 percent of people return home using the same mode as they used for the from-home trips, though the percentages vary depending on modes and purposes. This suggests that from-home trips constrain the modes and destinations of the subsequent segments such as returning-home trips. Therefore, for mode and destination choice, from-home trips are focused on and used to estimate the entire tour mode and destination choice model.

Eight most commonly used combinations of travel modes observed in the region are considered. These include auto drive alone, auto shared ride, motorcycle, taxi, motorcycle taxi, transit with motorized access, transit with non-motorized access, and non-motorized transport. Although auto drive alone and shared ride were treated as a single alternative in the previous SITRAMP study, these two alternatives have been clearly distinguished in order to make the model more sensitive to the transportation policies, especially those related to high-occupancy vehicles. Motorcycle taxi is a unique mode of transport but is quite common in urban areas of the developing world. It usually serves relatively shorter-distance trips using any types of roads from alleys to arterials, especially in cases where autos, taxis, or buses are hardly available. Transit has been divided into two, that is, transit with and without motorized access. The former includes park-and-ride or kiss-and-ride access by private auto or motorcycle; however, access by the above-mentioned motorcycle taxi is more common in the Jakarta Metropolitan Area. As for non-motorized transport, walking is a dominant mode though bicycles and pedicabs are also observed in some suburban areas. Mode shares based on the HTS and CTS datasets are summarized in Table 3.

Table 3. Mode shares by purpose

a) HTS (2002)

| Purpose | Auto Drive Alone | Auto Shared Ride | Motor-cycle | Taxi | Motor-cycle Taxi | Transit w/ Motorized Access | Transit w/o Motorized Access | Non-Motor ized Transport | Total |
|---|---|---|---|---|---|---|---|---|---|
| Work | 4.6% | 3.7% | 23.5% | 0.5% | 2.6% | 6.2% | 36.8% | 22.1% | 100.0% |
| School | 0.3% | 2.5% | 5.7% | 0.3% | 2.5% | 2.9% | 38.7% | 47.1% | 100.0% |

b) CTS (2010)

| Purpose | Auto Drive Alone | Auto Shared Ride | Motor-cycle | Taxi | Motor-cycle Taxi | Transit w/ Motorized Access | Transit w/o Motorized Access | Non-Motor ized Transport | Total |
|---|---|---|---|---|---|---|---|---|---|
| Work | 8.8% | 3.9% | 54.7% | 0.1% | 1.0% | 5.9% | 8.1% | 17.3% | 100.0% |
| School | 0.5% | 2.7% | 25.5% | 0.2% | 2.7% | 9.7% | 13.3% | 45.5% | 100.0% |

As for the destination choice, in order to reduce the complexity of the parameter estimation of the nested logit model, eleven representative destinations are considered for each tour. Although all traffic analysis zones (TAZs) in the region could be included in the simulation step to improve the quality of the model predications, inclusion of all zones can enormously increase the microsimulation time due to difficulty of computing logsum variables, leading to tens of days of microsimulation time for analysis of just one scenario.

As discussed above, for parameter estimation purpose, the destinations are sampled from the TAZs using the stratified importance sampling method, assuming consistency of alternative sampling with nested logit structure. Releasing this assumption for a more efficient estimation of the nested logit model with choice-based sample, as shown by Koppelman and Garrow (2005) and Koppelman *et al.* (2005), remains as a future task.

For each purpose, the strata of destinations are constructed based on the distance as well as a size variable which indicates the magnitude of attraction in the destination (Bradley *et al.*, 1998). Size variables have been set as total jobs for *work* and total students at school place for *school* tours. As a result, this sampling method leads to higher probabilities of being selected for zones closer to the origin (i.e., home) as well as for zones with larger potential of corresponding attraction.

Actual sampling strata for these 11 representative destination zones are as follows:

1) Zone 1, “sampled” from the origin zone;
2) Zones 2 and 3, sampled from a distance less than $D_1$;
3) Zones 4 and 5, sampled from a distance between $D_1$ and $D_2$ and total jobs less than $J$;
4) Zones 6 and 7, sampled from a distance between $D_1$ and $D_2$ and total jobs greater than $J$;
5) Zones 8 and 9, sampled from a distance greater than $D_2$ and total jobs less than $J$;
6) Zones 10 and 11, sampled from a distance greater than $D_2$ and total jobs greater than $J$,

where,

1) $D_1$ and $D_2$ are the 20$^{th}$ and 60$^{th}$ percentile distances from the origin zone to all other tour destinations for each purpose, respectively; and
2) $J$ is the 50$^{th}$ percentile size variable of all tour destinations for each purpose.

While the value of size variable, $J$, stays the same regardless of the origin zones, the values of distance, $D_1$ and $D_2$, are different depending on the origin zone. Hence, the composition of the above sampling strata for destination choice also differs by the origin zone.

As this is a joint model of mode and destination choice, total number of choice alternatives is presumed to be 88 (i.e., total number of modes multiplied by total number of destination zones). Meanwhile, frequencies of tours by each travel mode in relation to the tour origin-destination distance were investigated in the HTS and CTS datasets as shown in Figure 3. The graphs show that some travel modes are more frequently observed in the shorter-distance range and very rare in the longer-distance range; non-motorized transport stands out in this sense, followed by motorcycle taxi. Hence, it has been assumed that motorcycle taxi alternatives are unavailable if the distance to the destination zone is greater than $D_2$, and non-motorized transport alternatives are unavailable if the distance is greater than $D_1$. Thus, the maximum number of available alternatives is reduced to 76. Auto (drive alone) alternatives are made unavailable for individuals under 17 (i.e., pre-driving age) and for those who do not have access to any autos as indicated in the survey. Additionally, motorcycle alternatives are made unavailable for those who do not have access to any motorcycles.

a) HTS (2002)

b) CTS (2010)

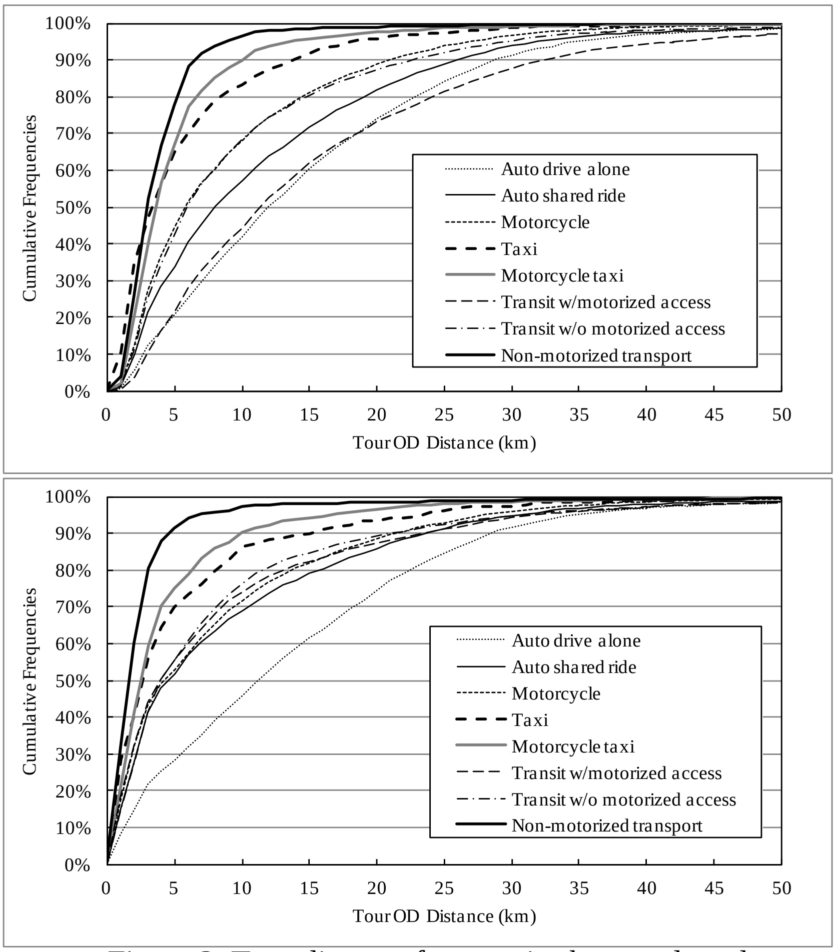



Figure 3. Tour distance frequencies by travel mode

The model has a two-tier nested logit structure. As shown in Figure 4, for each representative zone, auto drive alone, auto shared ride, and motorcycle; and taxi, motorcycle taxi, transit with motorized access, and transit with non-motorized access are each placed in the second tier under different nests while non-motorized transport is placed as a degenerate branch. Although nests are created for each representative destination zone, logsum parameters are set to be common for the nests which involve the same mode group. The model is estimated separately for each purpose (i.e., *work*, *school*). Samples have been taken from the HTS and CTS datasets.

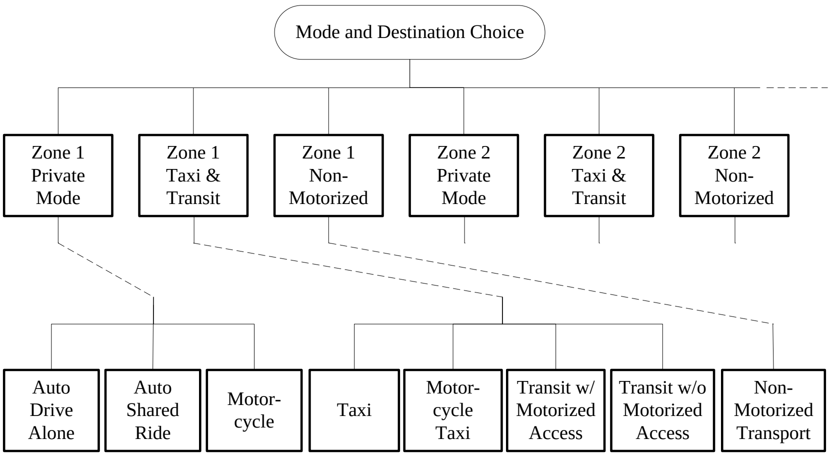



Figure 4. Modeling structure: mode and destination choice model

### 4.2 Explanatory Variables

The following variables have been tested and included in the utilities of household auto/motorcycle ownership choice and mode and destination choice for model estimation:

1) Household related variables: household income, household member composition, and auto and motorcycle ownership; and
2) Zone related variable: identities of origin/destination zones and zones in the urban area, fractions of land for business/commercial use, and densities of general jobs.

Particularly, for joint mode and destination choice, the following variables have been added:

3) Trip related variables: generalized travel time (including in-vehicle time, access and egress time, waiting time, transit fare, and highway toll), transit walk time, and travel distance, as well as travel time multiplied by household income;
4) Tour related variables: times of day for start of the tour and for start of the returning segment of the tour; and
5) Individual related variables: individual status, school type, gender, age, and commuting allowances provided by the employer.

While the majority of variables have been directly derived from the HTS data, for mode and destination choice, some other zone-based information were utilized such as generalized travel time, transit walk time, and travel distance skimmed from the preliminary highway and transit network assignment, and land use composition in each traffic analysis zone computed from the GIS database. Furthermore, natural logarithm of the corresponding size variable is included as a destination zone related variable. The coefficient of this variable is considered as the scale parameter (Ben-Akiva and Lerman, 1985), and the value was estimated at around 0.8 in the preliminary model estimation for each purpose. Following Ben-Akiva and Lerman (1985), this scale parameter has been constrained to 1 in the final model. However, this had little effect to the values of coefficients of other variables.

## 5. MODELING RESULTS

### 5.1 Household Auto/Motorcycle Ownership Choice Model

Results of the household auto/motorcycle ownership choice models estimated based on HTS in 2002 and CTS in 2010 are presented in Tables 4 and 5, respectively. Both models show a good fit with the adjusted rho-squared values of around 0.45. Modeling outcomes are summarized and discussed below.

Motorcycle is a most commonly used transportation mode in many urban areas in the developing countries. Particularly in the Jakarta Metropolitan Area, motorcycle becomes more important to own and utilize when there is an infant or child in the household. Many of middle- and low-income households, which take a majority, may think of having a motorcycle when they have an infant or child in the family to meet the infant or child’s needs.

One-member household dummy was included in the utility function of owning no auto/motorcycle because it is reasonable for those who are usually workers living alone to select the residence close to the workplace in order to avoid the transportation cost. Meanwhile, it is natural to assume one-member household tends to own only one auto or motorcycle.

Household income is always a key factor in both 2002 and 2010 models. That is, higher-income households tend to own more autos/motorcycles. Parameters for the household income become greater in the choice alternatives of more autos/motorcycles.

Urban area dummy, which is defined comprehensively for each zone based on the population density, percentage of farming households, and number of certain public facilities such as schools and markets, has also been included in the utility functions of most combinations of autos and motorcycles in both 2002 and 2010 models. However, comparing the parameters of the urban area dummy in the same choice combination alternatives, coefficients have generally become smaller from 2002 to 2010. Also, *t*-stat values have become less significant in some alternatives; for example, in 1 auto and 0 motorcycle combination alternative, this parameter became not significant and has been replaced with a Jakarta proper dummy. It may be because autos and motorcycles have widely diffused in the last decade and have been made available to many households regardless of the urban/rural distinction.

As for another zonal parameter, namely household density in the home zone, it has been included in both 2002 and 2010 models. However, while it was included in alternatives with 0 auto in the 2002 model, it has been included only in the 0 auto and 0 motorcycle alternative in the 2010 model. It implies that household density now takes a minor role in the utility functions of alternatives with 0 auto compared to 2002. As mentioned earlier, motorcycles have diffused so widely all over the Jakarta Metropolitan Area regardless of whether the zone is urban or rural, and regardless of whether the zone is in DKI Jakarta or not. Composition of households owning no auto/motorcycles has decreased to less than half, that is, from 56% in 2002 to 24% in 2010, as shown in Table 2.

Table 4. Household auto/motorcycle ownership choice model based on HTS (2002)

Observations = 162,358 Parameters = 25 $L(0)$ = -180727 $L(\hat{\beta})$ = -153007

$-2[L(0)-L(\hat{\beta})]$ = 55,440 $\bar{\rho}_0^2$ = 0.474 $\bar{\rho}_C^2$ = 0.153 AIC = 306063

| Alternative | 0 A, 0 M | | 0 A, 1 M | | 0 A, 2+ M | | 1 A, 0 M | | 1 A, 1+ M | | 2+ A | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | coeff. | *t-stat* | coeff. | *t-stat* | coeff. | *t-stat* | coeff. | *t-stat* | coeff. | *t-stat* | coeff. | *t-stat* |
| Alternative-specific constant | | | -1.144 | *-83.9* | -5.483 | *-95.1* | -3.478 | *-115.6* | -4.486 | *-84.4* | -6.783 | *-72.3* |
| Dummy: infant (age < 5) in household | | | 0.248 | *15.8* | | | | | | | | |
| Dummy: child (5 ≤ age < 17) in household | | | 0.235 | *20.2* | | | | | 0.308 | *11.1* | | |
| Dummy: only one adult in household | 0.655 | *25.0* | | | | | 0.722 | *14.4* | | | | |
| Number of adults (age ≥ 17) | | | | | 0.460 | *38.3* | | | 0.079 | *7.0* | 0.063 | *3.9* |
| Log of monthly household income (mil. Rp.) | | | 1.052 | *82.0* | 1.830 | *59.3* | 2.759 | *130.7* | 2.856 | *118.8* | 4.192 | *110.5* |
| Dummy: household in urban area | | | 0.622 | *39.6* | 1.094 | *21.2* | 0.958 | *27.5* | 1.225 | *28.4* | 1.450 | *19.0* |
| Household density (/ha) in the home zone | 0.009 | *16.5* | 0.005 | *9.2* | 0.005 | *9.2* | | | | | | |

Note: "A" is auto(s) and "M" is motorcycle(s).
Source: (Yagi, 2006)

Table 5. Household auto/motorcycle ownership choice model based on CTS (2010)

Observations = 177,508 Parameters = 30

$-2[L(0)-L(\hat{\beta})]=$ 349,440 $\bar{\rho}_0^2$ = 0.448

| Alternative | 0A, 0M | | 0A, 1M | | 0A, 2M | | 0A, 3+ M | |
|---|---|---|---|---|---|---|---|---|
| Variable | coeff. | *t-stat* | coeff. | *t-stat* | coeff. | *t-stat* | coeff. | *t-stat* |
| Alternative-specific constant | 8.533 | *135.0* | 7.367 | *117.4* | 5.119 | *82.1* | 3.111 | *44.8* |
| Dummy: infant (age < 5) in household | | | 0.319 | *28.0* | | | | |
| Dummy: child (5 ≤ age < 17) in household | | | 0.257 | *24.9* | | | | |
| Dummy: only one member household | 1.371 | *42.2* | 1.121 | *35.4* | | | | |
| Monthly household income (million Rp.) | | | 0.774 | *97.4* | 1.206 | *135.0* | 1.380 | *133.3* |
| Dummy: household in Jakarta proper | | | | | | | | |
| Dummy: household in urban area | | | 0.654 | *46.8* | 0.882 | *44.5* | 1.006 | *28.2* |
| Household density (/ha) in the home zone | 0.005 | *15.0* | | | | | | |

| Alternative | 1A, 0M | | 1A, 1M | | 1A, 2M | | 1A, 3+ M | | 2+ A | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variable | coeff. | *t-stat* | coeff. | *t-stat* | coeff. | *t-stat* | coeff. | *t-stat* | coeff. | *t-stat* |
| Alternative-specific constant | 1.587 | *22.4* | 2.572 | *39.8* | 1.742 | *26.1* | 0.354 | *4.0* | | |
| Dummy: infant (age < 5) in household | | | | | | | | | | |
| Dummy: child (5 ≤ age < 17) in household | | | | | | | | | | |
| Dummy: only one member household | 1.911 | *22.1* | | | | | | | | |
| Monthly household income (million Rp.) | 1.608 | *147.7* | 1.615 | *170.1* | 1.628 | *165.7* | 1.662 | *149.2* | 1.790 | *171.5* |
| Dummy: household in Jakarta proper | 0.632 | *14.2* | | | | | | | | |
| Dummy: household in urban area | | | 0.658 | *19.8* | 0.961 | *22.5* | 1.142 | *14.3* | 0.996 | *15.7* |
| Household density (/ha) in the home zone | | | | | | | | | | |

Note: "A" is auto(s) and "M" is motorcycle(s).

## 5.2 Joint Mode and Destination Choice Model

Results of the joint models of mode and destination choices for home-based *work* and *school* tours estimated based on HTS in 2002 and CTS in 2010 are presented in Tables 6 and 7 (for *work* tours), and Tables 8 and 9 (for *school* tours), respectively. The models show a good fit with the adjusted rho-squared value ranging from 0.37 to 0.55. The log-sum parameters from the lower-level alternatives range from 0.6 to 0.8 for both private modes and public modes, staying within a reasonable range with significant *t*-stat values. Modeling outcomes are summarized and discussed below, especially focusing on changes in the models from 2002 to 2010.

Table 6. Work tour mode and destination choice model based on HTS (2002)

Observations = 24037 L(*0*) = -100084 L(*β*) = -63039 $\rho^2$ = 0.370

| Logsum (expected maximum utility) | coeff. | *t-stat* |
|---|---|---|
| Private mode logsums | 0.737 | *62.2* |
| Taxi/transit mode logsums | 0.600 | *52.8* |
| **Generalized Travel Time (hr)** | **coeff.** | ***t-stat*** |
| for auto | -1.890 | *-16.0* |
| for motorcycle | -1.114 | *-22.8* |
| for taxi | -2.192 | *-7.2* |
| for motorcycle taxi and transit | -1.820 | *-36.6* |
| **Destination Land Use** | **coeff.** | ***t-stat*** |
| Dummy: origin zone | 2.190 | *65.7* |
| Tertiary job density (/ha) | 0.001 | *5.4* |
| Percentage of land for business use | 0.005 | *4.9* |
| Log of size variable (total jobs) | 1.000 | *constr.* |
| **Alternative / Variable** | **coeff.** | ***t-stat*** |
| *Auto Drive Alone* | | |
| Alternative-specific constant | -15.624 | *-19.2* |
| Log of travel distance (km) | 1.004 | *17.3* |
| Dummy: tour starts in p.m. peak or later | 0.361 | *2.3* |
| Dummy: one-member household | 0.817 | *2.3* |
| Dummy: car-owning household | 2.576 | *15.2* |
| Log of age of the individual | 2.168 | *10.3* |
| Dummy: male individual | 1.658 | *12.9* |
| Log of monthly ind. income (mil. Rp) | 0.353 | *4.4* |
| Dummy: toll allowance provided | 0.908 | *2.3* |
| Dummy: free parking provided | 0.557 | *2.0* |
| Dummy: private mode allowance provided | 2.418 | *13.0* |
| *Auto Shared Ride* | | |
| Alternative-specific constant | -19.899 | *-27.1* |
| Log of travel distance (km) | 0.966 | *16.4* |
| Dummy: tour starts in p.m. peak or later | 1.179 | *3.0* |
| Dummy: return trip starts in nighttime | 0.454 | *2.9* |
| Log of monthly hhd income (mil. Rp) | 0.733 | *9.1* |
| Dummy: car-owning household | 4.735 | *31.5* |
| Log of age of the individual | 2.900 | *15.4* |
| Dummy: toll allowance provided | 1.716 | *4.1* |
| Dummy: private mode allowance provided | 2.463 | *13.2* |
| *Motorcycle* | | |
| Alternative-specific constant | -4.032 | *-16.9* |
| Dummy: tour starts in a.m. peak | 0.673 | *9.1* |

| Alternative / Variable | coeff. | *t-stat* |
|---|---|---|
| *Motorcycle (continued)* | | |
| Dummy: infant (age < 5) in household | 0.362 | *3.6* |
| Dummy: child (age:5-17) in household | 0.285 | *4.3* |
| Log of monthly hhd income (mil. Rp) | -0.748 | *-12.5* |
| Dummy: motorcycle-owning household | 1.709 | *16.6* |
| Dummy: male individual | 1.633 | *17.6* |
| Dummy: allowance provided by employer | -1.893 | *-12.5* |
| Dummy: free parking provided | 0.842 | *2.4* |
| *Taxi* | | |
| Alternative-specific constant | -6.834 | *-6.0* |
| Dummy: return trip starts in nighttime | 0.676 | *3.0* |
| Dummy: high-income hhd (>4 mil. Rp/mo) | 1.701 | *6.8* |
| Dummy: male individual | -1.653 | *-7.8* |
| Dummy: full-time worker | -0.463 | *-1.8* |
| *Motorcycle Taxi* | | |
| Alternative-specific constant | -2.727 | *-23.5* |
| Dummy: tour starts in a.m. peak | 0.621 | *6.4* |
| Dummy: child (age:5-17) in household | 0.271 | *3.2* |
| Dummy: male individual | -0.919 | *-8.5* |
| *Transit w/ Motorized Access* | | |
| Alternative-specific constant | -2.682 | *-33.7* |
| Log of travel distance (km) | 1.271 | *32.0* |
| Dummy: tour starts in p.m. peak or later | -1.848 | *-4.1* |
| Dummy: male individual | -1.063 | *-12.3* |
| *Transit w/ Non-Motorized Access* | | |
| Alternative-specific constant | | |
| Transit walk time (hr) | -1.130 | *-13.8* |
| Log of travel distance (km) | 1.014 | *31.7* |
| Dummy: tour starts in p.m. peak or later | -1.394 | *-6.2* |
| Dummy: male individual | -0.837 | *-11.9* |
| *Non-Motorized Transport* | | |
| Alternative-specific constant | -9.027 | *-35.8* |
| Dummy: tour starts in early morning | -0.805 | *-17.6* |
| Dummy: return trip starts in nighttime | -0.563 | *-9.2* |
| Dummy: child (age:5-17) in household | 0.264 | *7.1* |
| Log of age of the individual | 1.010 | *17.5* |
| Dummy: part-time worker | 0.632 | *13.3* |
| Log of monthly ind. income (mil. Rp) | -2.642 | *-33.6* |
| Dummy: allowance provided by employer | -1.170 | *-13.0* |

Table 7. Work tour mode and destination choice model based on CTS (2010)

Observations = 24897 L(*0*) = -102347 L(*β*) = -56676 $\rho^2$ = 0.446

| Logsum (expected maximum utility) | coeff. | *t-stat* | Alternative / Variable | coeff. | *t-stat* |
|---|---|---|---|---|---|
| Private mode logsums | 0.686 | *66.1* | *Motorcycle (continued)* | | |
| Taxi/transit mode logsums | 0.618 | *34.3* | Dummy: motorcycle-owning household | 4.639 | *45.5* |
| **Generalized Travel Time (hr)** | **coeff.** | ***t-stat*** | Dummy: male individual | 1.310 | *16.9* |
| for auto | -1.213 | *-10.9* | Dummy: allowance provided by employer | -8.306 | *-43.1* |
| for motorcycle | -1.257 | *-36.8* | Dummy: private mode allowance provided | 4.784 | *14.1* |
| for taxi | -2.189 | *-4.2* | *Taxi* | | |
| for motorcycle taxi and transit | -0.412 | *-17.7* | Log of monthly hhd income (mil. Rp) | 0.594 | *2.2* |
| **Destination Land Use** | **coeff.** | ***t-stat*** | Alternative-specific constant | 13.505 | *10.3* |
| Dummy: origin zone | 2.182 | *57.1* | Dummy: male individual | -1.157 | *-3.3* |
| Tertiary job density (/ha) | 0.002 | *5.2* | *Motorcycle Taxi* | | |
| Percentage of land for business use | 0.014 | *8.8* | Alternative-specific constant | 15.626 | *12.4* |
| Log of size variable (total jobs) | 1.000 | *constr.* | Dummy: tour starts in a.m. peak | 0.226 | *1.7* |
| **Alternative / Variable** | **coeff.** | ***t-stat*** | Dummy: child (age:5-17) in household | 0.293 | *2.3* |
| *Auto Drive Alone* | | | Dummy: motorcycle-owning household | -0.494 | *-3.6* |
| Alternative-specific constant | 2.051 | *2.1* | Dummy: male individual | -1.343 | *-7.9* |
| Log of travel distance (km) | 0.466 | *7.9* | *Transit w/ Motorized Access* | | |
| Dummy: tour starts in a.m. peak | 1.119 | *8.6* | Alternative-specific constant | 16.730 | *13.3* |
| Dummy: one-member household | 0.742 | *2.0* | Log of travel distance (km) | 0.315 | *7.8* |
| Dummy: car-owning household | 4.823 | *24.6* | Dummy: male individual | -0.953 | *-7.8* |
| Log of age of the individual | 2.175 | *10.6* | *Transit w/ Non-Motorized Access* | | |
| Dummy: male individual | 1.770 | *12.7* | Alternative-specific constant | 17.355 | *13.7* |
| *Auto Shared Ride* | | | Log of travel distance (km) | 0.315 | *7.8* |
| Log of travel distance (km) | 0.485 | *7.3* | Log of monthly hhd income (mil. Rp) | -0.266 | *-4.9* |
| Dummy: tour starts in a.m. peak | 0.897 | *6.2* | Dummy: male individual | -0.961 | *-8.1* |
| Log of monthly hhd income (mil. Rp) | 0.806 | *8.0* | *Non-Motorized Transport* | | |
| Dummy: car-owning household | 4.823 | *24.6* | Alternative-specific constant | 4.769 | *7.4* |
| Log of age of the individual | 2.428 | *10.8* | Log of travel distance (km) | -0.330 | *-11.4* |
| *Motorcycle* | | | Dummy: tour starts in early morning | -0.934 | *-15.6* |
| Alternative-specific constant | 13.844 | *16.3* | Log of monthly hhd income (mil. Rp) | -1.837 | *-33.4* |
| Dummy: tour starts in a.m. peak | 0.938 | *12.2* | Log of age of the individual | 1.437 | *21.0* |
| Dummy: infant (age < 5) in household | 0.287 | *4.5* | Dummy: part-time worker | 0.409 | *8.5* |
| Log of monthly hhd income (mil. Rp) | -0.996 | *-15.8* | Dummy: allowance provided by employer | -5.501 | *-48.5* |

Table 8. School tour mode and destination choice model based on HTS (2002)

Observations = 24939 L(*0*) = -97062 L(*β*) = -44013 $\rho^2$ = 0.547

| Logsum (expected maximum utility) | coeff. | *t-stat* |
|---|---|---|
| Private mode logsums | 0.780 | *42.6* |
| Taxi/transit mode logsums | 0.740 | *59.0* |
| **Generalized Travel Time (hr)** | coeff. | *t-stat* |
| for auto | -2.079 | *-9.4* |
| for motorcycle | -1.215 | *-11.6* |
| for taxi | -4.412 | *-4.2* |
| for motorcycle taxi and transit | -1.968 | *-35.5* |
| **Destination Land Use** | coeff. | *t-stat* |
| Dummy: origin zone | 2.290 | *60.0* |
| Student density at school place (/ha) | 0.004 | *10.9* |
| Log of size variable (total students) | 1.000 | *constr.* |
| **Alternative / Variable** | coeff. | *t-stat* |
| *Auto Drive Alone* | | |
| Alternative-specific constant | -16.174 | *-7.7* |
| Log of travel distance (km) | 1.386 | *9.2* |
| Dummy: return trip starts in nighttime | 1.056 | *1.9* |
| Log of monthly hhd income (mil. Rp.) | 0.693 | *2.6* |
| Number of cars in household | 1.819 | *10.0* |
| Log of age of the individual | 4.157 | *6.3* |
| *Auto Shared Ride* | | |
| Alternative-specific constant | -3.404 | *-7.9* |
| Log of travel distance (km) | 0.582 | *7.0* |
| Dummy: tour starts in early morning | 1.557 | *6.9* |
| Dummy: tour starts in a.m. peak | 0.895 | *4.3* |
| Log of monthly hhd income (mil. Rp.) | 0.659 | *7.4* |
| Number of cars in household | 1.801 | *20.7* |
| Dummy: worker | 2.838 | *5.7* |
| *Motorcycle* | | |
| Alternative-specific constant | -0.526 | *-1.3* |
| Dummy: tour starts in a.m. peak | 0.812 | *7.7* |
| Number of motorcycles in household | 1.279 | *18.9* |
| Dummy: worker | 3.338 | *10.3* |
| Dummy: male adult (age ≥ 17) | 1.598 | *11.8* |
| Dummy: university/academy student | 0.745 | *5.3* |

| Alternative / Variable | coeff. | *t-stat* |
|---|---|---|
| *Taxi* | | |
| Alternative-specific constant | -1.201 | *-2.9* |
| Dummy: high-income hhd (> 4 mil. Rp/mo) | 0.817 | *2.7* |
| Dummy: university/academy student | 1.536 | *4.2* |
| *Motorcycle Taxi* | | |
| Alternative-specific constant | -2.014 | *-5.2* |
| Dummy: tour starts in a.m. peak | 0.501 | *4.6* |
| Log of age of the individual | 1.095 | *7.1* |
| *Transit w/ Motorized Access* | | |
| Log of travel distance (km) | 1.239 | *26.7* |
| Dummy: tour starts in early morning | 0.985 | *7.6* |
| Dummy: return trip starts in nighttime | 0.498 | *2.2* |
| Log of age of the individual | 3.859 | *22.2* |
| Dummy: female adult (age ≥ 17) | 0.473 | *3.7* |
| *Transit w/ Non-Motorized Access* | | |
| Alternative-specific constant | -10.001 | *-21.2* |
| Log of travel distance (km) | 0.755 | *24.4* |
| Dummy: tour starts in early morning | 0.460 | *4.3* |
| Log of monthly hhd income (mil. Rp.) | -0.426 | *-11.3* |
| Log of age of the individual | 3.093 | *26.1* |
| Dummy: female adult (age ≥ 17) | 0.301 | *3.4* |
| Dummy: part-time worker | -1.442 | *-3.5* |
| *Non-Motorized Transport* | | |
| Alternative-specific constant | -4.229 | *-14.0* |
| Travel time (hr) * hhd income (mil. Rp.) | -2.066 | *-35.8* |
| Dummy: tour starts in early morning | -0.432 | *-4.7* |
| Dummy: tour starts in a.m. peak | 0.521 | *11.6* |
| Dummy: tour starts in p.m. peak or later | 1.321 | *3.5* |
| Dummy: child (age:5-17) in household | 1.077 | *13.9* |
| Dummy: low-income hhd (< 1 mil. Rp/mo) | 0.237 | *5.8* |
| Log of age of the individual | -0.219 | *-2.6* |
| Dummy: male | 0.118 | *3.6* |
| Dummy: university/academy student | -2.284 | *-11.3* |

Table 9. School tour mode and destination choice model based on CTS (2010)

Observations = 23644 L(*0*) = -90564 L(*β*) = -43089 $\rho^2$ = 0.524

| Logsum (expected maximum utility) | coeff. | *t-stat* | Alternative / Variable | coeff. | *t-stat* |
|---|---|---|---|---|---|
| Private mode logsums | 0.680 | *46.1* | *Taxi* | | |
| Taxi/transit mode logsums | 0.623 | *42.5* | Alternative-specific constant | 1.018 | *2.5* |
| Generalized Travel Time (hr) | coeff. | *t-stat* | Dummy: zones in Jakarta proper | 2.158 | *4.1* |
| for auto | -1.479 | *-8.9* | Log of age of the individual | 0.496 | *2.8* |
| for motorcycle | -1.582 | *-21.6* | *Motorcycle Taxi* | | |
| for taxi | -4.024 | *-4.4* | Alternative-specific constant | 3.399 | *9.0* |
| for motorcycle taxi and transit | -0.549 | *-19.0* | Log of travel distance (km) | -0.651 | *-9.5* |
| Destination Land Use | coeff. | *t-stat* | Dummy: tour starts in a.m. peak | 0.678 | *6.5* |
| Dummy: origin zone | 2.256 | *51.3* | Log of age of the individual | 0.496 | *2.8* |
| Log of size variable (total students) | 1.000 | *constr.* | Dummy: male individual | -0.193 | *-2.0* |
| | | | *Transit w/ Motorized Access* | | |
| | | | Alternative-specific constant | 0.669 | *2.6* |
| Alternative / Variable | coeff. | *t-stat* | Log of travel distance (km) | -0.346 | *-7.5* |
| *Auto Drive Alone* | | | Dummy: return trip starts in nighttime | 0.571 | *3.1* |
| Alternative-specific constant | -0.328 | *-0.4* | Log of age of the individual | 2.159 | *15.1* |
| Log of travel distance (km) | 0.853 | *4.6* | *Transit w/ Non-Motorized Access* | | |
| Log of monthly hhd income (mil. Rp.) | 1.004 | *3.6* | Log of travel distance (km) | -0.230 | *-5.3* |
| Number of cars in household | 0.570 | *3.7* | Dummy: tour starts in early morning | 0.102 | *1.9* |
| Dummy: university/academy student | 1.537 | *3.5* | Log of monthly hhd income (mil. Rp.) | -0.481 | *-11.2* |
| *Auto Shared Ride* | | | Log of age of the individual | 2.700 | *19.7* |
| Alternative-specific constant | 0.256 | *0.5* | *Non-Motorized Transport* | | |
| Log of monthly hhd income (mil. Rp.) | 1.461 | *13.6* | Alternative-specific constant | 4.343 | *13.7* |
| Number of cars in household | 0.527 | *6.0* | Travel time (hr) * hhd income (mil. Rp.) | -2.898 | *-58.1* |
| *Motorcycle* | | | Dummy: tour starts in early morning | -0.326 | *-5.1* |
| Alternative-specific constant | 2.700 | *6.1* | Dummy: tour starts in a.m. peak | 0.478 | *7.8* |
| Dummy: tour starts in a.m. peak | 0.587 | *9.3* | Dummy: tour starts in p.m. peak or later | -0.761 | *-3.0* |
| Log of monthly hhd income (mil. Rp.) | 0.208 | *3.8* | Dummy: child (age:5-17) in household | 0.718 | *7.2* |
| Number of motorcycles in household | 1.279 | *30.3* | Log of monthly hhd income (mil. Rp.) | 1.140 | *24.8* |
| Dummy: male adult (age ≥ 17) | 1.771 | *18.9* | Log of age of the individual | -1.223 | *-17.2* |
| Dummy: university/academy student | 1.330 | *11.8* | Dummy: university/academy student | -1.516 | *-8.4* |

Among several types of cost and time-related variables, a composite variable of generalized travel time proved to work best in the model. It is computed from the preliminary network assignment highway or transit network by origin-destination zone pair and by mode, including not only travel times (in-vehicle time and waiting time in the case of transit) but also times that have been converted from monetary costs such as transit fares and highway tolls. For *work* and *school* tours, coefficients of the generalized time are estimated separately for auto, motorcycle, taxi, and motorcycle taxi and transit. While the coefficients for auto and taxi have greater absolute values, the coefficient for motorcycle shows the lowest sensitivity to the generalized time in the 2002 model. This result seemed reasonable because auto and taxi are generally used by middle to high-income people and motorcycle is used by low to middle-income people, as indicated by other income-related variables included in each mode. Meanwhile, the coefficient for motorcycle taxi and transit now indicates the lowest sensitivity to the generalized time in the 2010 model for both *work* and *school* tours. After the drastic shift from the transit mode to the private mode as mentioned earlier, the remaining transit users may have become less sensitive to the travel cost.

The generalized travel time also works as one of the variables that determine the utilities for destination choice. So does natural logarithm of the size variable (i.e., total jobs for work and total students at school place for *school* tours). As for other destination-related variables, the origin zone dummy has a very high *t*-stat value across all tour purposes, increasing the utility for intra-zonal tours. Other variables included in the mode and destination choice are densities of jobs and service jobs by zone. In addition, fractions of land for business and commercial use have been included in the models of *work* tours.

### 5.2.1 Work tour models

Comparing the *work* tour mode and destination choice models in 2002 and 2010, there are several variables of which impacts have been stronger or weaker. First of all, income-related variables have been included in four modes in the 2002 model and in five modes in the 2010 model. Income is included in auto shared ride, which often indicates those who do not actually drive but have chauffeurs, in both 2002 and 2010 models. Meanwhile, auto drive alone no longer includes income-related variables in the 2010 model. It can be inferred that usage of autos has spread more evenly across all income groups. Furthermore, income has been added to transit with non-motorized access and non-motorized transport in the 2010 model with a negative sign. This may imply that these modes have become common modes that are used by only lower-income workers, now that usage of private vehicles has so diffused. Thus, the gap between high- and low-income workers still exists and has brought more impact on the travel behavior regardless of the diffusion of private vehicles in the Jakarta Metropolitan Area.

Existence of auto(s) owned by the household for *work* tours is included in auto drive alone in the 2010 model with greater coefficient and *t*-stat compared to the 2002 model. This coincides with the fact that autos owned by households have been increasing in number, so that one household member can easily access auto drive alone. Existence of motorcycle(s) owned by the household has a similar tendency as auto drive alone, that is, greater coefficient and *t*-stat in the utility function of motorcycle compared to the 2002 model. As for its influence on motorcycle taxi, as the number of motorcycles has been growing so remarkably in Jakarta, existence of motorcycle(s) has been included in the utility function of motorcycle taxi with a negative sign in the 2010 model. Thus, the number or existence of auto or motorcycle has brought more impact on the mode choice for *work* tours.

As for gender and age of workers, the same variables with similar tendencies have also been observed with active and distinct roles in the 2002 and 2010 models. That is, males have a greater utility of motorcycle and auto drive alone, while females have greater utilities of public modes (i.e., taxi and transit). In addition, older workers have greater utilities of auto drive alone and shared ride.

With regard to variables indicating intra-household interactions such as existence of an infant or a child in the household, the number of such variables as well as the estimated coefficients has become smaller in the 2010 model. Such changing interactions among household members may also be a subject of interest though further investigation such as daily activity pattern choice modeling would be necessary.

Another variable that is worth mentioning is existence of transportation allowance provided by the employer. It is included in the utility function of motorcycle and non-motorized transport with a greater absolute value of coefficient with a negative sign in the 2010 model. This implies that workers will easily shift from motorcycle or non-motorized transport to transit if there is allowance provided. It implies that employers could provide the allowance for the workers in order to discourage them from using motorcycles.

The models have also captured tour-related variables such as start times of the tour or returning segment of the tour. Above all, tours starting in the a.m. peak have "increased" the utilities of especially private vehicles regardless of traffic congestion since the start times of work are relatively fixed in the morning in Indonesia.

### 5.2.2 School tour models

An income-related variable has been added to motorcycle in the 2010 model with a positive sign. Usage of motorcycle is diffusing among students, especially those from higher-income households as well, while motorcycles have already become so common among workers. Overall, students from lower-income household tend to use transit with non-motorized access, while students from higher income tend to use private autos/motorcycles. As for non-motorized transport, income-related variable has been totally changed and it is showing an opposite tendency. That is, while students from low-income households have a greater utility of non-motorized transport in the 2002 model, students from higher-income households have a greater utility of non-motorized transport in the 2010 model. Such a drastic change in the impact of the income-related variable may be due to the increase in the mode share of bicycles in *school* tours. In fact, based on the HTS and CTS datasets, the bicycle mode share from home to school increased from 2.5% in 2002 to 3.4% in 2010. It has been caused by DKI Jakarta's "bike to school" or "bike to work" campaign to promote the use of bicycles to go to work or school, which started in 2009. This program has brought such a great effect that it enhanced the usage of bicycle as part of the non-motorized transport, particularly among students. Furthermore, relatively expensive bicycles are used mostly by high school and university students, and, as a result, bicycle has become a "status" for students from higher-income households.

As for autos and motorcycles owned by the household, the same tendencies as in *work* tours are observed. However, as auto and motorcycle ownership ratio is growing, actual number of autos and motorcycles is included in the utility functions in the 2010 *school* tour model rather than the simple existence. That is, the number of autos or motorcycles owned by the household is important for students to utilize the corresponding mode. Thus, car and motorcycle competition between household members, which often has an influence on mode choice in the U.S., is beginning to become an "issue" in the case of Jakarta as well, especially for availability to students.

As for gender and age, different tendencies are observed in the 2010 model as compared to the 2002 model. Female older students, in particular, have a greater utility of motorcycle taxi while they are no longer significant in the utility functions of transit modes. This may also be one of the causes for the drastic drop of the transit mode share. Furthermore, gender has no more influence on the utility of non-motorized transport in the 2010 model while it was included in the 2002 model. This may be related to the fact that the average distance of inter-zonal school trips by non-motorized transport, the majority of which is walk, has decreased from 3.6 kilometers in 2002 to 2.2 kilometers in 2010 based on the datasets, making it easier to walk to school regardless of gender.

## 5. SUMMARY

This paper presented the results of models of household auto/motorcycle ownership and joint mode and destination choice for home-based *work* and *school* tours that had been developed based on the two large-scale travel surveys conducted eight years apart from each other, compared the models, and discussed implications of the changes that have been made in the Jakarta Metropolitan Area in the last decade. The modeling approach was a discrete choice model based on the random utility maximizing principles. From a time-series comparison point of view, so long as the context of the society will not change, the joint models of mode and destination choices should remain unchanged with fixed parameters over a period of time. However, the models that were estimated based on the surveys conducted nearly a decade apart have indicated quite different parameters with different degrees of significance. As discussed in our previous study on the mode choice models as well as the household auto/motorcycle ownership models (2), transferability of those disaggregate choice models may not always apply in urban areas of the developing world such as the Jakarta Metropolitan Area, even though the basic model structure may remain the same.

Different types of variables contributed significantly to the models, including variables related to trips, activities/tours, households, individuals, and origin/destination zones. Interpretation of the effects of these explanatory variables in the models estimated for 2002 and 2010 led to several interesting insights in light of the change in the transportation environment as well as the increase in complexity of the travel behavior in the Jakarta Metropolitan Area over time. Implications of such changes may also be important and hence worth studying for other urban areas of the developing world though similarities may be restricted to regions that share modal and cultural norms in common. In addition, this study should also extend to investigation of disaggregate choice models in urban areas other than Jakarta in order to show that transferability of disaggregate choice models is not always applicable in urban areas of the developing world.

Joint models of mode and destination choices for home-based *work* and *school* tours are usually placed at the "bottom" of the modeling hierarchy consisting of the higher levels, that is, trip generation or choices of daily activity-travel patterns and times of day. Thus, the authors' further effort will include establishment of a comprehensive activity-based models based on the latest travel survey data including CTS and comparison of the models in terms of changes in the people's daily activity-travel patterns that may have occurred in the last decade in the Jakarta Metropolitan Area. Although a variety of variables proved to be significant in this study, activity patterns were not included as explanatory variables in the mode choice models. Using the abundant travel data source available from CTS and other activity-related surveys conducted in 2010, a full-scale mode choice model that includes activity-related variables as input and returns full information to the upper-level choice of the modeling system could also be developed.

## ACKNOWLEDGMENT

The authors would like to express their gratitude to the National Development Planning Agency and the Coordinating Ministry for Economic Affairs of Indonesia for permitting us to use the survey data in this study.

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