Analysis of Household out-of-home energy consumption for Jakarta City *

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1. Introduction

Household are an important group when addressing energy conservation (R.M.J Benders, 2006). Understanding household energy usage in-home and out-of-home is vital for the planning of energy consumption and conservation. Common sense and score studies from around the world suggest that a few key factors have dominant impact on the amount of household energy consumption which includes income, household size, prices of energy and efficiency-use of equipments/vehicles (Leach, 1987). Household energy usage for out-of-home activities closed-related to the vehicle`s fuel/energy consumptions. The annual vehicular fuel consumption of households is clearly the outcome of complex decision that involve the number of vehicles the household own, the makes, model and vintages, allocation of vehicles and activities among drivers, and choice of activity sites, modes of transportation, and the chaining and combining of activities (T.F Golob, 2005). The other factor, household behavior in purchase-maintenance and usage-related energy behavior determine the energy use (Raaij, 1983). In the city level, urban density is found to affect fuel consumption, mostly through variations in the vehicle stock and in the distances travelled, rather than through fuel consumption per kilometer (vehicle technology) (N Karathodorou, 2010).

Vehicle ownership by household is a critical demographic characteristic influencing many aspects of travel demand and its impacts. A recent study expects sharp increase in passenger car ownership level when per capita income level reaches a level between US$ 3000 and US$ 5000 (Dargay, 1999). Due to rapid development and economic growth of developing Indonesian country, household income level increase gradually. GDP per capita of Jakarta city, the capital of Indonesia, reaches US$ 4992 in 2006 (Siadari, 2007) followed by Surabaya city, second largest city in Indonesia, which GDP per capita around US$ 3481 in the same period. Other study, Ingram and Liu (1999) estimate that passenger car ownership in developing countries is expected determinism-a sociological explanation-which associates car ownership in developing countries exclusively with the middle class life styles, and stresses the social forces on the middle class to sustain a mobility level tied to car ownership (Vanconcellos, 1997). A private car is regarded as a symbol of power, status, control and freedom (Goodwin 1997).

Multiple vehicle ownership including private car, motorcycle and bicycle was popular in developing Southeast Asian country like Indonesia. Sanko (2005) found a substitutability relationship between car and motorcycle ownership in Bangkok and Kualalumpur. Senbil (2007) use bivariate ordered probit model to analyzed household car and motorcycle ownership which are independent of each other in JABODETABEK. Refer to the comparative study between Osaka metropolitan area and Kualalumpur (Yamamoto, 2009), some portion of second cars in Osaka is replaced by Motorcycles in Kualalumpur. Fang (2008) developed a Bayesian Multivariate Ordered Probit and Tobit model to estimate a joint system of vehicle fuel efficiency choice and vehicle utilization in response to varying residential density.

To overcome the aforementioned fuel consumption of multiple vehicle ownership in Jakarta city, this paper attempts to provide a structure equation model to examine cause-effect relationship of household vehicle-type ownership and its usage on household fuel energy consumption.

2. Modeling Framework

To realize the above-mentioned out-of home energy consumptions and its cause-effects relationships, this paper attempts to establish a structural equation model (SEM) to capture the complex cause-effect relationships exiting in the framework of household vehicle ownership and its usage behavior (Figure 1). Methodologically, the SEM plays many roles, including simultaneous equation systems, linear causal analysis, path analysis, structural equation models, dependence analysis, and cross-legged panel correlation technique (Jöreskog and Sörbom, 1989). SEM is used to specify the phenomenon under study in terms of putative cause-effect variables and their indicators. Latent variables will be used to specify the social capacity and its influential factors.

The full model structure can be summarized as follows:
Structural Equation Model:

$$\eta = B\eta + \Gamma\xi + \zeta \qquad (1)$$

Measurement Model for y:

* Keyword : household energy consumption, structural equation model, Jakarta city
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$$\boldsymbol{y} = \boldsymbol{\Lambda}_y \boldsymbol{\eta} + \boldsymbol{\varepsilon} \quad (2)$$

Measurement Model for x:

$$\boldsymbol{x} = \boldsymbol{\Lambda}_x \boldsymbol{\xi} + \boldsymbol{\delta} \quad (3)$$

Here, $\boldsymbol{\eta}' = (\eta_1, \eta_2, ..., \eta_m)$ and $\boldsymbol{\xi}' = (\xi_1, \xi_2, ..., \xi_m)$ are latent dependent and independent variables, respectively. Vectors η and ξ are not observed, but instead $\boldsymbol{y}' = (y_1, y_2, ..., y_p)$ and $\boldsymbol{x}' = (x_1, x_2, ..., x_q)$ are observed dependent and independent variables. $\boldsymbol{\zeta}, \boldsymbol{\varepsilon}, \boldsymbol{\delta}$ are the vectors of error terms, and $B, \Gamma, \Lambda_x, \Lambda_y$ are the unknown parameters.

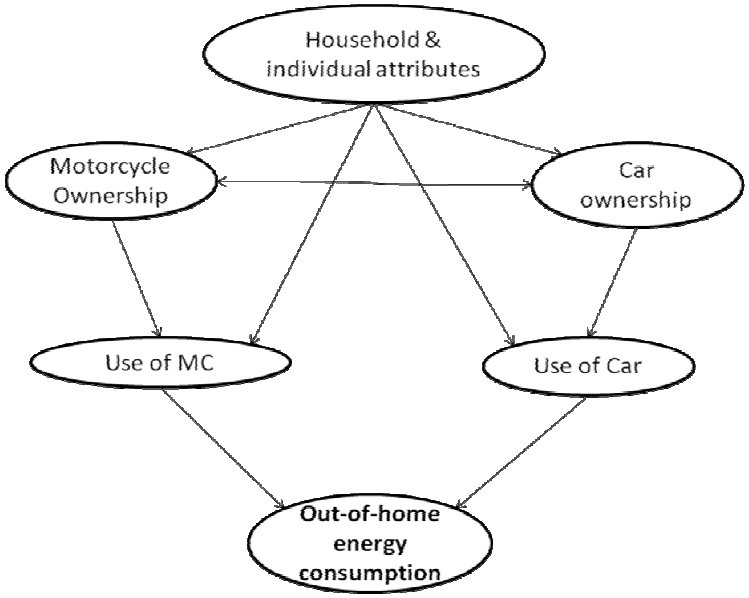

Figure 1 Household Energy Consumption

In this study, we focus on the fuel consumed by car and motorcycle owned and used by households. We also consider the household socio-economic factors, household attributes and physical characteristics of house as the other common factors influence on the ownership. We assume an interdependency of car and motorcycle usage behavior on the multiple vehicles owner's household. The vehicular fuel consumption of households is hypothetically assumed as the outcome of allocation of each vehicle.

3. Data

A questionnaire survey about household energy consumption was conducted at Jakarta metropolitan areas in 2009. The questionnaire items include: 1) personal attributes such as age, gender, occupation, academic background, income, household member, type of home, family type, home architecture, living period, the area of the house, commuting behavior and commuting trip time; 2) households ownership of vehicle and its usage behavior; and 3) household energy consumption for fossil fuels (gasoline and solar/diesel fuel). Respondents were asked to select the choice sets and also fill the questionnaire with a count data. Total sample sizes are 1009 households distributed in all Jakarta areas.

Based on person trip survey by JICA in 2000, 47.5% samples (1,08 Millions samples) households in JABODETABEK have vehicles in their house. It is consists of motorcycle holders 33,2%, car holders 7,8 % and multiple ownership of car and motorcycle 6.4% (table 1). Comparing the ownership type between two different data sets, we found similar pattern for single motorcycle owner and single car owner. The proportion of non-owner, multi motorcycle, multi car and multiple car-motorcycle owners are differ significantly from these two data sets.

Most of respondent used their own vehicle for commuting trips (2009) and the highest observed for MC owners which around 76% (Figure 2). Looking at multiple car and motorcycle holders, the use of car for commuting trip is higher than motorcycle (Figure 3). Furthermore, share of transit mode also higher compare to multi car or multi motorcycle holders. Looking at figure 5, total fuel consumption differs significantly for car and motorcycle owner.

4. Model Estimation and Evaluation of Household fuel consumption

In this paper, we use data observed in Jakarta city and estimated the model by using AMOS. Observing the model accuracy indices (i.e., GFI and AGFI), the model for the shows GFI (AGFI) value is around 0.756 (0.688). Based on the calculated GFI and AGFI values, the established model cannot statistically be rejected. Household socio-

economic factors such as household income, household member and family type gave positive influence on Motorcycle ownership and the use of car. In contrast, home-physics (household density, home type and architecture type) negatively influence on the vehicle ownership. Household attributes (age and education level) gave different sign for Motorcycle and car usage, and it is not significant for the use of car. Elder people and well educated respondents less to use car. Increasing the number of motorcycle in household will increase the use of motorcycle and reduce the use of car. In contrast, increasing number of car owned in the household also rising the use of motorcycle and reduces car usage. Total fuel consumption in households mostly affected by the use of car rather than the use of motorcycle.

Table 1 Vehicle Ownership

No	Type of vehicle ownership	2000*	2009**
1	Non-Owner	52.53	27.5
2	Single Motorcycle	30.1	30.4
3	Multi Motorcycle	3.15	9.9
4	Single Car	6.31	5.6
5	Multi Cars	1.55	3.3
6	Multiple Car & Motorcycle	6.36	23.3

Note: * Person trip survey-JICA, 2000 (JABODETABEK)
** Household energy consumption survey in Jakarta-GELs Program (N=1009)

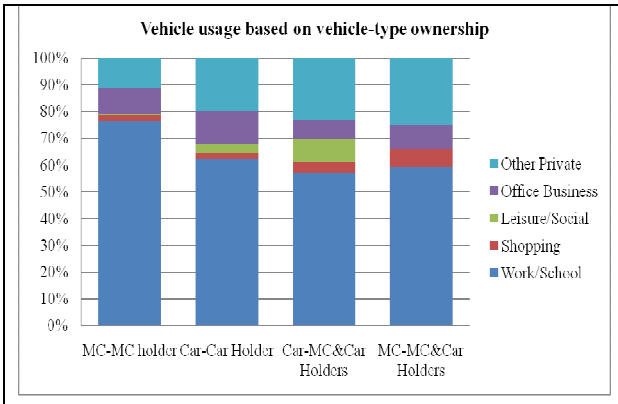

Figure 2 Purpose of vehicle use

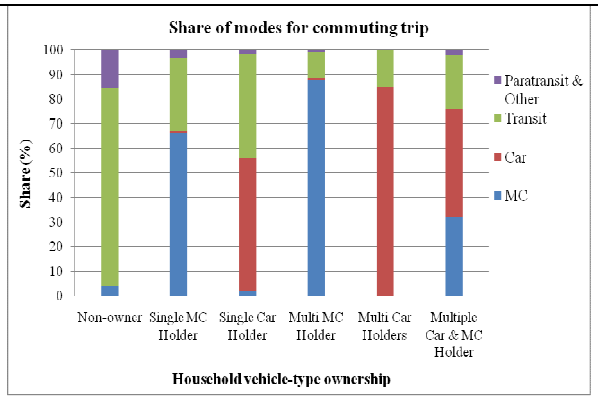

Figure 3 Commuting trip modes

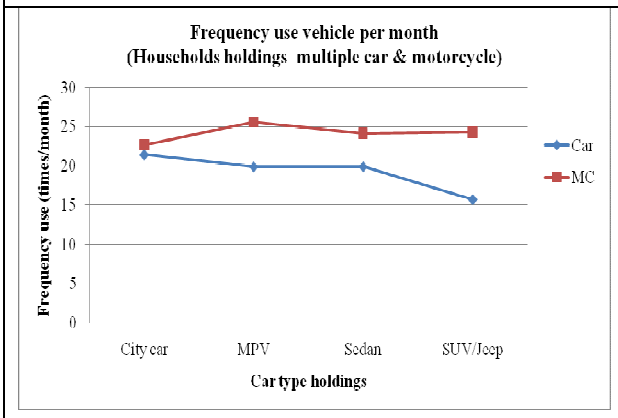

Figure 4 Frequency use of vehicles

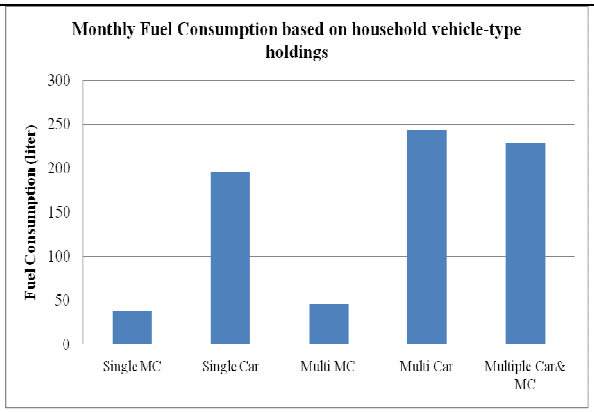

Figure 5 Monthly Fuel Consumption

Looking at the standardized total effects (Table 2), total fuel consumption of motorcycle positively affected by car usage, household socio-economics, and home physics. Comparing these three latent variables, estimation results for car usage is the biggest among others. Similar situation observed for car's fuel consumption, but we also found negative influence of household attributes on car's fuel. It means, well educated people and elder people consume less fuel.

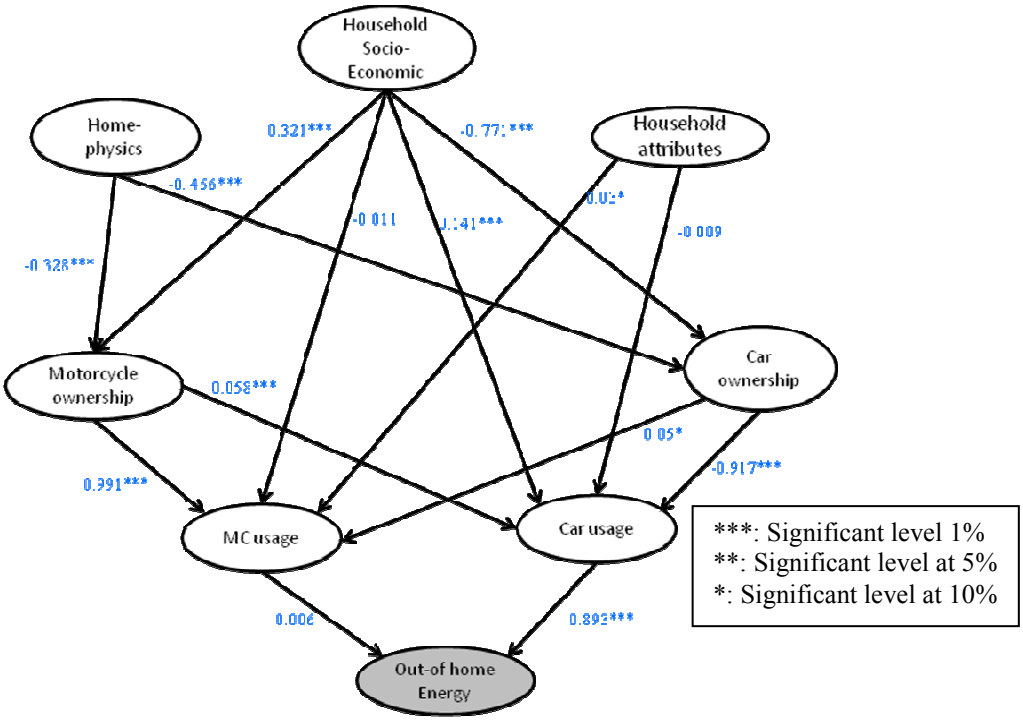

Figure 6 Estimation result of Household Fuel Consumption in Jakarta City

Table 2 Standardized Total Effects

Parameters	Household Attributes	Home Physic	HH Socio Econ	Ownership MC	Car Ownership	Use of MC	Use of Car	Fuel Consumption
Ownership MC	0.000	-0.326	0.321	0.000	0.000	0.000	0.000	0.000
Car Ownership	0.000	-0.458	-0.771	0.000	0.000	0.000	0.000	0.000
Use of MC	0.030	-0.346	0.269	0.991	0.050	0.000	0.000	0.000
Use of Car	-0.009	0.439	0.829	-0.058	-0.917	0.000	0.000	0.000
Fuel Consumption	-0.008	0.389	0.742	-0.045	-0.818	0.006	0.893	0.000
MC-Fuel consumption	0.000	0.018	0.035	-0.002	-0.038	0.000	0.042	0.047
Car-Fuel Consumption	-0.007	0.335	0.637	-0.039	-0.703	0.005	0.767	0.860
Use of MC								
Trip Purpose of MC usage	0.016	-0.186	0.144	0.532	0.027	0.537	0.000	0.000
Frequency use of MC	0.028	-0.328	0.255	0.941	0.047	0.950	0.000	0.000
Average MC Ridership	0.027	-0.310	0.241	0.890	0.045	0.897	0.000	0.000
Use of Car								
Trip Purpose of Car usage	-0.006	0.317	0.599	-0.042	-0.663	0.000	0.723	0.000
Average Car Ridership	-0.007	0.349	0.659	-0.046	-0.728	0.000	0.795	0.000
Frequency use of Car	-0.008	0.383	0.723	-0.050	-0.800	0.000	0.872	0.000

5. Conclusion

Using data collected from survey in Jakarta metropolitan area, we successful capture the out-of-home household energy consumption patterns. It is found in Jakarta city, household socio-economic conditions have dominant impact on out-of-home energy consumption follows by home physics. We also found hopes from well educated and elder people for household energy conservation. It was proven in our model that increasing ownership of motorcycle will reduce the use of car. On the other hand, it doesn't works for the rising of car ownership. It is necessary to evaluate the linkage between in-home and out-of home energy consumption by household.

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