How Much Does Land Use Mix Impact on Travel Frequency?: Evidence from the Jakarta Metropolitan Area, Indonesia

Hironori KATO [a], Takahiro IGO [b], Momoko FURUHASHI [c]

[a] *Graduate School of Engineering, The University of Tokyo, Tokyo, 113-8656, Japan; E-mail: kato@civil.t.u-tokyo.ac.jp*
[b] *Parts Logistics Engineering Department, Nissan Motor Co., Ltd, Kanagawa 231-8589, Japan; E-mail: t-igo@mail.nissan.co.jp*
[c] *South East Asia Division 3, South East Asia and Pacific Department, Japan International Cooperation Agency, Tokyo 102-8012, Japan; E-mail: Furuhashi.Momoko@jica.go.jp*

Abstract: This paper analyzes the impact of land use mix on travel frequency of individuals. Gini–Simpson Index and Dispersion Index are used for the land use mix indexes. Daily activity episode of individuals was collected through an interview-based local survey in the Jakarta metropolitan area, while the land use data for grid zones of 250 m by 250 m was prepared with the estimation of land use patterns using the existing official database. Seven categories of land use patterns are used for the empirical analysis. Then, ordered logit models are estimated, in which the dependent variable is the daily travel frequency of individuals and the independent variables are the thresholds of travel frequency, land use mix indexes, and individual and household attributes. The results show that higher-income females living in areas with mixed land use patterns composed of a few land use categories travel more frequently from home.

Keywords: Land use mix, Travel frequency, Developing cities, Jakarta metropolitan area

1. INTRODUCTION

It is widely pointed out that there is a relationship between land use development patterns and the travel behavior of individuals (Litman and Steele, 2012). Land use development pattern, which is sometimes called community design, built environment, spatial planning, urban geography, and urban form, refers to various land use factors such as accessibility, density, land use mix, centeredness, connectivity, and transit accessibility. A number of studies have evaluated the impacts of various land use factors on travel behavior, including Ewing et al. (2011), Brownstone and Golob (2009), Cao et al. (2009), Bhat and Guo (2007), Bento et al. (2005), the Transportation Research Board (2005), Zhang (2004), Cervero (2002), and Frank and Pivo (1995). Most of these, however, have analyzed cities in the developed world, including the US and Europe. Few studies have undertaken empirical analysis in developing regions. One of the reasons for this is the difficulty of data collection in such regions. In general, the formal database of land use patterns and travel behavior is not well organized, mainly because of the lack of governance in developing countries. One of the exceptions may be Cervero et al. (2009), who studied the association between land use factors and travel behavior in Bogota. The land use factors in this study include population density; the entropy index for measuring diversity; public park area; average lot size; the number of pedestrian bridges; the number of public schools, hospitals, public libraries, shopping centers, churches, and banks; the number of TransMilenio stations; the shortest network distance to the closest

TransMilenio station; and number of feeder TransMilenio stations.

The results show that road facility designs, such as street density, connectivity, and proximity to Ciclovía lanes, are associated with physical activity, but other attributes of the built environment, such as density and land use mixtures, are not. They also show that the historical background of the built environment in the developing city is quite different from cities in the US and Europe, which affects the results. This may suggest that the association of land use patterns with travel behavior may highly depend on the context of a city's development. Particularly in developing cities, land use patterns have been developed not under land use regulations but under the uncontrolled expansion of urban areas due to the high rate of migration from rural areas. Thus, the impacts of land use patterns in developing cities may be quite different from those in developed cities. Additionally, although previous research has typically highlighted the impact of land use patterns on travel distance and travel mode choice, it is expected that land use patterns also influence travel frequency. Past researches have shown major factors affecting travel frequency, for example travel distance, accessibility including transport component, spatial component, and individual component; and household's socio-economic characteristics (Chen et al., 2005; Pasra et al., 2011). The land-use mix may also increase the attractiveness of an area so that individuals can travel more. This paper then adds the new evidence on the impact of land use patterns on travel behavior, particularly in developing cities, to the research arena. The paper uses the data collected in the Jakarta metropolitan area, Indonesia. It highlights the land use mix as the land use factor and analyzes the daily frequency of travel as the travel behavior. It should be noted that the trip frequency is defined as the number of trips made by individuals traveling from one place to another place. This means the sequential trip or trip chaining behavior is not explicitly taken into consideration in this study.

The paper is organized as follows: the motivation and goal are presented in the Introduction. Next, the dataset used in the empirical analysis is described; this includes the data collected via the local questionnaire survey. Then, the impacts of land use patterns on individual travel behavior are analyzed with an ordered logit model. Finally, the findings and further issues are summarized.

2. DATASET

2.1 Activity Diary Data

The activity diary survey was designed and conducted by a study team from multiple academic institutes, which included the researchers of this study and their colleagues from the University of Indonesia. A questionnaire was designed for an interview-based household survey on daily activity with socio-demographic data and opinions on the various issues. The questionnaire sheets consisted of six parts: personal attributes, household attributes, the individual's daily behaviors, the household's daily behaviors, the individual's activity diary data, and the individual's values. For the personal attributes, the respondents were requested to provide basic information such as gender, age, occupation, religion, birthplace, ethnic background, and education level. They were also requested to provide their household attributes, including income, settlement, ownership of devices, and information about their maid. Next, the respondents were requested to provide information about their daily consumption, community activities, and religious activities, as well as information about household-based behavior such as goods consumption, joint leisure activities, and joint shopping. For the activity diary data, the activity episodes include all types of activities from

waking up in the morning to going to bed at night on both a typical workday and non-workday. The respondents were requested to provide the time allocated to each activity. In the survey sheet, activities are classified as out-of-home work, in-home work, learning at school, in-home activity, out-of home leisure, shopping, eating out, religious activity, and others. In addition to the types of activities, the respondents were requested to record travel episodes when they traveled from one place to another. Travel episodes covered origin, destination, travel mode, number of companions, and travel time. Finally, the questions regarding the individual's values requested the respondents to provide their opinions on family, human relationships, the environment, religion, money, politics, and work.

The survey days were November 25, 2011, through December 8, 2011, following a preparatory survey from September 23 to 29, 2011. The preparatory survey was implemented to test the survey method with a smaller sample, and was conducted in two areas, Cikini and Tangerang. The survey team obtained the support of a local professional survey company to implement the interviews. The respondents were chosen via a random sampling method. First, ninety kelurahan and desas were selected via the random sampling method considering the distribution of the population. Note that a kelurahan or desa is an administrative unit. One kelurahan or desa covers between one and ten square kilometers. Next, a rukun tetangga (harmonious neighborhood) was chosen randomly from the selected kelurahan and desas. The rukun tetangga (RT) is an official governmental organization. One RT consists of 30 to 100 households with one chief, who is elected by the RT's residents. Then, a list containing all households in the chosen RT was prepared. Using the household list, ten target households were selected randomly. Finally, a respondent was selected from the members of each selected household. A Kish grid was used to select an eligible respondent if there were multiple eligible respondents in the household. Note that only individuals fifteen years old or older were eligible for our survey. When the respondent selected in the above process was not the household head or spouse, one of them was additionally selected randomly to participate in the survey. See Furuhashi (2012) for further details on the local survey.

The survey was conducted in the metropolitan area of Jakarta known as Jabodetabek, which consists of the provinces of Jakarta and several districts in the provinces of Banten and
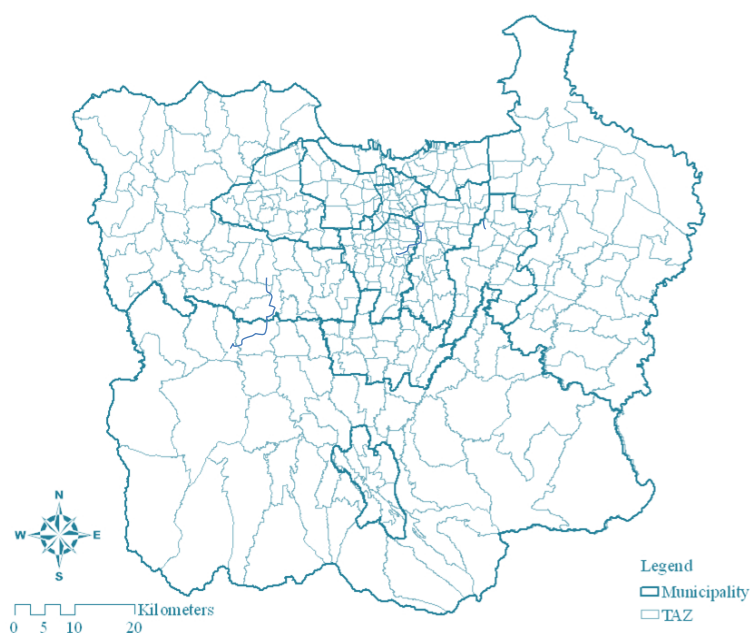

Figure 1. Map of Jabodetabek: Jakarta metropolitan area.

Source: Yagi (2006)

West Java. The areas surveyed were Jakarta Barat, Jakarta Utara, Jakarta Pusat, Jakarta Timur, Jakarta Selatan, Kabupaten Bogor, Kota Bogor, Kota Depok, Kabupaten Tangerang, Kota Tangerang, Kota TangSel, Kabupaten Bekasi, and Kota Bekasi. As of 2011, Jabodetabek has a population of about 23,500,000, about 6,200,000 households, in an area of approximately 7,500 square kilometers (see Figure 1 for the area of Jabodetabek). In all, 948 responses were obtained from the random sampling process.

Table 1 shows the descriptive statistics of the respondents. First, 45.7% of respondents were male, while 54.3% were female. Second, 36.3% of respondents finished senior high school, 30.7% finished primary school, and 25.3% finished junior high school; 3.5% finished a university degree, 2.6% went to an academy, and 1.6% of the respondents had never been to school. Third, 96.7% of the respondents were Muslim, followed by Non-Catholic Christian (2.4%), Catholic Christian (0.5%), and Buddhist (0.2%). Fourth, 30.8% of respondents were in their thirties, followed by twenties (25.3%), forties (20.0%), and fifties (9.8%), and 8.8% were between the ages of 15 and 19. The average age of respondents was 35.5. Fourth, 35.8% of respondents were housewives, followed by employees (22.0%), unauthorized self-employees (15.3%), laborers (5.4%), unemployed (5.3%), students (5.2%), part-time workers (4.2%), authorized self-employees (3.5%), government officers (1.9%), retirees (0.5%), lecturers (0.4%), farmers (0.4%), and employers (0.1%). Note that the unauthorized self-employees are typically the informal vendors of daily goods and/or foods.

Table 2 shows the descriptive statistics. First, for the daily travel frequency, 61.7% of respondents made two trips on a workday, followed by zero (23.5%) and four (6.4%) trips, while 52.5% of respondents made zero trips on a non-workday, followed by two (38.8%) and three (3.9%) trips. The average travel frequency is 1.9 on a workday and 1.1 on a non-workday.

Second, as for travel time, 45.2% of the total travel of respondents was 0-10 minutes on a workday, followed by 11-20 minutes (24.2%) and 21-30 minutes (13.5%), while 37.6% of the total travel made by respondents was 0-10 minutes on a non-workday, followed by 11-20 minutes (26.2%) and 21-30 minutes (18.3%). The average travel time was 22.1 minutes on a workday and 24.2 minutes on a non-workday. Third, as for travel distance, 65.9% of the total travel made by respondents was 0-5 kilometers on a workday, followed by 5-10 kilometers (13.6%) and 10-15 kilometers (8.1%), while 60.3% of the total travel made by the respondents was 0-5 kilometers on a non-workday, followed by 5-10 kilometers (15.0%) and 10-15 kilometers (9.4%). The average travel distance was 6.4 kilometers on a workday and 7.4 kilometers on a non-workday.

Table 1. Descriptive Statistics of Attributes of Respondents

Gender	Male	Female					
	45.70%	54.30%					
Education	No school	Primary	Junior high	Senior high	Academy	University	
	1.60%	30.70%	25.30%	36.30%	2.60%	3.50%	
Religion	Muslim	Non-Catholic	Catholic	Buddhist	Others		
	96.70%	2.40%	0.50%	0.20%	0.10%		
Age	15-19	20-29	30-39	40-49	50-59	60-69	70-
	8.80%	25.30%	30.80%	20.00%	9.80%	4.00%	1.30%
Occupation	Government officer	Housewife	Authorized self-employee	Unauthorized self-employee	Employee	Employer	Student
	1.90%	35.80%	3.50%	15.30%	22.00%	0.10%	5.20%
	Part time worker	Laborer	Unemployed	Retired	Lecturer	Farmer	
	4.20%	5.40%	5.30%	0.50%	0.40%	0.40%	

Table 2. Descriptive Statistics of Travels of Respondents

Travel frequency (daily)

Workday	0	1	2	3	4	5<	
	23.50%	0.00%	61.70%	4.70%	6.40%	3.80%	
	Mean	S.D.	Min.	25%	50%	75%	Max.
	1.9	1.4	0	2	2	2	9
Non-workday	0	1	2	3	4	5<	
	52.50%	0.00%	38.80%	3.90%	3.20%	1.50%	
	Mean	S.D.	Min.	25%	50%	75%	Max.
	1.1	1.3	0	0	0	2	8

Travel time (minutes)

Workday	0-10	11-20	21-30	31-40	41-50	51-60	61<
	45.20%	24.20%	13.50%	2.20%	3.30%	7.30%	4.30%
	Mean	S.D.	Min.	25%	50%	75%	Max.
	22.1	22.9	1	5	15	30	160
Non-workday	0-10	11-20	21-30	31-40	41-50	51-60	61<
	37.60%	26.20%	18.30%	2.20%	3.50%	7.90%	4.20%
	Mean	S.D.	Min.	25%	50%	75%	Max.
	24.2	24.9	1	10	15	30	180

Travel distance (kilometers)

Workday	0-5	5-10	10-15	15-20	20-25	25-30	30<
	65.90%	13.60%	8.10%	2.60%	3.40%	2.50%	3.80%
	Mean	S.D.	Min.	25%	50%	75%	Max.
	6.4	9.7	0.1	0.8	2.1	8.3	62.8
Non-workday	0-5	5-10	10-15	15-20	20-25	25-30	30<
	60.30%	15.00%	9.40%	4.20%	4.00%	3.00%	4.00%
	Mean	S.D.	Min.	25%	50%	75%	Max.
	7.4	10.6	0.1	1	2.9	9.8	62

Table 3. Characteristics of Respondents' Households

Number of children

	0	1	2	3	4	5	6<
Percentage	28.40%	29.30%	28.10%	10.20%	3.20%	0.70%	0.10%

Monthly household income (rupiahs)

	<1,000,000	1,000,000-1,500,000	1,500,000-2,000,000	2,000,000-2,500,000	2,500,000-3,000,000	3,000,000-4,000,000	4,000,000<
Percentage	7.50%	17.60%	30.60%	24.50%	11.60%	7.70%	6.90%

Car ownership

	0	1	2	3<
Percentage	97.60%	2.00%	0.40%	0.00%

Motorbike ownership

	0	1	2	3<
	30.80%	53.10%	13.60%	2.50%

Access travel time to the nearest bus stop (minutes)

	0-4	5-9	10-14	15-19	20-29	30-39	40<
Percentage	8.60%	22.80%	22.40%	16.50%	6.80%	11.30%	11.70%

Table 3 shows the major characteristics of respondents' households. First, 29.3% of the respondents' households had one child, followed by no child (28.4%), two children (28.1%), and three children (10.2%). The average number of children was 1.3. Second, 30.6% of the

respondents' households earned 1,500,000 to 2,000,000 rupiahs monthly, followed by 2,000,000 to 2,500,000 rupiahs (24.5%), and 1,000,000 to 1,500,000 rupiahs (17.6%). The average monthly income was 2,210,000 rupiahs. Third, 97.6% of respondents' households had no car, while only 2.0% had one car. Fourth, 53.1% of respondents' households owned one motorbike, followed by no motorbike (30.8%) and two motorbikes (13.6%). Fifth, concerning access travel time to the nearest bus stop, 22.8% of the respondents' households travel time was 5-9 minutes, followed by 10-14 minutes (22.4%) and 15-19 minutes (16.5%). The average access travel time to the nearest bus stop was 19.3 minutes.

2.2 Land use data

The land use dataset was prepared by rearranging the categories of land use patterns in the existing database. The land use patterns in our study include seven categories: kampung areas, planned residential areas, farm areas, commercial areas, industrial areas, public building areas, and wasteland areas. The land use data were constructed in a grid zone on a scale of 250 meters by 250 meters. To construct the dataset, three steps of data processes were implemented.

First, the land use patterns were categorized into six patterns based on the official land use database obtained from the local governments. As the definitions of land use categories vary among the local governments in the target area, the land use data of each local government were re-categorized into the six subgroups originally defined by the authors: regular housing, irregular housing, commercial areas, industrial areas, public buildings, and wasteland. This categorization follows past studies, including Cervero and Kockelman (2007) and Vance and Hedel (2007).

Second, "regular housing" and "irregular housing" are further re-grouped into three subgroups to reflect the local context of residential types in Jabodetabek, particularly the spatial segregation between informal settlements, new towns, and agricultural areas. In Indonesia, informal developments are ubiquitous, while formal developments are exceptionally few (Zhu, 2010). Informal settlements in Jakarta are called urban kampungs, which are characterized as overcrowded and physically deteriorated, with very limited amenities such as water and sewer connections and open spaces. Kampungs feature a common practice where those in poverty share what they have in order to survive (Evers, 1989). Silver (2008) estimated that about 60% of Jakarta residents live in kampungs. In addition, recent new town developments have apparently reinforced the spatial segregation in Jabodetabek. They have polarized middle- and upper-income groups of Jabodetabek residents, resulting in pockets of exclusive residential areas and new towns in which residents enjoy an exclusive lifestyle, with high security and much better infrastructure and facilities (Firman, 2004). This paper thus utilizes the land use data proposed by Hayashi (2011), in which the residential areas are categorized into kampungs, planned residential areas, and farms in Jakarta.

Third, the land use patterns in residential areas outside Jakarta City are estimated with the land use data proposed by Hayashi (2011). This is because Hayashi's data do not cover the area outside Jakarta City. The multinomial logit (MNL) model is estimated with the land use data for Jakarta City. The estimated results are shown in Table 4. Finally, the estimated results are applied to the zones in the rest of Jabodetabek.

Table 5 shows the results of the categorizations of land use patterns in Jabodetabek following the above processes. This shows that about 52% of the total area in Jabodetabek is used for residential purposes. In Jabodetabek, approximately 43% of the residential areas are kampung areas, whereas approximately 33% of are planned residential areas. Jakarta has the

highest share of commercial areas and public building areas among the different areas, but the lowest share of industrial areas. Kota Tangerang is mainly used for industrial and commercial use, whereas Kota Bekashi is mainly used for industrial use. Although the verification of the fitness of model outside of Jakarta City is ideally required, it cannot be done unfortunately due to the limitation of data availability. This is one of further research issues.

Table 4. Estimation Results of Land Use Patterns in Residential Areas of Jakarta City

Explanatory variables	Coefficients	t-statistics
Constant (*kampung* areas)	0.93	-3.80[*]
Constant (planned residential areas)	1.32	-2.94[*]
Population density $\times$ irregular housing dummy (*kampung* areas)	2.00	-13.79[*]
Population density $\times$ regular housing dummy (planned residential areas)	2.37	3.26[*]
Population density (farm areas)	0.39	18.55[*]
Agricultural soil index (farm areas)	2.70	11.35[*]
Number of observations	6552	
Initial log-likelihood	-9367	
Final log-likelihood	-3372	
Adjusted rho-squared	0.64	

Note 1: * indicates significance in 95% degree
Note 2: Zone-based population density is recalculated with the official database obtained from the local governments of the *desas* and *kelurahan*.
Note 3: The (ir)regular housing dummy is equal to 1 if the zone is categorized as a (an) (ir)regular housing area, and 0 otherwise. The agricultural soil index is equal to 1 if the share of agricultural-use soil is higher than that of urban-use soil in the zone, and 0 otherwise. The agricultural-use soil zone is defined as the area where the normalized difference soil index (NDSI; Faraklioti, and M. Petrou, 2001; Rogers and Hartnett, 2001) is equal to 80-90, whereas the urban-use soil zone is defined as the area where the NDSI is equal to 120-130.

Table 5. Results of Categorization of Land Use Patterns in Jabodetabek

	Jakarta		Kota Bogor		Kota Tangerang		Kota Bekasi		Total (Jabodetabek)	
Kampung area	3177	25.40%	535	25.30%	661	20.30%	480	12.40%	4853	22.33%
Planned residential area	2479	19.80%	205	9.70%	369	11.30%	639	16.60%	3692	16.99%
Farm area	1416	11.30%	122	5.80%	774	23.70%	504	13.10%	2816	12.96%
Commercial area	297	2.40%	32	1.50%	0	0.00%	38	1.00%	367	1.69%
Industrial area	1948	15.60%	444	21.00%	806	24.70%	1760	45.60%	4958	22.81%
Public building area	952	7.60%	54	2.60%	90	2.80%	10	0.30%	1106	5.09%
Wasteland area	2234	17.90%	719	34.10%	561	17.20%	430	11.10%	3944	18.15%
Total	12503	100.00%	2111	100.00%	3261	100.00%	3861	100.00%	21736	100.00%

Note: The numbers in the left of each category mean the numbers of zones.

3. EMPIRICAL ANALYSIS

3.1 Model

This study analyzes the association of built environment and travel behavior by highlighting the land use mix and the daily frequency of travel made by individuals. The ordered logit

model is a kind of regression model for ordinal dependent variables. In our case, the daily frequency of travels is regarded as the ordinal dependent variable (Greene and Hensher, 2010).

Let the utility function of an individual i be U_i. It is assumed that the utility function is a linear function with a random component, $U_i = \boldsymbol{\beta}\mathbf{x}_i + \varepsilon_i$, where $\mathbf{x}_i$ denotes a set of variables, including gender, income, and age; $\boldsymbol{\beta}$ denotes a set of coefficients; and ε_i denotes the random component following the logistic distribution. Then, the random ordered choice model for the travel frequency Y_i is formulated as

$$Y_i = 0 \quad \text{if} \quad -\infty < U_i \leq \alpha_{0/1} \tag{1},$$

$$Y_i = 1 \quad \text{if} \quad \alpha_{0/1} < U_i \leq \alpha_{1/2} \tag{2},$$

$$Y_i = 2 \quad \text{if} \quad \alpha_{1/2} < U_i \leq \alpha_{2/3} \tag{3},$$

where $\alpha_{j/j+1}$ denotes the threshold between travel frequency $Y_i = j$ and $Y_i = j+1$.

The probability that Y_i is equal to or lower than j, $\Pr(Y_i \leq j)$, and the probability that Y_i is equal to j, $\Pr(Y_i = j)$, are expressed respectively as

$$\Pr(Y_i \leq j) = \frac{\exp(\alpha_{j/j+1} + \boldsymbol{\beta}\mathbf{x}_i)}{1 + \exp(\alpha_{j/j+1} + \boldsymbol{\beta}\mathbf{x}_i)} \tag{4},$$

$$\Pr(Y_i = j) = \Pr(Y_i \leq j) - \Pr(Y_i \leq j-1) = \frac{\exp(\alpha_{j/j+1} + \boldsymbol{\beta}\mathbf{x}_i)}{1 + \exp(\alpha_{j/j+1} + \boldsymbol{\beta}\mathbf{x}_i)} - \frac{\exp(\alpha_{j-1/j} + \boldsymbol{\beta}\mathbf{x}_i)}{1 + \exp(\alpha_{j-1/j} + \boldsymbol{\beta}\mathbf{x}_i)} \tag{5}.$$

The coefficients in the utility function are estimated with the likelihood maximization procedure. The likelihood function is defined as

$$L = \prod_{i}^{I}\prod_{j}^{K-1}\left[\Pr(Y_i = j)\right]^{\delta_{i,j}} = \prod_{i}^{I}\prod_{j}^{K-1}\left[\frac{\exp(\alpha_{j/j+1} + \boldsymbol{\beta}\mathbf{x}_i)}{1 + \exp(\alpha_{j/j+1} + \boldsymbol{\beta}\mathbf{x}_i)} - \frac{\exp(\alpha_{j-1/j} + \boldsymbol{\beta}\mathbf{x}_i)}{1 + \exp(\alpha_{j-1/j} + \boldsymbol{\beta}\mathbf{x}_i)}\right]^{\delta_{i,j}} \tag{6},$$

where $\delta_{i,j}$ is equal to 1 if the travel frequency of an individual i is equal to j, and 0 otherwise, I denotes the number of individuals, and K denotes the maximum travel frequency.

3.2 Land use mix indexes

Land use mix refers to locating different types of land uses close together. The land use mix has typically been measured using entropy indexes or dissimilarity indexes (Litman and Steele, 2012). This study uses two kinds of indexes pertaining to land use mix. The first is the Gini–Simpson (GS) index, which is widely used in ecology. This is one of the entropy indexes. This index originates from the Simpson Index (Simpson, 1949), which is also known as the Herfindahl or Herfindahl–Hirschman index in economics. The Gini–Simpson index is equal to the probability that two entities taken at random from the dataset of interest represent different types. It can be expressed as

$$Gini - Simpson \ Index = 1 - \sum_{k}^{K} p_k^2 \tag{7},$$

where p_k indicates the share of zones belonging to a land use category k among the total zones. This index increases as the numbers of land use categories become better balanced in the given area. It should be noted that a higher GS index does not necessarily guarantee the

land use mix. This is because the GS index is possibly high even if the land use patterns are segregated in the given area. Thus, this index indicates the balance of land use patterns in the given area.

The second index relating to land use mix is the dispersion index. It is defined as

$$Dispersion\ Index = \frac{1}{K} \cdot \sum_{k=1}^{K} \frac{\sum_{n=1}^{N} \theta_{n,k} \cdot GD_{n,k}}{\sum_{n=1}^{N} \theta_{n,k}} \qquad (8),$$

where $\theta_{n,k}$ is equal to 1 if the zone n belongs to the land use category k, and 0 otherwise, $GD_{n,k}$ denotes the distance between the zone n and the gravity point in a subgroup of zones belonging to the land use category k, and N denotes the total zones. The grid zone located in an area where land use patterns are highly dispersed has a higher dispersion index. In other words, the segregated land use patterns should give a low dispersion index. Thus, this index indicates the segregation level of land use patterns in a given area.

3.3 Land use mix indexes

First, the correlations among the potential explanatory variables are summarized in Table 6. The "GS index dummy" is equal to 1 if the Gini–Simpson Index is greater than 0.9, and 0 otherwise. The Gini–Simpson index is estimated in the area covering a five square kilometer area around an individual's home. The "dispersion index dummy" is equal to 1 if the dispersion index is greater than 7.0, and 0 otherwise. The dispersion index is estimated in the area covering a five square kilometer area around an individual's home. "Income" is equal to 1 if the monthly income of the individual's household is equal to or greater than 2,250,000 rupiahs, and 0 if not. In our dataset, 2,250,000 rupiahs is close to the average monthly household income. "Gender" is equal to 1 if the individual is male, and 0 otherwise. "Age in 30s or 40s" is equal to 1 if the individual is in his or her 30s or 40s, and 0 otherwise. "Access to bus stop" is equal to 1 if the access travel time to the nearest bus stop from the individual's home is over 20 minutes, and 0 otherwise. 20 minutes is also approximately the average access travel time to the nearest bus stop from residents' households. "Car ownership" is equal to 1 if the individual owns a car, and 0 otherwise. "Motorbike ownership" is equal to 1 if the individual owns a motorbike, and 0 otherwise. "Children" is equal to 1 if the number of children who are less than 13 years old is over three, and 0 otherwise. "Kampung area dummy," "planned area dummy," and "farm area dummy" are equal to 1 if the zone where the individual's home is located belongs to a kampung area, a planned area, or a farm area, respectively, and 0 otherwise.

Table 6 shows that most of the combinations have a low correlation coefficient. It should be noted that the correlation coefficient between the GS index dummy and the kampung area dummy is -0.40. This means that the kampung area may be less balanced with respect to land use patterns. This is quite reasonable because the kampung areas are often developed into large agglomerations where many kampung areas are located together.

Table 7 shows the estimation results of ordered logit models. Model 1 uses all the potential variables; Model 2 removes "kampung area dummy" from Model 1 by reflecting the high correlation with "GS index dummy;" Model 3 is the model with the highest final-log-likelihood after the trial-and-error process with respect to the choice of explanatory variables. First, Model 3 shows that all thresholds are significantly estimated. Second, "dispersion index dummy" is significantly positive. This means that the individuals whose

home is located in the area where the land use patterns are highly dispersed travel more frequently. On the other hand, "GS index dummy" is negative in all models, although it is not significant at the 95% degree. This may mean that individuals whose home is located in the area where the land use categories are balanced tend to travel less frequently. Third, "income" is also significantly positive. This means that the individuals in higher-income households travel more frequently. Fourth, "gender" is significantly negative. This means that males travel less frequently. Fifth, "age in 30s or 40s" is positive, although it is less significant. This may mean that the individuals in their 30s or 40s tend to travel more frequently. Sixth, "car

Table 6. Correlation Matrix among Potential Explanatory Variables in Ordered Logit Model

	GS index dummy	Dispersion index dummy	Income	Gender	Age in 30s or 40s	Access bus stop
GS index dummy	1.00					
Dispersion index dummy	0.04	1.00				
Income	-0.07	0.06	1.00			
Gender	-0.08	0.07	0.00	1.00		
Age in 30s or 40s	-0.08	-0.02	-0.02	-0.08	1.00	
Access to bus stop	0.00	0.11	0.05	-0.05	0.03	1.00
Car ownership	-0.04	0.14	0.18	-0.05	-0.04	0.12
Motorbike ownership	-0.05	0.06	0.32	-0.02	-0.01	0.04
Children	-0.02	-0.05	-0.02	-0.07	0.09	-0.08
Kampung area dummy	-0.40	0.17	0.06	0.00	0.12	0.14
Planned area dummy	0.06	-0.13	0.09	0.03	-0.05	-0.13
Farm area dummy	0.21	-0.2	-0.12	-0.03	-0.05	0.05

	Car ownership	Motorbike ownership	Children	*Kampung* area dummy	Planned area dummy	Farm area dummy
GS index dummy						
Dispersion index dummy						
Income						
Gender						
Age in 30s or 40s						
Access to bus stop						
Car ownership	1.00					
Motorbike ownership	0.09	1.00				
Children	-0.01	-0.06	1.00			
Kampung area dummy	0.06	0.11	0.02	1.00		
Planned area dummy	-0.01	-0.01	0.01	-0.57	1.00	
Farm area dummy	-0.07	-0.02	-0.01	-0.37	-0.27	1.00

Table 7.   Estimation Results of Ordered Logit Models

	Model 1			Model 2			Model 3		
	Coef.	t-statistics		Coef.	t-statistics		Coef.	t-statistics	
0/2 threshold	0.31	1.11		0.13	0.68		0.26	1.78	*
2/3 threshold	2.37	8.01	**	2.19	10.04	**	2.32	13.07	**
3/4 threshold	2.83	9.25	**	2.66	11.44	**	2.78	14.31	**
4/5 threshold	3.74	10.84	**	3.56	12.69	**	3.69	14.69	**
GS index dummy	-0.12	-0.57		-0.20	-1.00		-0.23	-1.23	
Dispersion index dummy	0.44	2.02	**	0.42	1.94	*	0.45	2.18	**
Income	0.42	2.73	**	0.43	2.78	**	0.42	2.86	**
Gender	-0.50	-3.19	**	-0.50	-3.18	**	-0.49	-3.13	**
Age in 30s or 40s	0.22	1.50		0.23	1.55		0.23	1.61	
Access to bus stop	-0.22	-1.28		-0.20	-1.16				
Car ownership	0.54	1.26		0.53	1.22		0.50	1.17	
Motorbike ownership	-0.08	-0.48		-0.06	-0.37				
Children	-0.32	-1.27		-0.31	-1.25		-0.28	-1.13	

Kampung area dummy	0.24	0.89			
Planned area dummy	0.14	0.54	-0.04	-0.21	
Farm area dummy	-0.02	-0.05	-0.19	-0.83	
Initial log-likelihood	-1228		-1228		-1228
Final log-likelihood	-792		-793		-794
Number of observations	763		763		763

ownership" is also positive, although it is less significant. This may mean that a car owner tends to travel more frequently. Finally, "children" is negative, although it is less significant. This may mean that individuals with many children tend to travel less frequently.

3.4 Discussion

The estimation results seem quite reasonable. Higher-income individuals travel more frequently, probably because they are more able to participate in out-of-home activities. Females travel more frequently, probably because they often go shopping to purchase the daily food. Note that Kato et al. (2010) report the results of a consumer survey in Jakarta in which housewives cook the daily meal in 79.5% of households and often visit groceries and local markets to purchase the daily food. The positive impact of the dispersion index dummy on the utility function means that less segregated land use patterns around an individual's home make the individual travel more frequently. This is probably because individuals who live in areas where the mixed land use patterns are located can access different land use zones easily. The negative impact of the GS index dummy on the utility function means that less balanced land use patterns around an individual's home make individuals travel more frequently. This may be because only specific land use categories such as commercial areas and public building areas attract individuals more than other land use categories. One of the examples of less segregated and less balanced land use pattern is a mosaic pattern composed of only two types of land use categories like a chess board. In summary, the results suggest that higher-income females living in areas with mixed land use patterns composed of a few land use categories travel more frequently from home.

Does this mean that the land use mix has less impact on the global and local environments, or more? Unfortunately, the answer is not clear from this study. It should be noted that the dispersion index and GS index are calculated for an area of five square kilometers, and that over 60% of respondents travel less than five kilometers from their home. Our dataset shows that travels of less than two kilometers are predominantly made on foot, while 2-5 kilometer travels are mainly made by motorbike. The high modal share of motorbikes is one of the noteworthy characteristics in Jabodetabek that cannot be seen in American or European cities. Thus, decreased segregation of land use patterns may lead to more motorbike traffic than walking in our case. To discuss this, however, it is necessary to analyze the travel mode choice under the given land use patterns. This is beyond this study's scope, but it is one of the most important issues for future research.

4. CONCLUSIONS

This paper analyzed the impact of land use mix on the travel frequency of individuals in a developing city. Daily activity data were collected through interview-based local surveys in the Jakarta metropolitan area, while land use data were collected via the estimation of land use patterns using an existing official database. Seven categories of land use patterns are used, including three types of residential areas: kampung areas, planned residential areas, and farm areas. Then, ordered logit models were estimated, in which the dependent variable was the

daily travel frequency of individuals and the independent variables were the threshold of travel frequency, land use mix indexes, and individual and household attributes. The results show that higher-income females living in areas with less segregated land use patterns composed of less balanced land use categories travel more frequently from home.

Future research issues are summarized as follows: First, the work presented in this paper could be extended by accounting for the possible influences of self-selection on travel frequency. To do so, the attitudinal and lifestyle preference variables should be incorporated into the model. Second, the association between land use mix and the modal choice of individuals should be studied to determine the impacts of land use mix on the environment, particularly those caused by motorbikes. Third, the association of land use patterns with time use may be also investigated. In this case, the land use patterns around the destination zone should be used for the analysis. Fourth, the impact of factors other than land use mix on the travel behavior of individuals should also be analyzed. Fourth, the trip chaining behavior was not assumed in this paper although it may be one of the major characteristics of travelers in Asian urban areas. The detailed travel episode should be used for analyzing the trip chaining behavior. Finally, a comparative analysis between different developing cities may also be interesting. Although a meta-analysis on the association of the built environment and travel behavior has been presented (e.g., Ewing and Cervero, 2010), these studies have mainly used data from the developed world. Further empirical studies might contribute to land use and transportation policy in the developing regions.

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