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Relationship between Built Environment and Household Gasoline Consumption in the Jakarta Metropolitan Area: Residential Self-Selection and the Structural Equation Modeling Approach

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ABSTRACT

This study investigates the impact of the built environment on household energy consumption within a developing megacity; it does so by examining the case of the Jakarta Metropolitan Area in Indonesia. It highlights a residential self-selection effect on the relationship between the built environment and travel behavior. Empirical analyses are carried out with a dataset comprising 948 households that was captured through an interview-based survey in the Jakarta Metropolitan Area in 2011. Structural equation modeling is applied to the empirical analysis with regard to the causes of household gasoline consumption. The impacts of major factors that potentially influence household energy consumption—such as household sociodemographics, household attitudes, household ownership of goods, and built environment—are investigated. Our main findings are as follows: (1) the built environment, such as accessibility of residence to various facilities, has an effect on household gasoline consumption, even when the residential self-selection effect is accounted for, and (2) the attitudes of residents—most importantly, their attitude toward eco-friendly actions—have a negative effect on household gasoline consumption. Further analysis is performed to compare the impact on gasoline consumption between those who selected their residence themselves and those who inherited their residence from their parents. The results imply that land-use policies that improve the accessibility of traditional residential areas would contribute less significantly to controlling gasoline consumption than those in newly developed areas.

Keywords. Gasoline consumption, built environment, residential self-selection effect, structural equation modeling

INTRODUCTION

A number of studies provide evidence that there are associations between built environment—which is to say, the physical characteristics of the neighborhood and the locational characteristics of the residence—and travel behavior. The main focus of these studies is on which, and to what extent, built environment factors contribute to a reduction in the vehicle-miles travelled and thus to reducing greenhouse gas emissions. They are considered part of an important basis for urban design and planning—particularly in European and American cities, where compact and concentrated urban development is highlighted as a sustainable urban form. Accordingly, there is much evidence from developed cities in Europe and the United States; on the other hand, there is limited empirical evidence from developing cities, in spite of their huge potential impact, given that the urban population of developing countries is about twice as large as that of developed countries (*1*). Additionally most of the urban population growth in the future is expected to take place in cities within the developing world (*2*). Some commonalities between developed cities and developing cities are reported such as Yamamoto (*3*) which pointed out that found that population density had negative effect on ownership of cars in both cities of Osaka and Kuala Lumpur. On the other hand, there are claims that the dynamic change in developing cities should be considered; for example Zegras and Hannan (*4*) found from a study in Chile that the rapid motorization is altering the linkage of the urban form and travel behavior. The generalizability of findings from studies in developed cities to developing cities remains questionable; for example, the concept of the compact city—which is highly supported in Western cities as a sustainable urban form—may not be effective in developing cities. Many developing cities in Asia suffer from severe environmental conditions, including vehicular pollution due mainly to high population density (*5*).

This study reports empirical findings regarding the impact of the built environment on residents' travel behavior, in the context of a developing megacity and using data from the Jakarta Metropolitan Area. Structural equation modeling (SEM) is used to explain household gasoline consumption. Along with data pertaining to the built environment, household socioeconomic data and household attitudinal data are incorporated into the SEM. This study adds further insights to the results of an earlier study (*6*) that analyzed the impact of the built environment by using the same data sample used in the current study. That earlier study focused on interactions among the built environment, vehicle ownership, and travel behavior, whereas this study investigates interactions among the aforementioned factors and individuals' attitudinal factors. This study also highlights the residential self-selection effect on travel behavior—a hotly debated topic in research regarding the association between the built environment and travel behavior. The residential self-selection effect presumably comes into play when people select their residence according to their preexisting transportation preferences. For instance, suppose that an individual who cares about environmental issues chooses a residence with good public-transportation accessibility, to avoid the use of private cars. Although the observed travel behavior of an individual using public transportation seems to be a result of the built environment—as good transportation accessibility is, in reality, caused by that and other individuals' transportation preferences—it actually stems from his or her wish to refrain from using private vehicles. It is unclear whether unbiased impacts of the built environment on travel behavior can be estimated separate from the residential self-selection effect. Furthermore, this study assumes there are differences of impact of the built environment on household gasoline consumption, between traditional residents who inherited their residence from their parents, and newcomers who chose their residence themselves. Firman (*7*) examines spatial segregation in Jakarta, where traditional residential areas are associated with traditional lifestyles, and newly developed residential areas are associated with Western lifestyles. Investigations into differences in the built environment on household gasoline consumption are undertaken by comparing these subgroups (i.e., those who inherited their residence from their parents, and those who chose their residence themselves).

The remainder of this paper is organized as follows. In the second section, we review extensively the literature on the relationship between the built environment and travel behavior. In the third section, we present the empirical case of the Jakarta Metropolitan Area; this is followed by a description of the data used in the analysis. In the fourth section, we present a means of estimating gasoline consumption; this is followed by the fifth section, which contains the resulting model estimation results. The sixth section undertakes discussion, and the seventh section contains a summary of the findings, along with concluding remarks.

LITERATURE REVIEW

A number of studies address the association between the built environment and travel behavior. First, determinant factors of energy consumption have been studied, and resulting empirical evidence has concluded that the built environment is a critical factor affecting energy consumption. For example, 70% of the energy consumption in urban areas relates to land-use patterns (*8*). The built environment has also been highlighted from a policy perspective, as land-use characteristics can be potentially managed through the enactment of land-use policy.

Next, the effects of built-environment factors—such as density, diversity, distance to city center, and distance to transit—on travel behavior have also been investigated. Ewing and Cervero (*9*) show that the travel distance of individuals who reside in high population-density areas would be shorter than that of those who reside in low population-density areas. Holden and Norland (*10*) analyzed the relationship between household energy use and household distance to the city center, using survey data of residents in Oslo; they conclude that those who reside in an area far from the city center use more energy for transportation. Krizek (*11*) claims that an individual who resides in a neighborhood with better accessibility travels shorter distances, which results in less energy use. Brownstone and Golob (*12*) indicate that higher density in a neighborhood area would lead to less fuel consumption, due to shorter travel distances and reduced automobile ownership.

Recently, in empirical studies regarding the relationship between the built environment and travel behavior, more attention has been paid to attitudinal variables. Mokhtarian and Cao (*13*) summarize two major sources of residential self-selection—namely, individual attitudes, and sociodemographic traits. The residential self-selection hypothesis assumes that spatial differences in travel behavior are not so much related to differences in built environment as to the selective immigration of certain groups of people, together with their subjective location attitudes and preferences. Scheiner and Holz-Rau (*14*) present evidence of the self-selection effect where both an individual's sociodemographics and attitudes influence both the built environment and travel behavior. Handy *et al.* (*15*) also incorporated into their model subjective attitudinal variables concerning individual preference vis-à-vis neighborhood design; they conclude that the built environmental variable has an independent impact on travel behavior, but that the impact of attitudinal variables on travel behavior is also considerably significant.

EMPIRICAL STUDY

The Jakarta Metropolitan Area

The Jakarta Metropolitan Area is often referred to as *Jabodetabek*, an acronym for Jakarta, Bogor, Depok, Tangerang, and Bekasi. As of 2010, it had a population of over 25 million (*16*); this characterizes it as a megacity, and it has started to establish itself as a global city that represents Asia. The population continues to grow in the traditional urban core of Jakarta, but the population spillover to adjacent areas is more significant (*17*). Such growth has led to increased housing demand in both the traditional urban core and in adjacent areas; however, houses are being developed through the renewal of traditional urban residential areas (*kampung*), within the traditional urban core; meanwhile, in rural areas, they are being developed through the conversion of agricultural land to residential use. Firman (*6*) points out that these recent sociodemographic and housing development dynamics in Jakarta have created spatial segregation, where some individuals in the urban *kampung* follow the traditional lifestyle of living together as an extended family, whereas individuals in the new residential areas tend to prefer the Western lifestyle and live as a so-called nuclear family. Many studies—including those of Steinberg (*18*) and Krass (*19*)—point out the potential environmental deterioration that can come with high economic growth, the urban sprawl that often accompanies rapid increases in urban population, and changes in individual preferences toward the consumption-oriented lifestyle, and how such changes can contribute to an increase in energy consumption in the Jakarta Metropolitan Area.

Data

Our empirical analysis uses data captured in 2011 through a household survey in the Jakarta Metropolitan Area. A paper-based questionnaire survey asked 948 randomly selected respondents to answer questions in a face-to-face interview. As for the selection of the respondents, 90 target areas (250 m by 250 m grid zone) were randomly selected with considering the distribution of the population, whereby a local community consisting of 30 to 100 households were selected. 10 or more target households are then randomly selected from each selected local community. FIGURE 1 shows a map of the Jakarta Metropolitan Area and the locations of the respondents. Survey sheets contained questions on the personal attributes of the respondents, the respondents' household attributes, the daily activities of the respondents, as well as their values and attitudes. The survey sheet on the personal attributes of the respondents captured information on gender, age, occupation, and education level; that on household attributes captured household income, situation of residence, and energy consumption; that on daily activities captured information on the respondent's travel attitudes, travel behavior based on an activity diary, and communal and religious activities; and that on values and attitude captured information on the respondent's values vis-à-vis various aspects of life, attitude towards environmental issues, and his or her preference on accessibility of residence. For more information on the survey, please see Furuhashi (*20*) and Furuhashi and Kato (*21*). The location of each respondent residence was geocoded, to key it to a GIS database. The built environment attributes were derived from the GIS database, which includes the distance to the city center, the distance to regional core, and the distance to certain facilities.

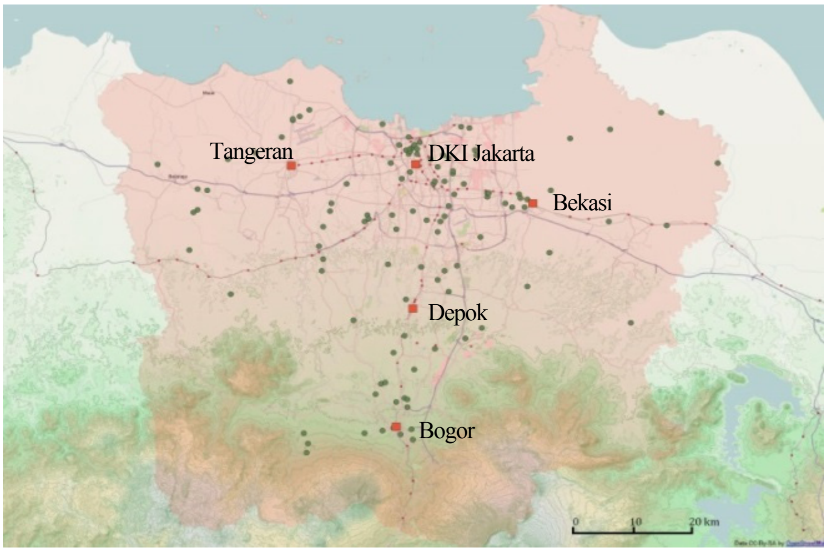

FIGURE 1 Map of the Jakarta Metropolitan Area, and Locations of Respondents.

Note: Dots indicate locations of survey areas; squares indicate regional cores.

TABLE 1 contains the descriptive statistics of the data from all respondents, as well as those within the inheritance and noninheritance subgroups. Note that the inheritance subgroup consists of respondents who acquired their residence through inheritance, while the noninheritance subgroup consists of respondents who did not inherit their residence. Of 948 households, 384 households (41%) belonged to the inheritance subgroup, and 564 households (59%) belonged to the noninheritance subgroup.

Overall, 302 of the 948 households answered that they do not consume any gasoline; this is simply because they do not own an automobile or motorbike. Second, the average access time to the nearest bus stop was 19.2 minutes; this means many respondents reside in an area where accessibility to public transit is quite poor. The respondents in the noninheritance subgroup tended to live closer to bus stops. Third, the average population density of the respondents' residential areas is 12,000/km^2; the highest population density is 52,500/km^2. High population density is typically observed in the *kampung*. The respondents in the noninheritance subgroup tend to live in more densely populated areas. Fourth, the average distance to the nearest hospital, religious facility, educational facility, business district, post office, and cultural center is 1.55 km, 0.5 km, 0.55 km, 2.18 km, 3.59 km, and 11.7 km, respectively. This indicates that religious facilities such as local mosques are located in the vicinity of each residence, thus reflecting the active religious lives of the local people. The respondents in the noninheritance subgroup tend to live closer to each of these destinations, save for educational facilities. Fifth, the average number of adult members (i.e., those aged 18 years and older) in a household is 2.71, while that of children is 1.33. This may indicate that many households do not contain a so-called nuclear family; nonetheless, it is worth noting that the respondents in the inheritance subgroup tend to have a large family. Sixth, the average monthly income is IDR2.21 million. (Note that as of 2011, USD1 was equivalent to IDR9,000.) The average income of the noninheritance subgroup is higher than that of the inheritance subgroup. Seventh, the average number of motorbikes per household is 0.89, and 292 of 948 households did not own a motorbike. (Note that only 23 households owned automobiles.) Additionally, the respondents in the inheritance subgroup owned more motorbikes per household. Eighth, the average participation score with respect to various eco-friendly activities is 3.19 in saving water, 3.23 in saving electricity, 2.46 in refraining from air conditioner use, 2.68 in using public transport, and 2.33 in reducing garbage. (Note that these scores were captured in terms of a four-point Likert scale: 1, “not at all”; 2, “not often”; 3, “often”; and 4, “very often.”) These scores indicate that the respondents participated in saving water and electricity more than in other activities; this may be because saving water and electricity contributes to reducing household expenses, and this is not the case with using public transportation or reducing garbage. The respondents in the inheritance subgroup scored higher in saving electricity, refraining from using the air conditioner, and using public transportation, whereas the respondents in the noninheritance subgroup scored higher in saving water and reducing garbage. Ninth, the average scores with respect to respondents’ concern about environmental issues were are follows: 3.20 for global warming, 3.30 for extreme climate, 2.98 for water pollution, 2.85 for air pollution, and 2.84 for loss of green space. These scores are derived from respondent answers—given also on a four-point Likert scale ranging from 1 (“not at all serious”) to 4 (“very serious”)—to the question: “How serious do you consider the following five environmental problems: water pollution, air pollution, loss of green space, global warming, and occurrence of extreme climate?” Greater concern about the global climate may derive from the Indonesian government’s recent efforts to enlighten and educate the populace about the global environment. A greater concern about extreme climate may reflect the growing number of natural disasters in Jakarta, which have caused frequent flooding in many areas. The inheritance subgroup tended to be more concerned about these environmental problems. Finally, the average preference score of respondents with regard to accessibility to a school, office, community service office, and public transport was 0.09, 0.07, 0.04, and 0.08, respectively. (The value of a preference score was set at 1 if the respondent attached much importance to accessibility to a given facility in daily life, and 0 otherwise.) This may indicate that individuals care less about accessibility to community service offices than to other public services. The respondents in the noninheritance subgroup cared more about proximity to a school, proximity to an office, and the availability of public transportation than those in the inheritance subgroup, while the respondents in the inheritance subgroup cared more about proximity to a community service office than those in the noninheritance subgroup.

TABLE 1 Descriptive Statistics of Sample Dataset

	Pooled data (N = 948)		Inheritance subgroup (N = 384)		Noninheritance subgroup (N = 564)		Difference between subgroup
	Average	(Std. Dev.)	Average	(Std. Dev.)	Average	(Std. Dev.)	t-statistics
Travel behavior							
Household monthly gasoline expenditure (IDR10^5/month)	1.45	(2.09)	1.56	(2.32)	1.38	(1.91)	-1.25
Built environment							
Access time to bus stop (min)	19.2	(21.4)	21.6	(23.8)	17.5	(19.4)	-2.80
Population density (10^4/km²)	1.20	(1.00)	1.07	(0.99)	1.29	(1.01)	3.30
Distance to hospital (km)	1.55	(1.10)	1.60	(1.11)	1.52	(1.09)	-0.80
Distance to religious place (km)	0.50	(0.41)	0.51	(0.40)	0.50	(0.42)	-0/55
Distance to educational facility (km)	0.55	(0.40)	0.54	(0.40)	0.56	(0.40)	0.18
Distance to business district (km)	2.18	(1.71)	2.25	(1.75)	2.14	(1.68)	-0.41
Distance to post office (km)	3.59	(2.58)	3.79	(2.71)	3.45	(2.47)	-1.79
Distance to cultural center (km)	11.7	(7.75)	11.9	(8.36)	11.6	(7.30)	1.24
Household sociodemographics							
Number of adults in a household	2.71	(1.21)	2.96	(1.28)	2.55	(1.12)	-5.11
Number of children in a household	1.33	(1.14)	1.53	(1.13)	1.20	(1.13)	-4.35
Monthly income (IDR10^6/month)	2.21	(1.32)	2.20	(1.05)	2.35	(1.45)	4.24
Vehicle ownership							
Number of motorbikes owned	0.89	(0.77)	0.94	(0.80)	0.86	(0.76)	-1.53

Attitude toward eco-friendly actions							
Saving water	3.19	(0.73)	3.15	(0.75)	3.21	(0.72)	1.41
Saving electricity	3.23	(0.68)	3.24	(0.66)	3.22	(0.69)	-0.52
Refraining from using air conditioner	2.46	(1.03)	2.52	(1.05)	2.41	(1.01)	-1.57
Using public transport	2.68	(0.82)	2.70	(0.80)	2.66	(0.83)	-0.67
Reducing garbage	2.86	(0.81)	2.82	(0.65)	2.90	(0.71)	1.84
Concern about environmental issues							
Concern about global warming	3.20	(0.76)	3.19	(0.74)	3.21	(0.77)	0.26
Concern about extreme climate	3.30	(0.70)	3.29	(0.69)	3.30	(0.70)	0.29
Concern about water pollution	2.98	(0.94)	2.98	(0.93)	2.98	(0.95)	0.02
Concern about air pollution	2.85	(0.85)	2.79	(0.85)	2.89	(0.85)	1.78
Concern about loss of green spaces	2.84	(0.82)	2.83	(0.82)	2.84	(0.81)	0.21
Preference on accessibility							
Proximity to school	0.09	(0.28)	0.08	(0.27)	0.09	(0.29)	0.77
Proximity to office	0.07	(0.26)	0.05	(0.23)	0.09	(0.28)	1.94
Proximity to community service office	0.04	(0.20)	0.05	(0.21)	0.04	(0.19)	-0.58
Availability of public transport	0.08	(0.27)	0.07	(0.26)	0.09	(0.29)	1.22

METHOD

Hypothetical Model of Travel Behavior

Travel behavior is affected by various factors, including the built environment, ownership of a private vehicle, household sociodemographics, and individual attitudes. The built environment can influence travel behavior either directly and indirectly, through vehicle ownership; it may also be influenced by sociodemographics and attitudes. One of the numerous methods proposed to analyze complex interrelationships among multiple factors is SEM. Golob (*22*) states that SEM bears some advantages, in that there are restrictions on neither the model structure nor the data form used; thus, SEM is considered a powerful tool in verifying hypotheses. SEM has been frequently used in the context of travel behavior analysis, which highlights the built environment and the self-selection effect. Cao *et al.* (*23*) report that SEM is useful in investigating the self-selection effect, as it allows the built environment variable to be treated as a mediating factor that influences travel behavior but, at the same time, is influenced by an individual's residential preference. Brownstone and Golob (*12*) applied SEM to analysis of the relationship between the built environment and travel behavior, while incorporating the self-selection effect and using data collected in California. Cao *et al.* (*24*) also used SEM to investigate causality between the built environment and travel behavior, while incorporating preferences with regard to residential choice and using data from northern California.

The current study also makes use of SEM, to investigate the complicated relationships among various factors that affect travel behavior. FIGURE 2 shows the hypothetical model used in SEM. First, it assumes that attitude toward eco-friendly actions and the ownership of vehicles both directly influence travel behavior. Second, concern about environmental issues influences both attitude toward eco-friendly actions and ownership of vehicles. Third, household sociodemographics have a direct impact on travel behavior, and also indirect ones through built environment, concern about environmental issues, ownership of vehicles, and attitude toward eco-friendly actions. Fourth, built environment has an impact on travel behavior directly, and also indirectly through three intermediating variables (i.e., concern about environmental issues, ownership of vehicles, and attitude toward eco-friendly actions). Finally, it also assumes that preference on accessibility is treated as an exogenous variable, influencing travel behavior both directly and indirectly through the built environment. This follows the residential self-selection theory that individuals select their residence, and thus the built environment, according to their accessibility preference. This model structure allows us to investigate the residential self-selection effect. This approach is taken in many studies (*13*, *24*, *25*).

The current study analyzes the residential self-selection effect by taking two approaches, using this hypothetical model. The first approach is to estimate the SEM model with the pooled data, and the second is to estimate two SEM models with the data from the inheritance subgroup and the noninheritance subgroup. The second approach reflects the hypothesis that the residential self-selection effect does not hold for those who have not chosen their residence themselves; thus, the model estimated with the data of the inheritance subgroup could identify the pure effect of the built environment, which is not biased by the residential self-selection effect. Distinguishing one subgroup from the other subgroup on the basis of residence inheritance would also contribute to a depiction of the "dualism" of lifestyles between individuals residing in traditional urban *kampung* and individuals residing in newly developed urban areas, as described by Firman (*16*).

RESULTS

Estimation Method

AMOS (v21.0.0) was used in model estimation. Three estimation methods are available in AMOS: the maximization of likelihood (ML) method, the generalized least squared method, and the asymptotic distribution-free method. This study uses the ML method to estimate the model, because it performs well when the sample size is sufficiently large (*26*)—although it has been frequently pointed out that the ML method fits more poorly than others when the data is not continuous or is otherwise nonnormal.

Model Estimation Results: Pooled Data

TABLE 2 shows the results of model estimation that explain household gasoline consumption, derived from using the pooled data. The goodness-of-fit index and root mean square error of approximation are 0.89 and 0.06, respectively, indicating that the estimated model fit well. Thirty-two variables, including 28 observed variables and four latent variables, were incorporated into the model. The latent variable is specified as a linear function (weighted averages) of a set of observed variables in the system. This means that those observed variables work as indicators of the latent variable (*22*). TABLE 3 shows the components of four separately estimated latent variables—namely, concern about environmental issues, attitude toward eco-friendly actions, destination accessibility, and preference on accessibility—while TABLE 4 shows the elasticity of gasoline consumption.

First, the results show that built-environment factors have a significant impact on household gasoline consumption, both directly and indirectly, via attitude toward eco-friendly actions, concern about environmental issues, and ownership of vehicles. The significant and negative impact of destination accessibility on the number of motorbikes suggests that individuals who reside in an area with better accessibility tend to own fewer motorbikes; this seems to be a plausible outcome, as individuals who live in a residence with easy access to various facilities could easily walk there, and this might lead to the relinquishing of motorbikes. The results indicate that destination accessibility has a negative effect on gasoline consumption, which means that better accessibility also has a direct effect on reducing gasoline consumption. This negative and direct effect might be explained by a reduction in travel distance involving a vehicle, among individuals who reside in more highly accessible areas. The results also show that the access time to a bus stop has a significant and positive effect on gasoline consumption: individuals who reside

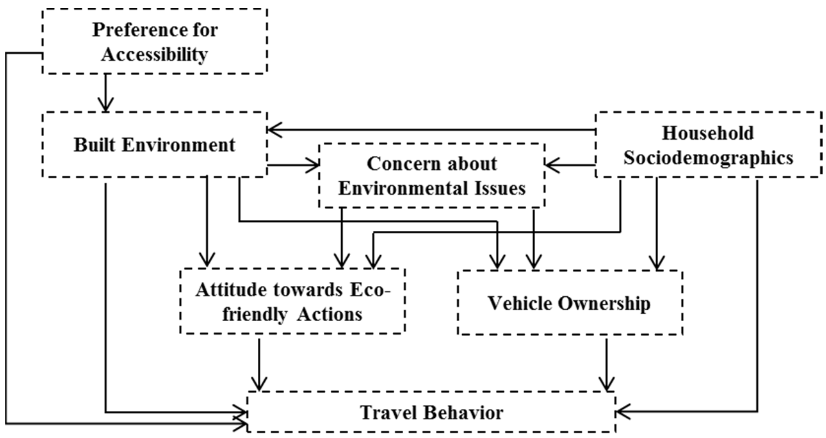

FIGURE 2 Structure of Hypothetical Model.

near to bus stops would likely use less gasoline, although the link between the access time to bus stop and the number of motorbikes is not significant. This would indicate that the proximity to a bus stop does not work to discourage the ownership of private vehicles, but that it would work to reduce the use of vehicles by encouraging people to use the bus.

Second, the results show that household sociodemographics have an effect on household gasoline consumption, both directly and indirectly, via concern about environmental issues and the ownership of vehicles. Monthly income has a strong influence on gasoline consumption, both directly and indirectly, via private vehicle ownership. Monthly income also has a positive impact on concern about environmental issues, meaning that wealthier households consider environmental issues more seriously. Unexpectedly, the number of children within a household has a significantly negative direct effect on gasoline consumption; this may be because adults within such a household might need to stay in the house longer than others, to care for their children, and thus travel less.

Third, an individual's attitude vis-à-vis eco-friendly actions has a significant and negative effect on household gasoline consumption; this suggests that individuals who have positive opinions and tend to take actions against environmental harm, such as saving water and electricity, are likely to refrain from using private vehicles. The results also indicate that an individual's concern about environmental issues have a significant and positive effect on the attitude towards eco-friendly actions. This indicates that individuals who are more concerned about environmental issues are more likely to take eco-friendly actions.

Fourth, an individual's preferences with regards to accessibility have a significant and negative effect on household gasoline consumption. This suggests that individuals who are aware of accessibility would travel less by motorized vehicles. However, the accessibility preference did not have a significant effect on the built environment; this means that residents did not necessarily select their residences in terms of accessibility needs. This may indicate that the effect of residential self-selection does not predominate.

Finally, the results show that monthly income has the largest impact on household gasoline consumption, followed by motorbike ownership and built-environment factors. These results suggest that the built environment does influence travel behavior, but its impacts may be smaller than those that stem from household income and motorbike ownership.

TABLE 2 Estimation Results with Pooled Data

	Endogenous variables				
	Gasoline consumption	Ownership of motorbikes	Attitude toward eco-friendly actions	Concern about environmental issue	Destination accessibility
	Std. Coeff. (t-statistic)	Std. Coeff. (t-statistic)	Std. Coeff. (t-statistic)	Std. Coeff. (t-statistic)	Std. Coeff. (t-statistic)
Built environment					
ln (Access time to bus stop)	0.12 (4.64***)	0.02 (0.81)	0.00 (–0.07)	–0.04 (–1.06)	
Destination accessibility	–0.06 (–2.33*)	–0.09 (–3.26***)	0.11 (3.14**)	0.12 (3.51***)	
Household sociodemographics					
Number of adults in a household	0.05 (1.91*)	0.19 (6.78***)	0.06 (1.68)	–0.05 (–1.44)	–0.08 (–2.49*)
Number of children in a household	–0.06 (–2.21*)	–0.01 (–0.48)	0.01 (0.25)	–0.04 (–1.27)	–0.15 (–4.65***)
ln (Monthly income)	0.27 (9.00***)	0.45 (15.6***)	–0.04 (–1.32)	0.06 (1.83*)	0.19 (5.82***)
Vehicle ownership					
Number of motorbikes owned	0.39 (13.1***)				
Household Attitudes					
Attitude toward eco-friendly actions	–0.06 (–2.30*)				
Concern about environmental issues		0.03 (1.06)	0.14 (4.29***)		
Preference on accessibility	–0.06 (–2.14*)				0.00 (–0.07)

Note: ***, **, and * denote significance at the 99.5%, 99%, and 95% confidence levels, respectively.

TABLE 3 Factor Loadings of Latent Variables

Concern about environmental issue	Global warming	Extreme climate	Water pollution	Air pollution	Loss of green space		
Factor loading	0.06	0.05	0.34	0.64	0.20		
t-statistics (confidence level)	6.28***	5.65***	23.3***	26.1***	17.8***		
Attitude toward eco-friendly action	Save electricity	Save water	Save air-conditioner	Use public transport	Reduce garbage		
Factor loading	0.37	0.97	0.05	0.07	0.09		
t-statistics (confidence level)	20.5***	23.9***	8.66***	4.45***	9.86***		
Destination accessibility	ln (Density)	ln (Distance to education center)	ln (Distance to business center)	ln (Distance to post office)	ln (Distance to cultural center)	ln (Distance to hospital)	ln (Distance to religious facility)
Factor loading	0.67	–0.03	–0.22	–0.17	–0.11	–0.08	–0.10
t-statistics (confidence level)	31.0***	-6.31***	-23.3***	-19.5***	-16.1***	-12.9***	-13.9***
Preference on accessibility	To school	To workplace	To community service facility	Availability of public transport			
Factor loading	0.06	0.06	0.19	0.60			
t-statistics (confidence level)	5.24***	4.68***	12.2***	14.3***			

Note: ***, **, and * denote significance at the 99.5%, 99%, and 95% confidence levels, respectively.

TABLE 4 Total Impact of Variables on Gasoline Consumption

Destination accessibility	ln (Access time to bus stop)	Number of children	Number of adults	ln (Income)	Number of motorbikes	Concern about environmental issue	Eco-friendly actions	Preference on accessibility
–0.13	0.13	–0.05	0.13	0.43	0.39	0.03	–0.06	–0.05

Model Estimation Results: Data from Inheritance and Noninheritance Subgroups

TABLE 5 shows the estimation results from using the household gasoline consumption model with the inheritance subgroup data; TABLE 6 shows the same results, albeit with the noninheritance subgroup data. The models are estimated using the simultaneous multi-group estimation method. The same variables as those used in the earlier model with the pooled data are incorporated therein. Note that the factor loadings of latent variables are fixed, so that they would be the same as those shown in TABLE 3.

First, for both subgroups, destination accessibility has a positive impact on concern about environmental issues; however, its impact is significant only in the noninheritance subgroup. This is simply because individuals who have chosen to reside in a residence with good accessibility are more concerned about living conditions than those who did not make that choice.

Second, the results show that for both subgroups, destination accessibility has a negative impact on the number of motorbikes; however, its impact is significant only in the noninheritance subgroup. This indicates that destination accessibility influences motorbike ownership among those who chose their place of residence themselves, but not among those who inherited their residence from their parents. (Recall that earlier analysis with pooled data showed that higher accessibility discourages individuals from owning motorbikes.)

Third, the results show that better accessibility significantly reduces household gasoline consumption in the noninheritance subgroup, but that this is not the case in the inheritance subgroup. Note that earlier analysis showed that better accessibility reduced household gasoline consumption. These results indicate that the preference on accessibility significantly reduces household gasoline consumption in the noninheritance subgroup, but not in the inheritance subgroup.

Fourth, the results show that for both subgroups, accessibility to a bus stop has a significant effect on household gasoline consumption. Its impact is more significant in the inheritance subgroup than in the noninheritance subgroup. We determined by executing a t-test that the difference of coefficient is significantly valid at the 95% confidence level. This may indicate that a shorter access time to a bus stop would encourage bus use among those who did not choose their residence, and thus lead to less vehicle use and less gasoline consumption. A possible reason for this is that individuals who did not choose their residence reside so far from a bus stop that the marginal effect of reducing the access time to a bus stop is comparatively larger; meanwhile, individuals who chose their residences reside so close to a bus stop that the marginal effect of reducing the access time to a bus stop is smaller.

DISCUSSION

First, the results of our analysis show that the built environment has an impact on household gasoline consumption, even when the residential self-selection effect is accounted for. Two built-environment variables—namely, destination accessibility and access time to nearest bus stop—significantly influence household gasoline consumption, incorporating the preference on accessibility variable. This may imply that the impact of residential self-selection is not overly prevalent in the context of the Jakarta Metropolitan Area. However, it should be noted here that looking at the total impact, household income had the most dominant effect on household gasoline consumption. This may be a characteristic of developing cities, as Zegras (*27*) also found in a study based in Santiago, Chile that income was the dominant factor for travel behavior.

Second, the results show that the effect of destination accessibility on gasoline consumption is significant in the noninheritance subgroup, but less so in the inheritance subgroup. Note here that the population density variable has the largest contributor for destination accessibility variable. This could be an implication that improvements to accessibility, or more specifically enhancement of population density in traditional residential areas may have less of an impact in reducing household gasoline consumption than those in newly developed residential areas.

Third, the results also indicate that for both subgroups, the access time to a bus stop does have a significant effect on reducing household gasoline consumption. This means that the introduction of a bus stop near to residential areas would induce people to use buses rather than private vehicles, thus reducing gasoline consumption. This may support a transportation strategy to provide a dense public transportation network. It should be noted that improving access to bus stops reduces household gasoline consumption more in the inheritance subgroup than in the noninheritance subgroup; this implies that improving accessibility to bus stops—for example, by increasing the density of the bus network—would be more effective in traditional residential areas in terms of reducing gasoline consumption than in newly developed residential areas. However, in this study, access time to bus stop was the only variable that represent the availability of bus services. Incorporating other variables such as frequency of the bus service could help to draw more useful implications regarding on the impact of public transportation system.

Finally, the results reveal that attitude toward eco-friendly actions has a significant effect on reducing household gasoline consumption. Voluntary actions made by people to protect the environment have been recently highlighted as helping to mitigate environmental degradation (*28*). These results imply that the promotion of environmentally friendly activities—for example, through education-based initiatives—could help encourage people to take up more voluntary actions that may lead to reduced household gasoline consumption.

TABLE 5 Estimation Results in the Inheritance Subgroup (N = 384)

	Endogenous variables				
	Gasoline consumption	Ownership of motorbikes	Attitude toward eco-friendly actions	Concern about environmental issue	Destination accessibility
	Std. Coeff. (t-statistic)	Std. Coeff. (t-statistic)	Std. Coeff. (t-statistic)	Std. Coeff. (t-statistic)	Std. Coeff. (t-statistic)
Built environment					
ln (access time to bus stop)	0.17 (3.99***)	–0.01 (–0.13)	0.01 (0.10)	–0.01 (–0.19)	
Destination accessibility	–0.04 (–0.97)	–0.08 (–1.70)	0.12 (2.24*)	0.07 (1.31)	
Household sociodemographics					
Number of adults in a household	0.01 (0.75)	0.19 (4.16***)	0.07 (1.39)	–0.10 (–1.92)	–0.03 (–0.60)
Number of children in a household	– 0.08 (1.80)	–0.03 (–0.71)	–0.02 (–0.40)	–0.03 (–0.67)	–0.17 (–3.35***)
ln (Monthly income)	0.27 (5.43***)	0.43 (9.13***)	–0.01 (–0.14)	0.11 (2.06*)	0.22 (4.27***)
Vehicle ownership					
Number of motorbikes owned	0.37 (7.54***)				
Household Attitudes					
Attitude toward eco-friendly actions	–0.05 (–1.12)				
Concern about environmental issue		0.08 (1.80)	0.05 (1.01)		
Preference on accessibility	–0.04 (–0.90)				0.02 (0.42)

Note: ***, **, and * denote significance at the 99.5%, 99%, and 95% confidence levels, respectively.

TABLE 6 Estimation Results in Noninheritance Subgroup (N = 564)

	Endogenous variables				
	Gasoline consumption	Ownership of motorbikes	Attitude toward eco-friendly actions	Concern about environmental issue	Destination accessibility
	Std. Coeff. (t-statistic)	Std. Coeff. (t-statistic)	Std. Coeff. (t-statistic)	Std. Coeff. (t-statistic)	Std. Coeff. (t-statistic)
Built environment					
ln (access time to bus stop)	0.07 (2.32*)	0.04 (1.10)	0.00 (–0.06)	–0.06 (–1.40)	
Destination accessibility	–0.07 (–2.10*)	–0.10 (–2.75***)	0.08 (1.89)	0.15 (3.60***)	
Household sociodemographics					
Number of adults in a household	0.07 (1.94)	0.16 (4.39***)	0.04 (0.96)	0.00 (–0.08)	–0.11 (–2.52*)
Number of children in a household	–0.06 (–1.73)	–0.02 (–0.53)	0.04 (0.89)	–0.05 (–1.22)	–0.11 (–2.76**)
ln (Monthly income)	0.29 (7.64***)	0.48 (13.1***)	–0.07 (–1.67)	0.03 (0.72)	0.15 (3.51***)
Vehicle ownership					
Number of motorbikes owned	0.41 (10.8***)				
Household Attitudes					
Attitude toward eco-friendly actions	–0.07 (–2.08*)				
Concern about environmental issue		0.00 (–0.05)	0.20 (4.78***)		
Preference on accessibility	–0.07 (0.03)				-0.02 (-0.42)

Note: ***, **, and * denote significance at the 99.5%, 99%, and 95% confidence levels, respectively.

CONCLUSIONS

This study empirically analyzed the impact of the built environment on household gasoline consumption in the Jakarta Metropolitan Area, using data that were captured through an interview-based survey and keyed to a GIS database. The SEM modeling approach was applied to investigate the association between various influential factors—including the built environment, household sociodemographics, vehicle ownership, attitude toward eco-friendly actions, and concern about the environment—and gasoline consumption. Two approaches were used in the empirical analysis. The first was a model estimation that used pooled data; the second was model estimation using two subgroup datasets. The main findings derived from the first analysis are summarized thus: (1) the built environment (such as accessibility of residence to various facilities) has an effect on household gasoline consumption, even when the residential self-selection effect is accounted for, and (2) the attitudes of residents—most importantly, those toward eco-friendly actions—have a negative effect on household gasoline consumption. The second analysis compared the impacts of built-environment factors on household gasoline consumption, between two sample subgroups: one subgroup contained respondents who had chosen their residence themselves, while the other contained respondents who had inherited their residence from their parents. The results suggest that the effect of the built environment varies between these two subgroups, and this implies that between them, land-use policies that improve accessibility within traditional residential areas would contribute less significantly to controlling gasoline consumption. The results also suggest that accessibility to bus stops has a more significant influence on gasoline consumption among those who had inherited their residence than those who personally chose their current residence. This implies that improving public transportation access in traditional residential areas may contribute less significantly to reducing gasoline consumption than would be the case in newly developed areas.

A number of issues can be fruitfully addressed in future research. First, this study used cross-sectional data, making it impossible to confirm true causality. To sufficiently identify causality, one would need to use longitudinal data, in which the same sample is tracked over several time periods. Second, while this study successfully determined that the impact of the built environment on travel behavior is significant, even when the mediating effect of residential self-selection is taken into account, it did not deeply examine the extent to which residential self-selection influences individual travel behavior. Further research could address these limitations.

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