VU Research Portal

DOES URBAN FORM AFFECT MOTORCYCLE USE? EVIDENCE FROM YOGYAKARTA, INDONESIA

Fevriera, Sotya; de Groot, Henri L.F.; Mulder, Peter

published in

Bulletin of Indonesian Economic Studies
2021

DOI (link to publisher)

[10.1080/00074918.2020.1747595](https://doi.org/10.1080/00074918.2020.1747595)

document version

Publisher's PDF, also known as Version of record

document license

Article 25fa Dutch Copyright Act

[Link to publication in VU Research Portal](#)

citation for published version (APA)

Fevriera, S., de Groot, H. L. F., & Mulder, P. (2021). DOES URBAN FORM AFFECT MOTORCYCLE USE? EVIDENCE FROM YOGYAKARTA, INDONESIA. *Bulletin of Indonesian Economic Studies*, 57(2), 203-232. <https://doi.org/10.1080/00074918.2020.1747595>

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal ?

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

E-mail address:

vuresearchportal.ub@vu.nl

Does Urban form Affect Motorcycle Use? Evidence from Yogyakarta, Indonesia

Sotya Fevriera, Henri L.F. de Groot & Peter Mulder

To cite this article: Sotya Fevriera, Henri L.F. de Groot & Peter Mulder (2021) Does Urban form Affect Motorcycle Use? Evidence from Yogyakarta, Indonesia, *Bulletin of Indonesian Economic Studies*, 57:2, 203-232, DOI: [10.1080/00074918.2020.1747595](https://doi.org/10.1080/00074918.2020.1747595)

To link to this article: <https://doi.org/10.1080/00074918.2020.1747595>

View supplementary material

Published online: 17 Aug 2021.

Submit your article to this journal

Article views: 188

View related articles

View Crossmark data

Citing articles: 2 View citing articles

DOES URBAN FORM AFFECT MOTORCYCLE USE? EVIDENCE FROM YOGYAKARTA, INDONESIA

Sotya Fevriera*

Satya Wacana Christian University

Henri L.F. de Groot

Vrije Universiteit Amsterdam

Peter Mulder

TNO Energy Transition Studies

Motorcycles dominate urban road traffic across Asia. We analyse how urban form influences preferences for motorcycle use, using a multinomial logistic regression model and data from a recent field study in the metropolitan area of Yogyakarta. We find that urban form explains about 20% of the observed variance in transport mode choice and that population density has a statistically significant positive effect on the likelihood of using a motorcycle for commuting. In addition, we find that the likelihood of choosing a motorcycle over other transport modes is highest for individuals living at intermediate distances from the city centre and that, in comparison with other transport modes, motorcycle use is most sensitive to travel distance. Our results suggest that a compact urban form, including a high population density and short commuting distances, may help in reducing the growth of motorcycle use in urban areas.

Keywords: commuting, Indonesia, motorcycle, population density, traffic, transport choice, urban form

JEL classifications: C25, R29, R41

INTRODUCTION

To what extent does urban form influence preferences for the use and ownership of motorcycles? Almost 80% of the world's motorcycles are found in Asia (ITF 2008). Across most of the region, the number of motorcycles is much higher than the number of passenger cars in urban road traffic (see table 1). The popularity of motorcycles can be explained by their low prices and maintenance costs, their ease of parking, their high average speeds in congested cities (Hsu, Dao and Sadullah 2003) and their suitability for use in the Asian climate, compared with cars.

However, the intensive use of motorcycles in urban areas comes at a cost. Road transport is a major source of energy-related nitrogen oxide emissions and primary particulate matter. Because cities are concentrations of people, economic activity, energy use and traffic, they tend to experience the most harmful concentrations

*Corresponding author. Email: sotya.fevriera@uksw.edu

TABLE 1 *Motorcycle Statistics for Asian Countries*

Country	No. of motorcycles per 1,000 people ^{1,2}	No. of motorcycles as % of total vehicles ¹	Households that own a motorcycle (%) ³
Vietnam	422	95	86
Malaysia	373	47	83
Indonesia	345	83	85
Thailand	286	59	87
Japan	94	13	21
India	92	72	47
China	69	38	60
Philippines	43	55	32
South Korea	43	9	9
Pakistan	31	61	43
Bangladesh	9	64	18

Note:

¹The number of motorised two- and three-wheelers and total number of registered vehicles (WHO 2015).

²Population is derived from the World Development Indicators (World Bank 2016).

³Percentage of households that owned a motorcycle or scooter in 2014 (Pousther 2015).

Data years for ¹ and ² are 2012 and 2013, except for Pakistan (2011) and Bangladesh (2014).

of air pollution. Each year, more than six million deaths can be attributed to air pollution, which, according to the World Health Organization (WHO), is a figure much higher than the number of deaths from HIV/AIDS, tuberculosis and road injuries combined (Hutt and Breene 2016). In urban areas, individual exposure to vehicle-generated pollutants is often higher on average than exposure to other sources, because emissions from pipes or road vehicles are close to the ground and thus close to people (IEA 2016). Many governments in Asian countries have therefore encouraged people to reduce their use of private motorised vehicles and to switch to public transport or non-motorised transport. Nevertheless, the dominance of motorcycles in urban road traffic across Asia is likely to continue for the foreseeable future, given the leading role of Asia in contemporary urbanisation and GDP growth trends. After all, an increase in GDP implies that motorcycles become affordable for more urban households that depend on non-motorised or public transport. At present, low- and middle-income countries in Asia account for most of the growth in global GDP, and by 2050, Asia is expected to produce more than 50% of the world's total urban population—with the total urban population in 2050 forecast to be larger than the entire global population today (UN 2015).

Many studies on transport mode choice have considered the urban form as a relevant explanatory variable (Asensio 2002; Dieleman, Dijst and Burghouwt 2002; Bento et al. 2005; Limtanakool, Dijst and Schwanen 2006; Buehler 2011; Clark, Chatterjee and Melia 2016; Sun, Ermagun and Dan 2017) because compact urban areas may reduce the use of private motorised vehicles, given that a high urban density implies shorter travel distances from homes to workplaces, schools or shopping areas, and better conditions for governments to provide good public

transport facilities (Dieleman and Wegener 2004; Neuman 2005). Some studies have indeed found that population density or population size has a statistically significant negative effect on the energy consumption or emissions attributable to transport (Newman and Kenworthy 1989; Banister, Watson and Wood 1997; Mindali, Raveh and Salomon 2004; Glaeser and Kahn 2010).

Most of these studies analyse cities in Europe or the United States and thus have focused on factors that affect preferences for owning and using private cars rather than using public transport (bus and/or train) and/or non-motorised transport (cycling and/or walking) (van Vugt, van Lange and Meertens 1996; Asensio 2002; Dieleman, Dijst and Burghouwt 2002; van Wee, Holwerda and van Baren 2002; Bento et al. 2005; Limtanakool, Dijst and Schwanen 2006; Buehler 2011; Clark, Chatterjee and Melia 2016; Heinen 2016). In addition, preferences for motorcycle use have been studied from a mode-choice perspective (Sheikh et al. 2006; Chen and Lai 2011; Irawan and Sumi 2011b; Putra 2013; Liu, Yun and Liu 2016; Marquet and Miralles-Guasch 2016). However, to the best of our knowledge, in these studies, the role of urban form in explaining motorcycle use in Asia has been underexplored. We help to fill this gap by studying how urban form influences preferences for the use of motorcycles in an Asian urban area, relative to other transport modes. To achieve this, we conducted a field study in the metropolitan area of Yogyakarta in Indonesia, part of Yogyakarta province (DI Yogyakarta). As does most of the existing literature on transport mode choice, we controlled for travellers' personal and household characteristics, travel characteristics (for example, travel distance and travel frequency), and type of travel activity or purpose of travel activity.

Our study relates to several studies on commuting behaviour in Indonesia. Most have described the characteristics of commuters and their travel behaviour (Leinbach and Suwarno 1985; Sitanala 2005; Bandonio 2010; Ismardani 2010; Batti 2011; Adhi 2012; Ansusanto et al. 2014; Pebrian and Rakhmatulloh 2013; BPS 2015b, 2015c). To the best of our knowledge, only the studies by Irawan and Sumi (2011a, 2011b), Yagi, Nobel and Kawaguchi (2012, 2014) and Putra (2013) explicitly examine the factors that affect transport modes, while only Yagi, Nobel and Kawaguchi (2012, 2014) assess the factors that influence car or motorcycle ownership. The latter two studies were also carried out in DI Yogyakarta. In investigating the factors that influence preferences for transport modes, Irawan and Sumi (2011a, 2011b) focused on the commuting behaviour of students, whereas Putra (2013) focused on the commuting behaviour of workers. We capture not only commuting behaviour for work and study activities but also travel for shopping and other regular activities such as leisure.

The structure of this article is as follows. In section 2, we discuss in more detail the potential role of urban form in determining transport mode choice, based on a review of the literature. Section 3 presents our data and regression methodology. Section 4 provides the results of our regression analyses. In section 5, we discuss the regression results. Section 6 concludes.

URBAN FORM AND TRANSPORT MODE CHOICE

The classic bid-rent model by Alonso (1960) predicts the existence of a trade-off between house prices and commuting costs: house prices fall with distance between homes and workplaces to compensate for the costs involved with longer commutes.

Households choose their location such that they maximise their utility, given this trade-off and given their budget constraints (Neuman 2005). As a result, commuters from high-to-medium-income households tend to live relatively near to city centres and have shorter commutes, whereas commuters from medium-to-low-income households tend to live farther away from city centres and have longer commutes. However, according to Glaeser, Kahn and Rappaport (2008), in the United States, poor people tend to live near or in city centres because they depend on public transport, which is more available in these centres, whereas wealthy people who can afford cars can live farther away from city centres.

In Indonesia, high-income people may also look for homes in peri-urban areas because it is difficult to find homes around city centres, especially if the homes are large or on sizeable land. Land prices around city centres, which are high and increasing (Suparmono 2012; Elmanisa et al. 2017), are hard to afford for people with low-medium incomes. Commuters with low-medium incomes who live far from city centres may choose to travel by motorcycle, which is suitable for long or medium travel distances and feasible given their budgets.

In addition, several factors deter people in Indonesia from using public transport or walking to get to work. In many cities or regencies in the country, the quality of public transport is poor both in terms of facilities and travel time reliability. The hot weather during the dry season and the heavy rain during the wet season often discourage people from walking to a place where they can access public transport. The same reasons deter commuters from walking to work. In addition, sidewalks are usually available beside relatively big roads, not small roads. And some parts of the sidewalks are often used by informal merchants for trade. For these reasons, online-based transport platforms have grown rapidly in recent years and are now very popular: people can easily order motorcycles or cars online to their homes in order to travel to workplaces, schools or shops. Of course, this development creates employment opportunities for minimum-wage workers who wish to supplement their incomes by part-time driving for these platforms (LD FEB UI 2019). At the same time, this development contributes to congestion because the involved motorcycles and cars often stop or park in inappropriate places (Pratama 2019).

Many studies have found that population density has a positive effect on the use of public transport and non-motorised transport (Asensio 2002; Limtanakool, Dijst and Schwanen 2006; Buehler 2011; Clark, Chatterjee and Melia 2016; Sun, Ermagun and Dan 2017). However, Bento et al. (2005) found that population density increases the likelihood of having one or two cars. An increase in population density of 1% increases the probability of having one or two cars by 0.1% and 0.15%, respectively. Bento et al. (2005) also found that a 1% increase in population density reduces the probability of commuters taking the bus by 2.7%.

In general, there is a relatively strong negative correlation between population density and distance from the home to the city centre (Muñiz and Galindo 2005; Larson and Yezer 2015). Thus, distance from the home to the city centre should have the opposite effect on transport mode choice to population density. Among the studies on transport mode choice that we reviewed, we found only one that examined a variable similar to distance from the home to the city centre. Sun, Ermagun and Dan (2017) discovered that distance from the home to the primary office complex in the city has a positive impact on preferences of people for travelling by car rather than by other transport modes.

Dieleman, Dijst and Burghouwt (2002), and Clark, Chatterjee and Melia (2016), found evidence that the type of residential area in which people live influences their transport mode choice. For the Netherlands, Dieleman, Dijst and Burghouwt (2002) found that, compared with people who live in one of the three largest cities of the country, people who live in other areas have a higher probability of travelling by car, cycling or walking than of using public transport. Limtanakool, Dijst and Schwanen (2006) obtained similar results. People who live in suburban or less urbanised areas in the rest of the Netherlands are more likely to travel by car than train. In the United Kingdom, Clark, Chatterjee and Melia (2016) showed that, compared with commuters who live in rural areas, those who live within either inner or outer London have a lower probability of travelling by car, cycling or walking, but commuters who live in urban areas have a higher likelihood of cycling or walking.

Distance from the home to a public transport stop can be used as a rough proxy for government policy on transport (Buehler 2011). The longer the distance to public transport, the more reluctant people tend to be to use public transport and the more interested they tend to be in using private vehicles. In Spain, Asensio (2002) found that greater distance from the home to public transport access increases the likelihood of using a car instead of public transport. For the United States, Buehler (2011) attained a similar result but only when the distance from the home to public transport was between 400 and 1,000 metres. When the distance from the home to a public transport stop or station is less than 400 metres, travellers are most likely to walk. He found a similar result for Germany, where the distance from the home to a public transport stop is up to 1,000 metres.

METHODOLOGY AND DATA

To study how the urban form influences people's preferences for the use of motorcycles, we employ a multinomial logistic (MNL) regression model as follows:

$$\ln \left(\frac{P_{iml}}{P_{kml}} \right) = \alpha_{0im} + \alpha_{1im} X_{1iml} + \alpha_{2im} X_{2iml} + \alpha_{3im} X_{3iml} + \alpha_{4im} X_{4iml} \quad (1)$$

where P_{iml} is the probability that traveller l chooses transport mode i (bus, car, bicycle or walking) for activity m (commuting or leisure); P_{kml} is the probability that traveller l chooses transport mode k (motorcycle) for activity m ; X_{1iml} is a set of household characteristics of traveller l using transport mode i for activity m ; X_{2iml} is a set of travel activities of traveller l using transport mode i for activity m ; X_{3iml} is a set of travel characteristics of traveller l using transport mode i for activity m ; X_{4iml} is a set of urban form variables in the living area of traveller l using transport mode i for activity m ; α_0 is a constant; and α_{1im} , α_{2im} , α_{3im} and α_{4im} are the regression coefficients.

The household characteristics (X_1) are the percentage of female household members, the average age of household members, the average education level attained by household members, the average income of household members, the household size, the number of young children (younger than 7 years old) in the household, the number of older children (7–16 years old) in the household, the number of motorcycles or cars owned by the household and the number of bicycles owned

by the household. The travel activities (X_2) are work, study and shopping. The travel characteristics (X_3) include travel distance and travel frequency for commuting and leisure activities. The urban form (X_4) is described by distance from the home to the city centre, population density in the district where a household lives,¹ whether a household lives in an urban area, whether a household lives in a rural area, distance from the home to the closest or most accessible public transport station, and distance from the home to the closest or most accessible fuel station.

In the next section, we present the results of this MNL regression in terms of the relative risk ratio (RRR) and marginal effects. The RRR is defined as $e^{\alpha_{tim}}$ where $t = 1, 2, 3, 4$, with α_{tim} being the regression coefficient obtained from equation (1). When 'motorcycle' is the reference category, the RRR value shows the ratio of the probability that transport mode i will be preferred relative to the probability that the motorcycle (k) will be preferred. An RRR that is lower than 1 represents a negative effect of the explanatory variable. An increase in the explanatory variable by 1 unit increases the RRR by $(1 - \text{RRR}) \times 100\%$, keeping other variables constant. On the other hand, an RRR that is higher than 1 represents a positive effect of the explanatory variable. An increase in the explanatory variable by 1 unit decreases the RRR by $(\text{RRR} - 1) \times 100\%$, keeping other variables constant.

In the MNL regression, if other explanatory variables are held constant, the marginal effect for transport mode category m demonstrates the average probability that a traveller uses transport mode category m or k if an explanatory variable increases by one unit. For a dummy variable, the marginal effect shows the change in the probability that a traveller uses transport mode category m if the criterion in the dummy variable is fulfilled.

Our regression analysis is based on the results from a field study on energy consumption and travel behaviour, conducted in 2016 in the metropolitan area of Yogyakarta. Situated on the island of Java, the Special Region of Yogyakarta (DI Yogyakarta) has an estimated population of 3.7 million and a population density of 1,188 inhabitants per square kilometre (table 2a) (BPS 2017).² The urban area features more than 900 registered motorcycles per 1,000 people, which is the second-highest rate in Java (after DKI Jakarta) and about 10 times more than the number of registered passenger cars (see table 2b). Because we aim to study the effect of urban form on transport mode choice, we exclude from our sample the households that live in rural areas of DI Yogyakarta. We differentiate residential areas into urban and peri-urban areas. BPS (2015a) classifies urban areas as big and medium cities and peri-urban areas as small cities.

We surveyed 823 households in the areas of Yogyakarta city, Sleman regency and Bantul regency (see figure 1). Those three areas were chosen because of their urban character, defined in terms of a relatively high population density as well as a high per capita GRDP (see table A1 in the online appendix). As in much of

1. A city or regency consists of administrative areas called districts.

2. DI Yogyakarta consists of Yogyakarta city, Sleman regency, Bantul regency, Kulon Progo regency and Gunung Kidul regency. The research was conducted in Yogyakarta city and two regencies that surround Yogyakarta city: Sleman and Bantul. The total population and population density were calculated for the research area. Yogyakarta city and some districts in Sleman and Bantul are also known as the Yogyakarta Urban Agglomeration (figure 1).

TABLE 2a *Population, Density and Gross Regional Domestic Product (GRDP), 2016*

Province	Population (1,000)	Population density (people/km ²)	Per capita GRDP (Rp million)
DI Yogyakarta	3,721	1,188	29.6
DKI Jakarta	10,278	15,478	211.8
West Java	47,379	1,341	34.9
Central Java	34,019	1,037	32.1
East Java	39,075	817	47.5
Banten	12,203	1,263	42.3

Note: Data are from Statistics Indonesia (BPS 2017). DI Yogyakarta = Special Region of Yogyakarta. DKI Jakarta = Special Capital Region of Jakarta.

TABLE 2b *Private Motor Vehicles across Java Island*

Province	Motorcycle- to-car ratio (2016)	Registered private motor vehicles per 1,000 people			
		Motorcycles (no. in 2016)	Cars (no. in 2016)	Growth in motorcycles (%, 2005–16)	Growth in cars (%, 2005–16)
DI Yogyakarta	10.1	923	92	25.1	28.1
DKI Jakarta	4.0	1,438	363	91.1	52.4
West Java	6.2	177	29	100.0	96.3
Central Java	12.6	402	32	57.4	95.0
East Java	9.6	346	36	43.1	33.8
Banten	15.6	203	13	210.0	61.1

Note: Data on the number of registered private motor vehicles for 2016 are from Statistics Indonesia (BPS 2017). Data on the number of registered private motor vehicles for 2005 are from BPS (2009). The ratio of motorcycles to cars, the number of registered private motor vehicles per thousand people and the total growth were calculated by the authors. DI Yogyakarta = Special Region of Yogyakarta. DKI Jakarta = Special Capital Region of Jakarta.

Asia, the motorcycle is by far the dominant mode of urban transport in Yogyakarta Province: 95% of households in Yogyakarta own a motorcycle and almost 30% of households own more than two motorcycles. Motorcycles are the preferred transport mode for 66% of commuters in Yogyakarta.

In our survey, we employed the definition of commuting used by BPS (2015b). However, we modified the commuting characteristics as defined by Mantra (2000) and BPS (2015b) in several ways. First, we assumed that commuting activity is not limited or defined by administrative borders. Applying administrative borders is likely to lead to incorrect identification of commuters, depending on their travel route and location relative to the administrative border. Second, we did not assume that a commuter always returns home on the same day; rather, we assumed that the activity must be carried out within 24 hours. We defined the average commuting distance as the one-way travel distance from a household's residence to the

FIGURE 1 *Indonesia and Yogyakarta*

location of the main activity of a household member—assuming that the member follows the same route on the way home. In the survey, a commuter is defined as a household member who regularly travels to the location of their main activity (such as working, studying or shopping) and then returns home within 24 hours. The questionnaire is shown in the online appendix. For reasons of analytical tractability, we assumed that travellers use the same transport modes to travel to and from the location of their activity; we recorded only the dominant commuting activity in case multiple activities took place during the same trip (for example, working and escorting children to school); we included the job with the highest

travel frequency and the longest travel distance and time in case travellers had multiple jobs; and we included the main transport mode in case commuters made use of more than one transport mode.

Following other studies (Damayanti and Handinoto 2005; Sugiyanto et al. 2011; Utari 2015), we identified the Malioboro region in Yogyakarta as the city centre in order to measure distance from the home to the city centre. Typically, the city centre is the city area with a concentration of political power, cultural manifestations, historical sites, business and financial services, shopping facilities and entertainment. Distance between the home and the Malioboro region was estimated using Google Maps and the home address.

We employed both travel distance and travel frequency as travel characteristics in our analysis. We excluded travel time from the models, because some respondents could not estimate their travel time; in these cases, we had to estimate their travel time based on their travel distance, assuming a high correlation between the two variables. We did not differentiate the models of transport mode choice for commuting based on the purpose of travel. Instead, we included three types of commuting activity as explanatory variables—work, study and shopping activities—while using ‘other commuting activity’ as the reference category. Other commuting activity is a routine activity completed within 24 hours that cannot be classified as work, study or shopping. People whose activities fall into this category, for example, include persons who have retired and have routine exercise scheduled—including those who regularly undergo medical treatment, participate in group exercise for the elderly or travel to collect their pension money.

We also controlled in our analysis for distance from a person’s home to the nearest public transport and to the gasoline or diesel fuel station that they use most. Public transport stops include stops or stations for buses, pedicabs, taxis (motorcycle or car) and trains. Note that the number of people who use forms of public transport other than buses is limited. Also note that the most-used fuel station is not necessarily the nearest fuel station to the home.³ Studies have analysed how refuelling patterns determine gasoline demand (Nicholas 2010) and how they affect the choice between gasoline and natural gas (Kuby, Kelley and Schoenemann 2013). However, as far as we know, we are the first to use distance from the home to a fuel station as an explanatory variable to explain transport mode choice. The idea behind using the variable is that a shorter distance to a fuel station might discourage the traveller from commuting on public transport and encourage them to use a private motor vehicle instead.

In our regression models, income is represented by the average income of household members. The number of children per family is classified into two groups, based on age. The age category of younger children represents the general age of children who have not entered school and children who are in kindergarten (younger than 7 years old). The category of older children reflects the common age of students in primary school and middle school (aged 7–16 years old), who are capable of going to school independently (without being escorted by their parents).

3. Some respondents buy fuel from a station on the way to their destination, which is not necessarily the nearest station to their home.

TABLE 3 *Average Travel Distance and Energy Consumption, by Transport Mode*

Variable	Car	Bus	Motorcycle	Bicycle	Walking
Commuting					
Average travel distance per trip (km/person)	9.4	6.9	6.1	2.8	0.4
Observation	164	48	1,653	241	399
Distance travelled (by % of people):					
Very short: < 1 km	4.2	6.3	11.4	24.9	85.6
Short: 1–5 km	42.8	45.8	45.6	62.2	13.2
Medium: >5 to ≤ 10 km	22.9	25.0	24.5	7.9	
Long: >10 to ≤ 20 km	22.3	20.8	13.9	5.0	
Very long: >20 km	7.8	2.1	4.6		1.2
Total distribution	100.0	100.0	100.0	100.0	100.0
Average travel distance per month (km/person)	333.0	227.6	241.9	112.2	17.3
Observation	163	48	1,653	241	397
Total fuel consumption per month (toe)	4.8	0.3	18.5		
Observation	163	48	1,658		
Leisure					
Average travel distance per trip (km/person)	22.9	36.8	12.6	11.9	0.6
Observation	219	24	507	22	176
Distance travelled (by % of people):					
Very short: < 1 km	1.3		11.2	27.3	92.1
Short: 1–5 km	25.4	16.7	40.0	36.4	5.6
Medium: > 5 to ≤ 10 km	18.3	16.7	18.8	4.5	
Long: > 10 to ≤ 20 km	18.3	20.8	13.5	9.1	0.6
Very long: > 20 km	36.6	45.8	16.5	22.7	1.7
Total distribution	100.0	100.0	100.0	100.0	100.0
Average travel distance per month (km/person)	207.0	367.0	151.2	136.3	10.6
Observation	217	24	507	22	176
Total fuel consumption per month (toe)	3.2	0.2	1.9		
Observation	217	19	507		

Note: toe = tonnes of oil equivalent.

The upper bound of age for older children is the minimum age necessary to obtain a licence to ride a motorcycle in Indonesia.

We considered five modes of transport: bus, car, motorcycle, bicycle and walking. Other modes of transport were excluded from the models because data on them is produced too infrequently. Clearly, motorcycles are favoured (see table 3).

Before we present the results of our regression analysis, we document key descriptive statistics of our dataset, including correlations between key variables. In figure 2, we present the cross-district correlations between distance from the home to the city centre and, respectively, population density, income, commuting distance and travel distance for the leisure activities for DI Yogyakarta.

The figure shows a negative correlation between distance from the home to the city centre, and per capita income. Hence, people who live near the city centre tend to have a higher income, which also enables them to own a car. Figure 2c shows that people who live farther from the city centre tend to have longer commutes.

FIGURE 2 Relationships between the Distance (km) to the City Centre from the Home (x axis) and Travellers' Characteristics (y axis) across DI Yogyakarta

Note: ln = natural logarithm.

We can see that the rate of increase in commuting distance decreases as distance to the city centre increases. Travel time seems to matter more for commuters with long travel distances. Obviously, motorcycles are more suitable than cars for use on congested roads.

In figure 3, we show the correlations between population density and travellers' characteristics. The scatter plots show largely positive relationships between population density and income, education, commuting distance and distance to leisure activities. Hence, people who live in high-density areas tend to have higher education and a higher income (also see figure 4). People who live in high-density areas are also likely to have shorter distances for commuting to work and travelling for leisure activities. We can see that the commuting distance decreases in high-density areas. In figure 4, we show that people who are highly educated and have high income are inclined to have shorter distances for commuting to work and

FIGURE 3 Relationships between Population Density (x axis) and Travellers' Characteristics (y axis) across DI Yogyakarta

Note: Population density = the natural logarithm (ln) of people/km². Education level = the average education level attained by household members. Codes for education level in the survey: 1 = no schooling; 2 = not completed primary school; 3 = primary school (age 7–12); 4 = middle school (age 13–15); 5 = high school (age 16–18); 6 = diploma I/II; 7 = diploma III; 8 = diploma IV/bachelor degree; and 9 = master/doctoral degree.

travelling for leisure activities. This indicates that most of the centres for offices, schools, shopping and entertainment are located around the city centre.

To allow a better understanding of the effect of travel distance on transport mode choice, table 3 shows travel distances and fuel consumption, by type of activity and transport mode.

Table 3 shows that people who use bicycles, buses and motor vehicles tend to travel farther for leisure activities than for work. For commuting to work or travelling for leisure activities, people are likely to walk if the distances are very short (less than 1 kilometre). For commuting, based on the average travel distance per trip, bicycles are mostly used for short distances (1–5 kilometres), whereas motor-cycles, buses and cars are typically used for medium distances (5–10 kilometres).

FIGURE 4 Relationships between Per Capita Income (y axis) and Travellers' Characteristics (x axis) across DI Yogyakarta

Note: Per capita income = the natural logarithm (ln) of international dollars. Education level = the average education level attained by household members. Codes for education level in the survey: 1 = no schooling; 2 = not completed primary school; 3 = primary school (age 7–12); 4 = middle school (age 13–15); 5 = high school (age 16–18); 6 = diploma I/II; 7 = diploma III; 8 = diploma IV/bachelor degree; and 9 = master/doctoral degree.

For travelling for leisure activities, based on the average travel distance per trip, motorcycles and bicycles are preferred for long distances (10–20 kilometres), and buses and cars are typically used for very long distances, exceeding 20 kilometres.

Finally, our data reveal that the average distances between the city centre and the home in urban areas, peri-urban areas and rural areas are 5.5 kilometres, 11.3 kilometres and 17.3 kilometres, respectively. The distance from the home to a public transport stop influences transport mode preference. In our sample, the average distance from the home to a public transport stop for urban, peri-urban and rural areas is about 364 metres, 1 kilometre and 1.3 kilometres, respectively. Thus, in our study area, public transport is more accessible in urban areas than in peri-urban and rural areas.

Table A2 in the online appendix shows the summary statistics of all the variables used in the various regression models. Also, online appendix table A5 shows that most of the data values from our survey are close to data values from other sources, indicating that our survey yielded representative data.

RESULTS

In this section, we present the results for the regression models of transport mode choice, as introduced in the first part of section 3. Throughout all of the analyses, the explanatory variables consist of travellers' personal household characteristics, travel characteristics and some indicators of urban form (see tables 4–7). In certain models, we include only travellers' personal and household characteristics, without including income and household size. In other models, we add income and household size. We also include travel characteristics and some indicators of urban form in various models to show how they influence the effects of travellers' personal and household characteristics. The effects are relatively stable when those variables are added. Following Muñiz and Galindo (2005), we also include population density and distance from the home to the city centre in separate models, because the two variables strongly correlate. The results of those models are similar. Because population density and distance between the home and the city centre are negatively correlated, most of the effects of the distance between the home and the city centre work in the opposite direction to the effects of population density.

As described in section 3, to identify the role of urban form in preferences for the use of motorcycles, we employed a multinomial logistic (MNL) regression model. We present the results of this MNL regression in terms of the relative risk ratio (RRR) and marginal effects. In tables 4 and 5, we present the RRR of the preferences for using motorcycles for commuting and for travelling to leisure activities, respectively. Tables 6 and 7 contain the marginal effects for using motorcycles for commuting and for travelling to leisure activities, respectively. We include shopping as a commuting activity (Dieleman, Dijst and Burghouwt 2002) because, just like working and studying, it is usually a regular activity, such as for someone whose main activity is taking care of their home and children. Also, travel for shopping at certain traditional or modern markets is usually repeated daily, weekly or monthly (Andersson, Skoog and Svensson 2014, 1; Kunc et al. 2012).

In tables 4 and 5, the pseudo R^2 shows that travellers' personal and household characteristics can explain, respectively, about 23%–24% and 35%–37% of the variance in transport mode choice for commuting to work and for travelling to leisure activities. Including travel characteristics and the urban form increases the pseudo R^2 in the models for commuting to work and for travelling to leisure activities to 42% and 52%, respectively. Hence, the urban form and travel characteristics contribute substantially to explaining transport mode preferences. We continue by describing in detail the role of urban form and travel characteristics in determining transport mode choice. Please refer to the appendix for a detailed description of how travellers' personal and household characteristics affect their transport mode choices for commuting and leisure activities.

With regard to the role of the urban form and travel characteristics in transport mode choice, we first find that, compared with commuters who live in a peri-urban area, those who live in a rural area are more likely to walk than to use a

motorcycle (see model B1 in table 4). We also find that, for commuting, an increase in distance between the home and city centre decreases the probability of using a car and increases the probability of using a bicycle, relative to the probability of using a motorcycle (see model B1 in table 4). In other words, people who live near the city centre are more likely to travel by car than by motorcycle, and people who live far from the city centre are more likely to travel by bicycle than by motorcycle. However, the effect is not big. An increase of one kilometre in the distance between the home and city centre reduces the probability of driving a car by 0.26% and increases the probability of cycling by 0.18% (see model B5 in table 6). For travel to leisure activities, distance between the home and city centre has an insignificant effect on transport mode preference (model B3 in table 5 and model B7 in table 7).

In addition, we find that, for commuting, the urban or rural character of areas has no statistically significant effect on transport mode preference (see tables 4 and 6). For travel to leisure activities, however, we find that people who live in urban and rural areas are less likely to use a car than a motorcycle, compared with people who live in peri-urban areas (see models B3–4 in table 5). More precisely, compared with people who live in peri-urban areas, travellers who live in urban or rural areas have, respectively, a 3.5%–3.6% and 6.3%–6.6% lower probability of driving a car than a motorcycle (see models B7–8 in table 7). Travellers who live in a rural area have a 3.0%–3.5% higher probability of cycling relative to those who live in an urban area (see models B7–8 in table 7).

For commuting, we find that population density has a significant negative effect on the likelihood of cycling and walking, compared with motorcycling (see model B2 in table 4). A 1% decrease in population density decreases the likelihood of using a motorcycle by 0.035% and increases the probability of cycling by 0.024% (see model B6 in table 6). People who live in less dense areas tend to have lower incomes—our data show a positive correlation between population density and per capita income (see figure 3 and table A3). For travel for leisure activities, we find that population density has a negative significant effect on the probability of using a bus, compared with a motorcycle (see model B4 in table 5). A 1% denser area reduces interest in taking a bus by 0.0135% (see model B8 in table 7).

Our results also show that for commuting, distance from the home to a public transport stop has a statistically significant negative impact on the likelihood of using a bus and a statistically significant positive effect on the probability of using a car, compared with a motorcycle (see models B5–6 in table 6). An increase of one metre in the distance from the home to a public transport stop decreases the probability of using a bus by 0.001% and raises the probability of using a car by 0.0006% (see models B5–6 in table 6). Furthermore, for travel for leisure activities, we find that an increase in the distance between the home and a public transport stop increases the probability of riding a bicycle, compared with a motorcycle (see models B7–8 in table 7). An increase of one metre in the distance from the home to a public transport stop increases the probability of cycling by 0.0004%–0.0005% (see models B7–8 in table 7).

Distance from the home to a fuel station does not affect the transport mode choices of commuters. However, for people travelling for leisure activities, a longer distance between the home and a fuel station does decrease the chance of riding a bicycle rather than a motorcycle (see models B3–4 in table 5 and models B7–8 in table 7). Thus, a longer distance to a fuel station does not discourage these people

TABLE 4 *Relative Risk Ratios for Commuting Transport*

Explanatory variable	Model A1				Model A2			
	Transport mode (reference: motorcycle)				Transport mode (reference: motorcycle)			
	Bus	Car	Bicycle	Walking	Bus	Car	Bicycle	Walking
Female	3.543***	0.586**	1.048	2.130***	3.617***	0.563**	1.046	2.159***
Age	1.039***	1.031***	1.006	1.038***	1.038***	1.033***	1.006	1.037***
Education	0.753***	1.145**	0.521***	0.697***	0.753**	1.064	0.519***	0.714***
Income per capita (log.)					1.401*	2.159***	1.043	0.952
Household size					1.758***	1.179	1.188**	1.351***
No. of children <7 years old	1.075	0.954	0.533***	1.339***	0.681	1.021	0.458***	0.981
No. of children >7 years old	1.011	1.799***	1.122	1.197*	0.760	1.855***	1.012	0.967
Motorcycle owned	0.502***	0.567***	0.618***	0.692***	0.357***	0.541***	0.564***	0.591***
Car owned	0.972	8.288***	0.614**	0.876	0.795	5.913***	0.624*	0.920
Bike owned	1.061	0.981	0.614***	0.923	0.986	1.015	1.986***	0.883*
Constant	0.043***	0.014***	1.731*	0.395***	0.002***	0.000***	0.994	0.266**
Wald Chi ²		792.26***				840.18***		
Pseudo R ²		0.23				0.24		
N		2,502				2,502		

Explanatory variable	Model B1				Model B2			
	Transport mode (reference: motorcycle)				Transport mode (reference: motorcycle)			
	Bus	Car	Bicycle	Walking	Bus	Car	Bicycle	Walking
Female	3.139***	0.531**	0.832	1.422**	3.158***	0.535**	0.839	1.442**
Age	1.054***	1.028**	1.056***	1.030***	1.054***	1.027***	1.056***	1.031***
Education	0.765***	1.005	0.651***	0.792***	0.771**	1.023	0.654***	0.800***
Income per capita (log.)	1.379	1.902***	1.130	1.055	1.430*	1.969***	1.161	1.070
Household size	1.830***	1.205	1.289**	1.318***	1.844***	1.228*	1.311***	1.333***
No. of children <7 years old	0.579	0.977	0.448***	0.735*	0.577	0.923	0.445***	0.726**
No. of children >7 years old	0.736	2.006***	0.925	0.941	0.725	2.041***	0.892	0.921
Motorcycle owned	0.309***	0.524***	0.532***	0.670***	0.305***	0.525***	0.526***	0.655***

TABLE 4 *Continued*

Explanatory variable	Model B1				Model B2			
	Transport mode (reference: motorcycle)				Transport mode (reference: motorcycle)			
	Bus	Car	Bicycle	Walking	Bus	Car	Bicycle	Walking
Car owned	0.517	6.799***	0.590**	1.021	0.515	6.698***	0.588**	1.014
Bike owned	1.062	1.007	2.041***	0.905	1.063	0.964	2.062***	0.910
Distance to city centre	1.004	0.933**	1.029*	1.010				
Population density (log.)					0.743	1.073	0.638***	0.769**
Residing in urban area	0.828	0.675	0.757	1.123	0.893	0.825	0.788	1.187
Residing in rural area	0.585	0.892	1.374	1.610*	0.491	0.724	1.196	1.388
Distance to pub. trans. ¹	0.999**	1.000**	1.000	1.000	0.999**	1.000**	1.000	1.000
Distance to fuel station ²	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Travel distance	1.063***	1.041***	0.870***	0.159***	1.058***	1.036***	0.865***	0.160***
Travel frequency	0.775**	0.750***	1.044	0.933	0.779***	0.745***	1.056	0.943
Travel for work	0.737	0.669	3.321	1.715	0.769	0.660	3.580	1.809
Travel for study	3.267	0.362	40.154***	2.202	3.512	0.368	44.661***	2.463
Travel for shopping	1.264	0.371*	6.452*	3.017**	1.273	0.370*	7.013*	3.181**
Constant	0.004***	0.004***	0.006***	0.823	0.038**	0.001***	0.217	6.065
Wald chi ²		849.30***					816.53***	
Pseudo R ²		0.42					0.42	
N		2,440					2,440	

Note: In model A1, we include only travellers' personal and household characteristics, without including income and household size. In models A2, B1 and B2, we include income per capita and household size. In models B1 and B2, we also include travel characteristics and some indicators of urban form to show how they influence the effects of travellers' personal and household characteristics. Lastly, in model B1, we include distance from the home to the city centre, while in model B2, we include population density. We did this because there is a strong correlation between distance from the home to the city centre and population density. By separating the two variables, we can see that other effects are relatively stable, while distance from the home to the city centre has the opposite effect to that of population density. Robust standard errors are not displayed. Ratios are calculated using multinomial logistic regression.

¹ Distance to a public transport station. ² Distance to the most-frequently visited fuel station.

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

TABLE 5 *Relative Risk Ratios for Transport to Leisure Activities*

Explanatory variable	Model A3				Model A4			
	Transport mode (reference: motorcycle)				Transport mode (reference: motorcycle)			
	Bus	Car	Bicycle	Walking	Bus	Car	Bicycle	Walking
Female	1.817	0.901	0.625	2.565***	1.844	0.923	0.680	2.689***
Age	1.017	1.008	1.032**	1.043***	1.017	1.013	1.033**	1.042***
Education	0.965	1.091	0.812	0.735***	0.902	1.055	0.831	0.780***
Income per capita (log.)					1.885*	1.466*	0.728	0.559***
Household size					1.028	0.847	0.687*	0.937
No. of children <7 years old	1.334	3.933***	1.154	1.313	1.717	4.983***	1.457	1.168
No. of children >7 years old	1.090	3.092***	1.219	1.776***	1.253	3.786***	1.348	1.547***
Motorcycle owned	0.328***	0.479***	0.690*	0.773***	0.308***	0.542***	0.860	0.858
Car owned	2.478	63.917***	1.398	1.562	1.755	55.486***	1.628	2.133**
Bike owned	0.550*	1.227	1.689***	1.015	0.598*	1.268	1.813***	1.017
Constant	0.163*	0.018***	0.039***	0.187***	0.005**	0.002***	0.365	3.841
Wald Chi ²		310.73***				353.34***		
Pseudo R ²		0.35				0.37		
N		962				962		

Explanatory variable	Model B3				Model B4			
	Transport mode (reference: motorcycle)				Transport mode (reference: motorcycle)			
	Bus	Car	Bicycle	Walking	Bus	Car	Bicycle	Walking
Female	2.216*	0.803	0.605	2.153***	2.270*	0.804	0.627	2.188***
Age	1.012	1.010	1.027*	1.029***	1.013	1.009	1.026	1.029***
Education	0.867	1.172**	0.825	0.903	0.861	1.179**	0.828	0.903
Income per capita (log.)	2.067*	1.292	0.672	0.619***	2.049*	1.297	0.667	0.631***
Household size	1.125	0.727*	0.652*	0.839	1.129	0.726*	0.676*	0.851
No. of children <7 years old	1.803	4.445***	1.793	1.279	1.971	4.435***	1.860	1.325
No. of children >7 years old	0.637	4.515***	1.320	1.584***	0.571	4.664***	1.232	1.612***
Motorcycle owned	0.279***	0.560***	0.936	0.877	0.283***	0.566***	0.927	0.863
Car owned	1.936	81.042***	2.124	2.086*	1.732	83.808***	2.058	2.070*
Bike owned	0.637	1.202	1.898***	1.034	0.640	1.177	1.866***	1.009

TABLE 5 *Continued*

Explanatory variable	Model B3				Model B4			
	Transport mode (reference: motorcycle)				Transport mode (reference: motorcycle)			
	Bus	Car	Bicycle	Walking	Bus	Car	Bicycle	Walking
Distance to city centre	1.068	0.974	1.030	0.979				
Population density (log)					0.483**	1.160	0.520	0.919
Residing in urban area	0.884	0.506*	1.781	1.014	0.948	0.531*	2.173	1.144
Residing in rural area	0.366	0.284**	4.706**	1.113	0.386	0.290*	3.718*	0.959
Distance to pub. trans. ¹	1.000	1.000	1.000***	1.000	1.000	1.000	1.000***	1.000
Distance to fuel station ²	1.000	1.000	1.000***	1.000	1.000	1.000	0.999***	1.000
Travel distance	1.037***	1.029***	0.991	0.403*	1.036***	1.029***	0.992	0.406*
Travel frequency	1.089	0.420***	1.261	1.089	1.103	0.416***	1.263	1.100
Constant	0.002**	0.016**	0.406	14.146**	1.532	0.004*	112.287	21.181*
Wald chi ²		374.69***				381.34 ***		
Pseudo R ²		0.52				0.52		
N		921				921		

Note: In model A3, we include only travellers' personal and household characteristics, without including income and household size. In models A4, B3 and B4, we include income per capita and household size. In models B3 and B4, we also include travel characteristics and some indicators of urban form to show how they influence the effects of travellers' personal and household characteristics. In model B3, we include distance from the home to the city centre, while in model B4, we include population density. Robust standard errors are not displayed. Ratios are calculated using multinomial logistic regression.

¹ Distance to a public transport station. ² Distance to the most-frequently visited fuel station.

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

from using a private motor vehicle, probably because people tend to travel farther for leisure activities and because travelling by private motor vehicle is more convenient than by public transport or non-motorised transport, especially if the travel distance is long.

We find that, for both commuting to work and travelling for leisure activities, an increase in travel distance significantly increases the probability of using a bus, car, motorcycle or bicycle, and reduces the likelihood of walking. For commuting, a one-kilometre-longer travel distance increases the probability of travelling by bus, car, motorcycle or bicycle by 0.56%, 0.62%, 10.34% and 1.6%, respectively, and reduces the likelihood of walking by about 13% (see models B5–6 in table 6). For travel for leisure activities, an increase in the travel distance of one kilometre

TABLE 6 *Marginal Effects for Transport Mode for Commuting*

Explanatory variable	Model A5					Model A6				
	Bus	Car	Motorcycle	Bicycle	Walking	Bus	Car	Motorcycle	Bicycle	Walking
Female	0.0195***	-0.0264***	-0.0674***	-0.0103	0.0846***	0.0195***	-0.0276***	-0.0662***	-0.0106	0.0849***
Age	0.0005***	0.0010***	-0.0050***	-0.0003	0.0039***	0.0004**	0.0011***	-0.0049***	-0.0003	0.0037***
Education	-0.0020	0.0090***	0.0629***	-0.0385***	0.0314***	-0.0020	0.0059***	0.0626***	-0.0388***	-0.0277***
Income per capita (log.)						0.0057*	0.0300***	-0.0245**	0.0012	-0.0124
Household size						0.0081**	0.0040	-0.0459***	0.0054*	0.0284***
No. of children < age 7	0.0011	-0.0021	0.0043	-0.0476***	0.0443***	-0.0053	0.0030	0.0421**	-0.0521***	0.0123
No. of children > age 7	-0.0014	0.0221***	-0.0404***	0.0036	0.0161	-0.0053	0.0245***	-0.0139	0.0005	-0.0058
Motorcycle owned	-0.0093***	-0.0189***	0.0814***	-0.0243***	-0.0289***	-0.0142***	-0.0191***	0.1037***	-0.0270***	-0.0433***
Car owned	-0.0003	0.0859***	-0.0303	-0.0359**	-0.0193	-0.0041	0.0711***	-0.0225	-0.0343**	-0.0102
Bike owned	4.5e-5	-0.0020	-0.0266***	0.0494***	-0.0209***	-0.0010	-0.0003	-0.0219***	0.0487***	-0.0255***

Explanatory variable	Model B5					Model B6				
	Bus	Car	Motorcycle	Bicycle	Walking	Bus	Car	Motorcycle	Bicycle	Walking
Female	0.0193***	-0.0244***	-0.0040	-0.0178*	0.0268**	0.0193***	-0.0243***	-0.0051	-0.0175*	0.0277**
Age	0.0006***	0.0008**	-0.0055***	0.0028***	0.0012**	0.0006***	0.0007*	-0.0055***	0.0028***	0.0013***
Education	-0.0029	0.0018	0.0349***	-0.0233***	-0.0104**	-0.0028	0.0024	0.0332***	-0.0230***	-0.0098**
Income per capita (log.)	0.0043	0.0224***	-0.0316***	0.0050	-0.0001	0.0048	0.0237***	-0.0352***	0.0064	0.0003
Household size	0.0087***	0.0049	-0.0388***	0.0105*	0.0146***	0.0087**	0.0056	-0.0407***	0.0112*	0.0151***
No. of children < age 7	-0.0065	0.0020	0.0598***	-0.0452***	-0.0100	-0.0064	-0.0001	0.0620***	-0.0449***	-0.0106
No. of children > age 7	-0.0055	0.0256***	-0.0111	-0.0047	-0.0043	-0.0056	0.0265***	-0.0090	-0.0066	-0.0054
Motorcycle owned	-0.0166***	-0.0199***	0.0829***	-0.0304***	-0.0161**	-0.0167***	-0.0199***	0.0845***	-0.0305***	-0.0174***
Car owned	-0.0117	0.0704***	-0.0286	-0.0355**	0.0054	-0.0117	0.0704***	-0.0283	-0.0355**	0.0050

Bike owned	-0.0004	0.0009	-0.0278***	0.0462***	-0.0170***	-0.0004	-0.0025	-0.0269***	0.0466***	-0.0168***
Distance to city centre	3.9e-5	-0.0026**	0.0003	0.0018**	0.0005					
Population density (log.)						0.0033	0.0043	0.0354***	-0.0240**	-0.0123
Residing in urban area	-0.0024	-0.0137	0.0205	-0.0180	0.0136	-0.0015	-0.0068	0.0087	-0.0167	0.0163
Residing in rural area	-0.0107	-0.0054	-0.0307	0.0150	0.0317	-0.0127	-0.0122	-0.0078	0.0090	0.0236
Distance to pub. trans. ¹	-1.0e-5*	6.0e-6***	9.8e-7	2.7e-6	3.1e-6	-1.0e-5*	5.5e-6**	2.7e-6	1.9e-6	2.0e-6
Distance to fuel station ²	5.5e-7	4.2e-7	-1.8e-7	6.2e-9	8.2e-7	3.9e-7	-2.5e-6*	5.1e-6	1.2e-6	4.1e-7
Travel distance	0.0056***	0.0062***	0.1034***	0.0159***	-0.1310***	0.0055***	0.0061***	0.1032***	0.0157***	-0.1304***
Travel frequency	-0.0039**	-0.0100***	0.0134*	0.0048	-0.0043	-0.0039**	-0.0103***	0.0125*	0.0053*	-0.0037
Travel for work	-0.0087	-0.0177	-0.0678	0.0698	0.0244	-0.0083	0.0186	-0.0732	0.0732	0.0270
Travel for study	0.0104	-0.0464**	-0.1919***	0.2211***	0.0068	0.0109	-0.0466**	-0.2017***	0.2246***	0.0128
Travel for shopping	-0.0020	-0.0420**	-0.1163*	0.1038	0.0565	-0.0023	-0.0427***	-0.1214**	0.1075	0.0588

Note: In model A5, we include only travellers' personal and household characteristics, without including income and household size. In models A6, B5 and B6, we include income per capita and household size. In models B5 and B6, we also include travel characteristics and some indicators of urban form. In model B5, we include distance from the home to the city centre, while in model B6, we include population density. Robust standard errors are not displayed. Effects are calculated using multinomial logistic regression.

¹ Distance to a public transport station. ² Distance to the most-frequently visited fuel station.

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

TABLE 7 *Marginal Effects for Transport Mode to Leisure Activities*

Explanatory variable	Model A7					Model A8				
	Bus	Car	Motorcycle	Bicycle	Walking	Bus	Car	Motorcycle	Bicycle	Walking
Female	0.0083	-0.0229	-0.0870***	-0.0153	0.1170***	0.0090	-0.0210	-0.0919***	-0.0138	0.1178***
Age	0.0001	-0.0003	-0.0051***	0.0004	0.0048***	0.0001	0.0001	-0.0050***	0.0004	0.0044***
Education	0.0008	0.0111**	0.0290***	-0.0030	-0.0380***	-0.0011	0.0078*	0.0248***	-0.0027	-0.0288***
Income per capita (log.)						0.0154**	0.0311**	0.0342*	-0.0047	-0.0760***
Household size						0.0017	-0.0089	0.0180	-0.0074*	-0.0034
No. of children < age 7	-0.0002	0.0836***	-0.0916***	-0.0013	0.0092	0.0050	0.0968***	-0.0958***	0.0037	-0.0097
No. of children > age 7	-0.0053	0.0636***	-0.1084***	-0.0012	0.0512***	-0.0022	0.0766**	-0.1052***	0.0012	0.0296*
Motorcycle owned	-0.0207***	-0.0393***	0.0759***	-0.0046	-0.0113	-0.0226***	-0.0320***	0.0578***	-0.0006	-0.0027
Car owned	0.0036	0.2599***	-0.2406***	-0.0041	-0.0187	-0.0063	0.2406***	-0.2578***	0.0022	0.0257
Bike owned	-0.0143*	0.0140*	-0.0100	0.0111***	-0.0008	-0.0124*	0.0154**	-0.0133	0.0125***	-0.0022

Explanatory variable	Model B7					Model B8				
	Bus	Car	Motorcycle	Bicycle	Walking	Bus	Car	Motorcycle	Bicycle	Walking
Female	0.0141	-0.0188	-0.0451*	-0.0132	0.0630***	0.0143	-0.0190	-0.0470*	-0.0126	0.0642***
Age	0.0001	0.0002	-0.0028***	0.0004	0.0021**	0.0001	0.0002	-0.0028***	0.0004	0.0021***
Education	-0.0029	0.0098**	0.0052	-0.0038	-0.0083	-0.0030	0.0101**	0.0049	-0.0037	-0.0083
Income per capita (log.)	0.0139*	0.0150	0.0186	-0.0073	-0.0403***	0.0136*	0.0152	0.0176	-0.0075	-0.0388***
Household size	0.0038	-0.0150*	0.0293**	-0.0077	-0.0104	0.0039	-0.0153*	0.0279**	-0.0070	-0.0095
No. of children < age 7	0.0052	0.0728***	-0.0918***	0.0084	0.0054	0.0066	0.0723***	-0.0957***	0.0089	0.0080
No. of children > age 7	-0.0147	0.0762***	-0.0890***	0.0017	0.0258**	-0.0168	0.0784***	-0.0894***	0.0001	0.0276**
Motorcycle owned	-0.0216***	-0.0248*	0.0489***	0.0007	-0.0032	-0.0210***	-0.0243**	0.0492***	0.0005	-0.0045
Car owned	-0.0045	0.2199***	-0.2430***	0.0051	0.0226	-0.0069	0.2226***	-0.2423***	0.0043	0.0223

Bike owned	-0.0094	0.0098*	-0.0134	0.0131***	-1.3e-5	-0.0091	0.0089	-0.0108	0.0128***	-0.0017
Distance to city centre	0.0013	-0.0015	0.0012	0.0007	-0.0018					
Population density (log.)						0.0135**	0.0119	0.0185	-0.0132	-0.0038
Residing in urban area	-0.0003	-0.0362*	0.0191	0.0132	0.0042	0.0005	-0.0352*	0.0053	0.0167	0.0126
Residing in rural area	-0.0154	-0.0657**	0.0324	0.0345**	0.0142	-0.0139	-0.0633*	0.0443	0.0299*	0.0029
Distance to pub. trans. ¹	-5.6e-6	-3.0e-7	-1.0e-5	4.8e-6**	1.1e-5	-7.1e-6	2.6e-5	-8.2e-6	4.4e-6**	1.1e-6
Distance to fuel station ²	-4.5e-6	-2.2e-6	1.3e-5	-1.1e-5***	4.0e-6	-5.0e-6	2.8e-6	1.8e-6*	-1.1e-5***	3.9e-7
Travel distance	0.0026**	0.0080***	0.0593**	0.0031**	-0.0730**	0.0026**	0.0079**	0.0589**	0.0031**	-0.0725**
Travel frequency	0.0042	-0.0464***	0.0241**	0.0060*	0.0121	0.0045	-0.0472***	0.0238**	0.0060*	0.0129*

Note: In model A7, we include only travellers' personal and household characteristics, without including income and household size. In models A8, B7 and B8, we include income per capita and household size. In models B7 and B8, we also include travel characteristics and some indicators of urban form. In model B7, we include distance from the home to the city centre, while in model B8, we include population density. Robust standard errors are not displayed. Effects are calculated using multinomial logistic regression.

¹ Distance to a public transport station. ² Distance to the most-frequently visited fuel station.

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

increases the probability of travelling by bus, car, motorcycle or bicycle by about 0.3%, 0.8%, 5.9% and 0.3%, respectively, and reduces the likelihood of walking by about 7.3% (see models B7–8 in table 7). However, a longer travel distance increases the likelihood of taking a bus or using a car and decreases the chance of walking, compared with using a motorcycle (see models B7–8 in table 7 and models B3–4 in table 5). For commuting, the travel distance also has a negative significant effect on the probability of using a bicycle relative to a motorcycle (see models B1–2 in table 4). Furthermore, we find for both commuting to work and travelling for leisure activities that an increase in travel frequency reduces the likelihood of travelling by car, compared with travelling by motorcycle (see models B1–2 in table 4 and models B3–4 in table 5). For commuting, an increase in travel frequency also decreases the tendency to travel by bus, compared with by motorcycle (see models B1–2 in table 4). For commuting, one additional trip per week increases the probability of using a motorcycle by 1.25%–1.34% and decreases the chance of using a bus or car by about 0.4% and 1.0%, respectively (see models B5–6 in table 6). For travel to leisure activities, the effect of the travel frequency on the probability of motorcycling, cycling or walking is positive. An increase of one trip per week increases the probability of each by about 2.4%, 0.6% and 1.21%–1.29%, respectively, and reduces the likelihood of driving a car by about 4.6%–4.7% (see models B7–8 in table 7). The relatively lower chance of travelling by bus than by motorcycle when the travel frequency is high may be due to motorcycle use being largely cheaper than bus travel.

DISCUSSION

An important finding in our study is that an increase in population density increases the probability of motorcycling more than the probability of cycling or walking. In addition to observing that residents of less dense areas tend to have lower incomes, we conclude that people with low incomes tend to have less ability to use more ‘comfortable’ transport. Higher income may allow a person to afford a car, which may be comfortable for travel during hot, sunny weather or rainy days. Higher income may also allow a person to buy a motorcycle, which can shorten the travel time. This is beneficial in hot weather and for long travel distances. With a higher income, a person can have a motorcycle or car, which can speed up the trip, compared with travelling by public transport. To use public transport, people sometimes have to wait a long time for a vehicle to pick them up or drop them off. Also, public transport vehicles, such as buses, often stop many times during travel. Sometimes they stop for a long time while picking up passengers. This finding suggests that it is more suitable to cycle or walk in a low-density area than in a high-density area. Furthermore, our results support the hypothesis that, although distances to public transport stops in Yogyakarta are generally not very far, even in peri-urban areas, Indonesia’s hot climate is likely to negatively influence people’s willingness to walk to access public transport.

Our finding that the probability of driving a car is lower for people in urban and rural areas than in peri-urban areas is in line with the findings of studies on Europe. The same holds for our finding that the probability of cycling is high among people who live in rural areas, compared with people who live in urban areas. For example, researchers found in the Netherlands that people who live in

suburbs or less-urbanised areas tend to travel by car, but the research used 'public transport' as a reference for comparison (Dieleman, Dijst and Burghouwt 2002; Limtanakool, Dijst and Schwanen 2006). Clark, Chatterjee and Melia (2016) found that people who live in rural areas in the United Kingdom are more likely to cycle or walk than those who live in inner or outer London. They also found that people who live in inner or outer London are less likely to use cars than those who live in rural areas. However, this is not in line with our study's findings.

In addition, we found that, for both commuting to work and travelling to leisure activities, an increase in travel distance significantly increases the probability of travelling by bus, car, motorcycle or bicycle, while reducing the likelihood of walking. A longer travel distance especially increases the likelihood of taking a bus or using a car. These results are in line with the significant positive correlation between the average commuting distance and per capita energy expenditure on transport of household members that we found in a different study (Fevriera and Mulder 2017). Also, these results reinforce the findings of Müller, Tscharaktschiew and Haase (2008); Irawan and Sumi (2011b); Heinen, Maat and van Wee (2013); Clark, Chatterjee and Melia (2016); and Marquet and Miralles-Guasch (2016). Yagi, Nobel and Kawaguchi (2014) found that travel distance for work activity has a significant positive effect on the preference to use a car or public transport in Jakarta. For travel to study activities, however, they discovered that travel distance has a positive significant effect on the use of cars and a negative significant effect on the use of public transport.

Based on our survey, the contribution of motorcycles to the total CO₂ emissions from transport is about 66%. From buses and bicycles, the emissions are, respectively, about 2% and 9% of the total. Hence, encouraging people to substitute private motorised vehicles for public transport or non-motorised transport in order to decrease energy consumption and emissions is a huge challenge. In Yogyakarta's metropolitan area, one mode of transport is the Trans Jogja bus. Our results suggest that a compact urban form, including a dense population and short travel distances, may help in reducing the growth of motorcycle use in urban areas.

However, the strong dominance of motorcycles as the preferred mode of transport also makes it clear that it will be very difficult to motivate people to substitute motorcycles for bus services, such as the one offered by the Trans Jogja service. An alternative long-term policy option is to encourage people to replace conventional motorcycles with electric motorcycles. Until now, the market share of electric motorcycles in Indonesia has been very small. This is largely due to barriers to the use of electric vehicles, such as inadequate supporting infrastructure; unclear electric-vehicle regulation; relatively high prices; short battery lifespans; relatively long refuelling times; and limited travel ranges, power and speed (Jeghesta 2016; Ravel 2016).

In early August 2019, President Joko Widodo signed Presidential Regulation 55/2019 on the Acceleration Program for Battery-Powered Electric Vehicles for Road Transportation. The regulation covers government incentives for using electric vehicles, electricity-charging infrastructure, an electricity tariff for electric vehicles and technical provisions for electric vehicles and environmental protection (Sekretariat Kabinet RI 2019). Given the large number of motorcycles in urban areas in Indonesia, stimulating the growth of the market for electric motorcycles or even bicycles is, in principle, a potentially promising urban policy strategy.

CONCLUSIONS

In this article, we analysed the influence of urban form on motorcycle choice in comparison with other transport modes. Across Asia, urban road traffic is dominated by motorcycles, owing to their low prices and maintenance costs, ease of parking, relatively high average speeds in congested cities and suitability for the local climate. But the popularity of motorcycles in urban areas comes at the cost of severe local air pollution.

Our analysis is based on data that we collected during a field study on energy consumption and travel behaviour, conducted in the metropolitan area of Yogyakarta in Indonesia in 2016 and including 823 urban households from different areas of Yogyakarta. To assess how urban form influences preferences for the use of motorcycles, we employed a multinomial logistic (MNL) regression model. We controlled in our regression analyses for the influence of personal and household characteristics, such as gender, education level, income and household size. Furthermore, we distinguished between commuting to work and travelling for leisure activities.

We found that urban form explains about 20% of the observed variance in transport mode choice. Another key result of our analysis is that population density has a statistically significant positive effect on the likelihood of using a motorcycle and a statistically significant negative effect on the probability of cycling for commuting. In addition, we found that people who live near the city centre have a higher probability of travelling by car than by motorcycle; in contrast, people who live far from the city centre have a higher probability of travelling by bicycle than by motorcycle. In other words, the likelihood of choosing a motorcycle over other transport modes is highest for people with intermediate distances between the home and the city centre. This distance effect, however, is relatively small. We also found that both for commuting and for travelling for leisure activities, motorcycle use is the most sensitive to travel distance. Together, these results suggest that a compact urban form, including a dense population and short commuting distances, may help in reducing the growth of motorcycle use in urban areas.

ACKNOWLEDGMENTS

We thank Satya Wacana Christian University in Salatiga, Indonesia, and the Department of Spatial Economics at Vrije Universiteit Amsterdam, the Netherlands, for funding the survey that led to the research we report here. We thank the editors and anonymous referees of this journal for support and constructive comments. Sotya Fevriera is grateful to the Directorate General of Higher Education at the Ministry of Education and Culture of the Republic of Indonesia for granting a scholarship to pursue a doctoral program at Vrije Universiteit Amsterdam, of which this article is one of the outcomes. This article was written while Peter Mulder worked at the Department of Spatial Economics at Vrije Universiteit Amsterdam.

REFERENCES

- Adhi, Rizky Pratama. 2012. 'Preferensi Pemilihan Moda dalam Pergerakan Penglaju Koridor Bogor-Jakarta Terkait dengan Pemilihan Tempat Tinggal (Studi Kasus: Moda Bus AC dan Moda KRL Ekspres)' [Preference for mode selection in the movement of Bogor-Jakarta

- corridor commuters in relation to residence selection (case study: AC bus mode and express KRL mode)]. *Jurnal Perencanaan Wilayah dan Kota* 23 (1): 67–84.
- Alonso, William. 1960. 'A Theory of the Urban Land Market'. *Regional Science* 6 (1): 149–57. <https://doi.org/10.1111/j.1435-5597.1960.tb01710.x>
- Andersson, Asa, Sara Skoog and Johanna Svensson. 2014. 'Commuter Shopping: A Study in Understanding Commuting in the Context of Shopping'. Bachelor thesis, University of Jönköping.
- Ansusanto, J. Dwijoko, Achmad Munawar, Sigit Priyanto and Bambang Hari Wibisono. 2014. 'Karakteristik Pola Perjalanan di Kota Yogyakarta' [Analysis of Yogyakarta city travel patterns]. *Jurnal Transportasi* 14 (1): 61–8. <https://journal.unpar.ac.id/index.php/journaltransportasi/article/view/1375>
- Asensio, Javier. 2002. 'Transport Mode Choice by Commuters to Barcelona's CBD'. *Urban Studies* 39 (10): 1,881–95. <https://doi.org/10.1080/0042098022000003000>
- Bandono, Markus Setio. 2010. 'Pengaruh Pendapatan, Penguasaan Lahan, Status Pernikahan, Pendidikan, Jenis Kelamin, Umur terhadap Keputusan Tenaga Kerja Menjadi Commuter' [The influence of income, land tenure, marital status, education, gender and age on decisions for commuters]. Bachelor thesis, University of Diponegoro.
- Banister, D., S. Watson and C. Wood. 1997. 'Sustainable Cities: Transport, Energy, and Urban Form'. *Environment and Planning B: Planning and Design* 24 (1): 125–43.
- Batti, Joy Fredi. 2011. 'Studi Karakteristik Pelaku Perjalanan dalam Wilayah Pelayanan Trayek Mambo – Manonda di Kota Palu' [Study of traveller characteristics in the service area for the Mambo–Manonda route in Palu city]. *Jurnal Rekayasa dan Manajemen Transportasi* 1 (2): 119–28.
- Bento, Antonio M., Maureen L. Cropper, Ahmed Mushfiq Mobarak and Katja Vinha. 2005. 'The Effects of Urban Spatial Structure on Travel Demand in the United States'. *Review of Economics and Statistics* 87 (3): 466–78.
- BPS (Statistics Indonesia). 2009. *Statistical Yearbook of Indonesia 2009*. Jakarta: BPS.
- BPS (Statistics Indonesia). 2015a. *Daerah Istimewa Yogyakarta in Figures*. Bantul: BPS.
- BPS (Statistics Indonesia). 2015b. 'Komuter DKI Jakarta Tahun 2014' [DKI Jakarta commuters of 2014]. *Berita Resmi Statistik*, BPS DKI Jakarta province, 16 February. <https://jakarta.bps.go.id/pressrelease/2015/02/20/59/komuter-dki-jakarta-tahun-2014.html>
- BPS (Statistics Indonesia). 2015c. 'Statistik Komuter Kota Bekasi 2014' [Bekasi city commuter statistics 2014]. *Berita Resmi Statistik*, BPS Bekasi city, 15 January. <https://bekasikota.bps.go.id/pressrelease/2015/04/21/95/statistik-komuter-kota-bekasi-2014.html>
- BPS (Statistics Indonesia). 2017. *Statistical Yearbook of Indonesia 2017*. Jakarta: BPS.
- Buehler, Ralph. 2011. 'Determinants of Transport Mode Choice: A Comparison of Germany and the USA'. *Journal of Transport Geography* 19 (4): 644–57. <https://doi.org/10.1016/j.jtrangeo.2010.07.005>
- Chen, Ching-Fu and Wen-Tai Lai. 2011. 'The Effects of Rational and Habitual Factors on Mode Choice Behaviors in a Motorcycle-Dependent Region: Evidence from Taiwan'. *Transport Policy* 18 (5): 711–8. <https://doi.org/10.1016/j.tranpol.2011.01.006>
- Clark, Ben, Kiron Chatterjee and Steve Melia. 2016. 'Changes to Commute Mode: The Role of Life Events, Spatial Context and Environmental Attitude'. *Transportation Research Part A: Policy and Practice* 89 (July): 89–105. <https://dx.doi.org/10.1016/j.tra.2016.05.005>
- Damayanti, Rully and Handinoto. 2005. 'Kawasan "Pusat Kota" dalam Perkembangan Sejarah Perkotaan di Jawa' [The 'central city' area in the development of urban history in Java]. *Dimensi Teknik Arsitektur* 33 (1): 34–42.
- Dieleman, Frans M., Martin Dijst and Guillaume Burghouwt. 2002. 'Urban Form and Travel Behaviour: Micro-level Household Attributes and Residential Context'. *Urban Studies* 39 (3): 507–27. <https://doi.org/10.1080/00420980220112801>
- Dieleman, Frans and Michael Wegener. 2004. 'Compact City and Urban Sprawl'. *Built Environment* 30 (4): 308–23. <https://doi.org/10.2148/benv.30.4.308.57151>

- Elmanisa, A. M., A. A. Kartiva, A. Fernando, R. Arianto, H. Winarso and D. Zulkaidi. 2017. 'Land Price Mapping of Jabodetabek, Indonesia'. *Geoplanning: Journal of Geomatics and Planning* 4 (1): 53–62. <https://doi.org/10.14710/geoplanning.4.1.53-62>
- Fevriera, Sotya and Peter Mulder. 2017. 'The Impact of Urbanization on Energy Consumption in Indonesia. Evidence from Indonesian Cities'. Paper presented at the 6th Indonesian Regional Science Association (IRSA) International Institute conference, Manado, Indonesia, 17–18 July.
- Glaeser, Edward L., Matthew E. Kahn and Jordan Rappaport. 2008. 'Why Do the Poor Live in Cities? The Role of Public Transportation'. *Journal of Urban Economics* 63 (1): 1–24. <https://doi.org/10.1016/j.jue.2006.12.004>
- Glaeser, Edward L. and Matthew E. Kahn. 2010. 'The Greenness of Cities: Carbon Dioxide Emissions and Urban Development'. *Journal of Urban Economics* 67 (3): 404–18. <https://doi.org/10.1016/j.jue.2009.11.006>
- Heinen, Eva. 2016. 'Identity and Travel Behaviour: A Cross-sectional Study on Commute Mode Choice and Intention to Change'. *Transportation Research Part F: Traffic Psychology and Behaviour* 43 (November): 238–53. <https://dx.doi.org/10.1016/j.trf.2016.10.016>
- Heinen, Eva, Kees Maat and Bert van Wee. 2013. 'The Effect of Work-Related Factors on the Bicycle Commute Mode Choice in the Netherlands'. *Transportation* 40 (1): 23–43. <https://doi.org/10.1007/s11116-012-9399-4>
- Hsu, Tien-Pen, Nguyen Xuan Dao and Ahmad Farhan Mohd Sadullah. 2003. 'A Comparative Study on Motorcycle Traffic Development of Taiwan, Malaysia and Vietnam'. *Journal of the Eastern Asia Society for Transportation Studies* 5 (October): 179–93.
- Hutt, Rosamond and Keith Breene. 2016. '7 Shocking Facts About Air Pollution'. World Economic Forum, 27 October. <https://www.weforum.org/agenda/2016/10/air-pollution-the-true-cost-in-numbers/>
- IEA (International Energy Agency). 2016. 'Cities are the Frontline of the Energy Transition'. IEA News, 7 September. <https://www.iea.org/news/cities-are-at-the-frontline-of-the-energy-transition>
- Irawan, Muhammad Zudhy and Tomonori Sumi. 2011a. 'Modeling Departure Time of Students on Public Transports in Yogyakarta, Indonesia'. *Modern Applied Science* 5 (4): 3–10.
- Irawan, Muhammad Zudhy and Tomonori Sumi. 2011b. 'Promoting Active Transport in Students' Travel Behavior: A Case from Yogyakarta (Indonesia)'. *Journal of Sustainable Development* 4 (1): 45–52.
- Isnardani. 2010. 'Studi Karakteristik Pelaku Perjalanan (Traveler) pada Zona Kecamatan Palu Barat Kota Palu Sulawesi Tengah' [Study of the characteristics of travellers in West Palu, Palu city and Central Sulawesi]. *Jurnal SMARTek* 8 (2): 83–96.
- ITF (International Transport Forum). 2008. 'Trends in Motorcycles Fleet Worldwide'. Paper presented at the Workshop on Motorcycling Safety, Lillehammer, Norway, 10 June. <https://www.itf-oecd.org/sites/default/files/docs/lillehammer08rogers.pdf>
- Jeghesta, Manuel. 2016. 'Motor Listrik Sulit Diterima Masyarakat Indonesia' [Electric motors hard to accept for Indonesian Society]. *SINDOnews*, 18 August. <https://otomotif.sindonews.com/berita/1132187/121/motor-listrik-sulit-diterima-masyarakat-indonesia>
- Kuby, Michael J., Scott B. Kelley and Joseph Schoenemann. 2013. 'Spatial Refueling Patterns of Alternative-Fuel and Gasoline Vehicle Drivers in Los Angeles'. *Transportation Research Part D: Transport and Environment* 25 (December): 84–92. <https://doi.org/10.1016/j.trd.2013.08.004>
- Kunc, Josef, Petr Tonev, Zdeněk Szczyrba and Bohumil Frantál. 2012. 'Commuting for Retail Shopping as a Part of the Daily Urban System (Brno, the Czech Republic)'. *Geographia Technica* 1 (2012): 36–45.
- Larson, William and Anthony Yezer. 2015. 'The Energy Implications of City Size and Density'. *Journal of Urban Economics* 90 (November): 35–49. <https://dx.doi.org/10.1016/j.jue.2015.08.001>

- LD FEB UI (Demographic Institute of the Faculty of Economics, Universitas Indonesia). 2019. *Hasil Riset LD FEB UI Tahun 2018: GOJEK Sumbang Rp 44,2 Triliun ke Perekonomian Indonesia* [LD FEB UI research results 2018: GOJEK donates Rp 44.2 trillion to the Indonesian economy]. LD FEB UI. Accessed 10 January. <https://ldfebui.org/wp-content/uploads/2019/03/Berita-Pers-Lembar-Fakta-LD-UI-Dampak-GOJEK.pdf>
- Leinbach, Thomas R. and Bambang Suwarno. 1985. 'Commuting and Circulation Characteristics in the Intermediate Sized City: The Example of Medan, Indonesia'. *Singapore Journal of Tropical Geography* 6 (1): 35–47.
- Limtanakool, Narisra, Martin Dijst and Tim Schwanen. 2006. 'The Influence of Socioeconomic Characteristics, Land Use and Travel Time Considerations on Mode Choice for Medium- and Longer-Distance Trips'. *Journal of Transport Geography* 14 (5): 327–41. <https://doi.org/10.1016/j.jtrangeo.2005.06.004>
- Liu, Fang, Meiping Yun and Guangyang Liu. 2016. 'Will Motorcyclists Shift to Bus or Car in Commuting: A Case Study of Zhongshan, China'. Paper presented at the Transportation Research Board 95th Annual Meeting, Washington, DC, United States, 10–14 January.
- Mantra, Ida Bagus. 2000. *Demografi Umum*. Yogyakarta: Pustaka Pelajar.
- Marquet, Oriol and Carme Miralles-Guasch. 2016. 'City of Motorcycles. On How Objective and Subjective Factors Are Behind the Rise of Two-Wheeled Mobility in Barcelona'. *Transport Policy* 52 (November): 37–45. <https://dx.doi.org/10.1016/j.tranpol.2016.07.002>
- Mindali, Orit, Adi Raveh and Ilan Salomon. 2004. 'Urban Density and Energy Consumption: A New Look at Old Statistics'. *Transportation Research Part A: Policy and Practice* 38 (2): 143–62. <https://doi.org/10.1016/j.tra.2003.10.004>
- Müller, Sven, Stefan Tscharaktschiew and Knut Haase. 2008. 'Travel-to-School Mode Choice Modelling and Patterns of School Choice in Urban Areas'. *Journal of Transport Geography* 16 (5): 342–57. <https://doi.org/10.1016/j.jtrangeo.2007.12.004>
- Muñiz, Ivan and Anna Galindo. 2005. 'Urban Form and the Ecological Footprint of Commuting. The Case of Barcelona'. *Ecological Economics* 55 (4): 499–514. <https://doi.org/10.1016/j.ecolecon.2004.12.008>
- Neuman, Michael. 2005. 'The Compact City Fallacy'. *Journal of Planning Education and Research* 25: 11–26. <https://doi.org/10.1177/0739456X04270466>
- Newman, Peter W.G. and Jeffrey R. Kenworthy. 1989. *Cities and Automobile Dependence: An International Sourcebook*. Aldershot: Gower.
- Nicholas, Michael A. 2010. 'Driving Demand: What Can Gasoline Refueling Patterns Tell Us about Planning an Alternative Fuel Network?'. *Journal of Transport Geography* 18 (6): 738–49. <https://doi.org/10.1016/j.jtrangeo.2010.06.011>
- Pebrian, Haldi and Anita Ratnasari Rakhmatulloh. 2013. 'Pola Pergerakan Pekerja Komuter Sayung – Semarang' [Sayung – Semarang Commuter Worker Movement Pattern]. *Teknik PWK* 2 (4): 978–87.
- Pousther, Jacob. 2015. 'Car, Bike or Motorcycle? Depends on Where You Live'. Pew Research Center, 16 April. <http://www.pewresearch.org/fact-tank/2015/04/16/car-bike-or-motorcycle-depends-on-where-you-live/>
- Pratama, Akhdi Martin. 2019. 'Menhub Ingin Batasi Jumlah Driver Ojek Online' [The transport minister wants to limit the number of online Ojek drivers]. *Kompas*, 12 November. <https://money.kompas.com/read/2019/11/12/151700826/menhub-ingin-batasi-jumlah-driver-ojek-online>
- Putra, Teguh Pradana. 2013. 'Studi Karakteristik Pelaku Perjalanan Komuter Kota Yogyakarta yang Berdomisili di Daerah Sleman dan Bantul' [Study of characteristics of commuters in Yogyakarta city who live in Sleman and Bantul]. Bachelor thesis, University of Gadjah Mada.
- Ravel, Stanly. 2016. 'Ini Kendala Utama Motor Listrik di Indonesia' [This is the main obstacle for electric motors in Indonesia]. *Otomania*, 3 September. <https://otomania.gridoto.com/read/241175583/ini-kendala-utama-motor-listrik-di-indonesia>

- Sekretariat Kabinet RI (Cabinet Secretariat of the Republic of Indonesia). 2019. Peraturan Presiden Republik Indonesia Nomor 55 Tahun 2019 [Presidential Regulation 55/2019]. Republic of Indonesia, Jakarta. Accessed 30 August. https://sipuu.setkab.go.id/PUUdoc/175904/Perpres_Nomor_55_Tahun_2019.pdf
- Sheikh, Ibrahim A.K. Radin Umar R. S., Habshah M., Kassim H., Mark Stevenson and Ahmed Hariza. 2006. 'Mode Choice Model for Vulnerable Motorcyclists in Malaysia'. *Traffic Injury Prevention* 7 (2): 150–4. <https://dx.doi.org/10.1080/15389580600550354>
- Sitanala, Frans. 2005. 'Pergerakan Penduduk Kota Depok Menuju ke Tempat Bekerja Tahun 2001' [Movement of Depok's city population to workplaces in 2001]. *Makara Journal of Science* 9 (1): 41–4.
- Sugiyanto, Gito, Siti Malkhamah, Ahmad Munawar and Heru Sutomo. 2011. 'Estimation of Congestion Cost of Motorcycles Users in Malioboro, Yogyakarta, Indonesia'. *International Journal of Civil & Environmental Engineering* 11 (1): 34–41.
- Sun, Bindong, Alireza Ermagun and Bo Dan. 2017. 'Built Environmental Impacts on Commuting Mode Choice and Distance: Evidence from Shanghai'. *Transportation Research Part D: Transport and Environment* 52 (B): 441–53. <http://dx.doi.org/10.1016/j.trd.2016.06.001>
- Suparmono. 2012. Accessibility to Center Business District and Land Price. *Economic Journal of Emerging Markets* 4 (2): 143–52.
- UN (United Nations). 2015. *World Urbanization Prospects: The 2014 Revision*. New York: United Nations.
- Utari, M. G. Endang Sri, 2015. 'Analisis Sistem Pusat Pelayanan Permukiman di Kota Yogyakarta Tahun 2014' [Analysis of the settlement service center system in Yogyakarta city in 2014]. *Journal of Economics and Policy* 8 (1): 62–72.
- Van Vugt, Mark, Paula A. M. van Lange and Ree M. Meertens. 1996. 'Commuting by Car or Public Transportation? A Social Dilemma Analysis of Travel Mode Judgements'. *European Journal of Social Psychology* 26 (3): 373–95.
- Van Wee, Bert, Hans Holwerda and Rick van Baren. 2002. 'Preferences for Modes, Residential Location and Travel Behaviour: the Relevance for Land-Use Impacts on Mobility'. *European Journal of Transport and Infrastructure Research* 2 (3/4): 305–16.
- WHO (World Health Organization). 2015. *Global Status Report on Road Safety 2015*. Geneva, Switzerland: WHO.
- World Bank. 2016. 'World Development Indicators'. Databank. Accessed 16 December. <http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators>
- Yagi, Sadayuki, Deo Nobel and Hirohisa Kawaguchi. 2012. 'Time Series Comparison of Models of Auto and Motorcycle Ownership and Mode Choice in a Changing Transportation Environment'. *Journal of the Transportation Research Board* 2317 (1): 44–50. <https://doi.org/10.3141/2317-06>
- Yagi, Sadayuki, Deo Nobel and Hirohisa Kawaguchi. 2014. 'Time-Series Comparison of Auto/Motorcycle Ownership and Joint Mode and Destination Choice Models Based on Two Large-Scale Surveys in Jakarta'. *Asian Transport Studies* 3 (1): 46–65.