

HOW DOES THE BUILT ENVIRONMENT INFLUENCE CAR AND MOTORCYCLE OWNERSHIP
AND USE IN METRO MANILA?

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Abstract

Metro Manila is the Philippines' political and economic capital. With 20 million inhabitants and a land area of only 550 sq. miles, it is Southeast Asia's most densely populated megacity. In many ways, Metro Manila's urban development mirrors the challenges faced by rapidly urbanizing cities: economic opportunities are disproportionately concentrated in the capital, rising land values in the urban core have pushed residents towards the fringes, weak planning and enforcement have resulted in unchecked development, and unreliable public transportation coupled with a growing middle class have increased motorization rates.

To address these challenges, cities have turned to land use strategies, which have the potential to influence travel and ownership behavior. While several studies have explored this relationship, research on how the built environment's effect varies across private motorized modes remains limited. To fill this gap, I sought to answer the following research questions: What is the relationship between the built environment and car ownership and use in Metro Manila? How does this relationship differ for motorcycle ownership and use?

Using data from the 2015 Metro Manila Urban Transportation Integration Study Home Interview Survey, I find that the built environment influences vehicle ownership and use differently. Population, job, and intersection densities as well as the land use mix influence car ownership, while population and job densities and distance to the central business district are correlated with motorcycle ownership and use. Proximity to a railway station and diverse land uses influence both motorcycle and car use. These findings could help inform strategies for reducing motorization rates and shifting towards more sustainable transportation in Metro Manila.

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Introduction

Rapidly urbanizing cities in the developing world face a different set of challenges from more advanced economies: economic opportunities are disproportionately concentrated in the capital, rising land values in the urban core have pushed residents towards the fringes, weak planning and enforcement have resulted in unchecked development, and unreliable public transportation coupled with a growing middle class have increased motorization rates.

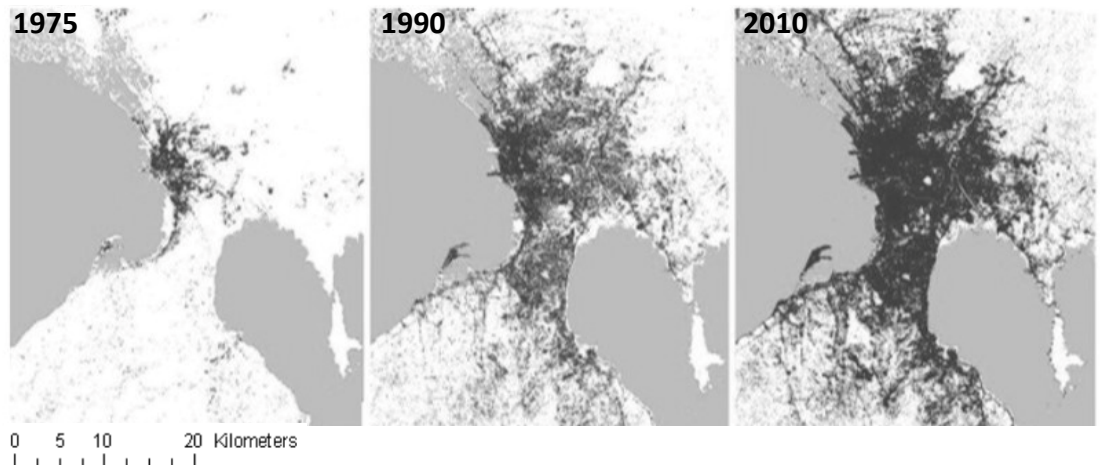
Although the total number of registered vehicles globally has grown significantly in the last decade, motorization rates have increased much faster in rapidly urbanizing cities. Asian cities now account for over half of registered cars and close to 80% of motorcycles globally, while motorcycle registrations in Southeast Asia alone already account for almost half of the total worldwide (ADB, 2020). Increased motorization has improved access to areas unserved by public transportation, but it has also inflicted high economic costs including worsening traffic congestion, increased greenhouse gas emissions, and concerns on road safety.

Case Context

Metro Manila, the Philippines' political and economic capital, mirrors the challenges faced by several developing cities. While it is second to Jakarta in terms of total population, with 20 million inhabitants and a land area of only 1,424 sq km, it is Southeast Asia's most densely populated megacity. With a growing population and rising land

values, Metro Manila has expanded significantly over time. From 2010 to 2015, neighborhoods in its peripheries experienced the largest population growth (ADB, 2020).

Figure 1. Urban Sprawl in Metro Manila Over Time



Source: The German Remote Sensing Data Center

Economic activities are heavily concentrated in Metro Manila, with the region accounting for 42% of the country's gross domestic product. In search of better opportunities, people from nearby provinces travel to Metro Manila daily, bringing the daytime population up by at least 1 million (ALMEC, 2015). Like other megacities such as Bangkok and Mexico City, this influx of commuters contributes to traffic congestion, longer motorized trips, and air pollution, and could lead to decreased labor productivity, low quality of life, and other undesirable outcomes (Cervero, 2013).

Rising Motorization Levels

Transit investments have stagnated and failed to keep pace with urban expansion even as the government continues to construct miles of highways each year. Metro Manila only has one commuter and three urban railway lines, with a total length

of 52.4 km. In contrast, Bangkok has 8 lines, while Mexico City has 12 lines, with a total length of 210 km and 226 km respectively. Unlike rail travel, which is heavily subsidized by the government, road-based transit modes, such as buses and jeepneys which make up 67% of public transportation trips, rely on farebox revenues. This encourages competition among small industry players, leading to congestion and unsafe driving.

Since the public transportation system is inefficient and insufficient, Filipinos have turned to automobiles and motorcycles. From 1996 to 2015, commercial vehicle sales have increased by 27%, although the share of household car ownership has gone down from 18.6% in 1996 to 11.5% in 2015 (ALMEC, 1999; ALMEC, 2015). Due to flexibility and affordability, motorcycles have become increasingly popular in the last decade. The total growth in registered motorcycles, attributed in part to the use of motorcycles in delivery and logistics services as well as the popularity of motorcycle taxis, has surpassed the increase in registered cars (ADB, 2020). In 1999, motorcycles, which only accounted for 0.7% of trips, were never considered a popular transport mode (ALMEC, 1999). But in 2015, the share of trips made by motorcycles jumped to 8.3% (ALMEC, 2015), which highlights how motorcycles have become a primary mode of motorized transport.

Economic Costs of Traffic Congestion

Although roughly 49% of the total travel demand is serviced by public transportation, private vehicles, which account for 20% of trips, take up 78% of the road space (ALMEC, 2015). Unsurprisingly, the Asian Development Bank (ADB) ranked Metro Manila as the most congested city out of 278 Asian cities included in its study (ADB,

2019). The Japan International Cooperation Agency (JICA) estimates that the country lost \$70 Million a day in 2017 due to traffic congestion. Without any interventions in place, this figure could increase to \$108 Million by 2035 (JICA, n.d.). Beyond financial costs, the passenger road transport sector within Metro Manila contributed 13.78 million tons of CO₂ emissions in 2015 (Ahanchian & Biona, 2014). In 2019, motorcycle accidents were also the ninth leading cause of death among Filipinos (ADB, 2020).

Since several negative externalities are associated with rising motorization and urbanization rates, developing cities would benefit from coordinating transportation and land development patterns, alongside strategies that encourage the use of nonmotorized modes. In cities with higher densities and a more diverse mix of land uses, residents are less likely to own and use vehicles. Since average incomes and car ownership are generally lower compared to more advanced countries, researchers hypothesize that the built environment might play a more important role in shaping travel decisions (Cervero, 2013).

Although a growing body of work has examined the relationship between land use and travel, researchers have focused on how built environment affects car ownership and use, and there is a dearth of studies on how this effect varies across private motorized modes in Metro Manila as well as in several developing cities. My research aims to answer the following questions: *What is the relationship between the built environment and car ownership and use in Metro Manila? How does this relationship differ for motorcycle ownership and use?* I use data from the Metro Manila Urban Transportation Integration

Study Home Interview Survey (MMUTIS-HIS). This data set includes a sample of 51,188 households in Metro Manila, which is comprised of seventeen cities and municipalities, and its adjacent provinces. The study area is also divided into 350 traffic analysis zones, which I use to represent the origins and destinations of trips. I then develop built environment measures organized around density, diversity, design, distance to transit, and destination accessibility. To disentangle the effects of the built environment on travel choices, I control for socioeconomic characteristics.

Building on previous research, I find that several built environment features have a statistically significant relationship with vehicle ownership in Metro Manila. Although income and other socioeconomic variables also explain a household's decision to own vehicles, proximity to a rail station, diversity of land uses, population, job, and intersection densities also have an effect. For both car and motorcycle use, being half a mile from a rail station as well as residing in more diverse areas reduce the passenger kilometers traveled. The distance of a household's residence to the Central Business District would also affect the motorcycle vehicle kilometers traveled.

As Metro Manila shifts towards more sustainable transportation systems, the findings of this study underscore the need for decisionmakers to focus on strategies that promote more compact and connected urban development and redirect investments from highways to mass transit. Improving the quality of the pedestrian environment could encourage a shift to more sustainable transportation modes. Railway or transit expansion plans should also focus on connecting areas with higher motorcycle ownership rates.

The rest of this paper is organized as follows. I examine studies analyzing the relationship between the built environment and travel demand more broadly and focus on car and motorcycle ownership and use in developing cities. In the methodology section, I discuss the travel survey dataset, my built environment measures, and my model specifications. I then present my model results in the discussion section. Finally, I summarize the study and discuss its potential policy implications.

Literature Review

Travel Demand and Built Environment

According to traditional utility-based models, travel demand is a derived demand, which means that trips are made to access services. To reduce travel demand, several cities have looked to urban design and land use strategies. Synthesizing findings from previous research, Cervero and Kockelman (1997) popularized the 3Ds—density, diversity, and design— as measures of the built environment that determine the number of trips made, the mode used, and the route taken. Neighborhoods that are dense and compact generally require less time to travel from one destination to the next and could reduce car use. When there is a mix of land uses and activities in an area, trips are generally short and walkable, and people are more likely to avoid vehicle trips. Similarly, design elements, such as bike lanes and bike parking, wide sidewalks, and street trees, can encourage more walking and cycling trips. Ewing & Cervero, (2010) later identified two additional Ds: destination accessibility and distance to transit. Other

researchers have also added a sixth variable, demand management, to include parking supply.

In addition to these built environment variables, socioeconomic and demographic characteristics play an important role in shaping travel behavior. Across geographies, empirical studies have found that income significantly affects vehicle ownership. Other variables, including the number of workers, age of household, education levels, gender, and the number of children also had varying effects on vehicle ownership (Rubite & Tiglao, 2003; Yamamoto, 2009; Zegras, 2010; Rith et al., 2019). In their review of literature, Cervero & Ewing (2010) noted that the number of trips made is primarily influenced by socioeconomic characteristics followed by built environment variables, while trip length is primarily affected by the built environment.

Although there is a consensus that the built environment influences travel demand, earlier work exploring this relationship was criticized due to model specification and estimation issues, which could potentially produce biased results, as well as the use of aggregate level data which do not account for variations within neighborhoods (Handy, 1996; Boarnet & Crane, 2001). Over time, researchers have shifted to disaggregate multivariate regression analysis to address these deficiencies. Still, issues such as endogeneity remain a challenge (Jiang et al., 2017) and disentangling the effects of the built environment variables is complex. Some studies have also argued that lifestyle and attitudinal differences within similar socioeconomic groups influence travel behavior, mode choice, as well as residential location choice. For instance, a

household's preference to travel by car might influence residential location choice, which could overstate the impact the built environment might have on travel behavior. To account for this, researchers have included attitudinal data in their analysis (Lee & Goulias, 2018).

Car Ownership and Use

In developed cities, higher population and job densities, a more diverse land use mix, and a connected street network have been found to influence mode choice (Cervero & Kockelman, 1997; Cervero & Wu, 1997; Potoglou & Kanaroglou, 2008). In addition to more traditional measures of the built environment, Keller & Vance (2013) found that the percentage of open space, density of businesses, and proximity to urban disamenities, such as dump sites, had a positive effect on car ownership.

Built environment variables that were found to influence the likelihood of households to own and use cars in more advanced economies may not necessarily be generalizable to developing cities which face different set of urban challenges including rising motorization rates, high population densities, poorly planned road networks, and extreme traffic congestion. The urban forms in these cities are also markedly different compared to those in wealthier countries: urban primacy and monocentricity are more prevalent, developing cities are at least twice as dense, the road network is less developed, and there is a spatial mismatch wherein lower-income residents tend to live far from the urban core (Cervero, 2013).

Although a growing body of research has explored the links between land use and car ownership in rapidly urbanizing areas, these studies conclude that socioeconomic and demographic characteristics largely explain vehicle ownership, and land use variables, such as land use mix, population density, and access to public transportation, had limited or no effect (Senbil et al., 2006; Zegras, 2010). A study focused on Metro Manila reached the same conclusion. Rith et al. (2019) found that while car ownership is largely determined by a household's socioeconomic characteristics, built environment features also had some effect on car ownership. Access to public transportation and proximity to essential facilities were found to make vehicle ownership less appealing in Metro Manila, while population and road density had the opposite effect contrary to other empirical findings. Their research builds on earlier work which found that in addition to socioeconomic determinants, households who lived near EDSA, the longest and one of the most congested roadways in the metropolis, preferred not to own a car (Rubite & Tiglao, 2003). The authors hypothesized that this is partly because of the residents' proximity to central business districts as well as their accessibility to different public transportation modes.

In addition to car ownership, some researchers have examined the built environment's impact on car use, typically measured by the distance traveled. Accessibility to destinations, intersection density, job density, transit supply, proximity to highways, and mixed land uses were generally found to reduce trip length (McCormack et al., 2001; Zhang, 2006; Ewing & Cervero, 2010; Guerra, 2014). However,

some indicators, such as residential density, have mixed associations with car use. Zhang et al. (2021) found that residential density did not have a linear effect on car use in Beijing, suggesting that beyond a certain threshold, densification will have little effect on driving distance.

Motorcycle Ownership and Use

Motorcycles have become increasingly popular in many developing cities, especially in Asian cities, and empirical studies have sought to understand the factors influencing motorcycle ownership. While researchers have found associations between the built environment and motorcycle ownership, the results are mixed. In their analysis on urban form and preference for motorcycle use in Yogyakarta, Indonesia, Fevriera et al. (2021) found that population density had a positive effect on the likelihood of motorcycle ownership since areas that are more dense also tend to have higher-incomes. However, population density had a negative impact on motorcycle ownership for both Osaka and Kuala Lumpur, but the effects are larger for the former likely because the railway network is denser in areas with higher population density (Yamamoto, 2009). Still, proximity to transit does not guarantee lower motorcycle ownership. In Bogota, access to the TransMilenio BRT had no effect on motorcycle ownership (Gómez-Gélvez & Obando, 2014). In some developing cities, where the built environment is more conducive to transit, investments have not always produced the desired outcomes. In Jakarta, the Bus Rapid Transit system introduced in 2004 did not significantly increase ridership. Instead, there was a large increase in motorcycle

ownership (Gaduh et al., 2021). Distance to the city center also influences motorcycle ownership and use although the results are inconclusive, with studies finding both negative and positive correlations (Yamamoto, 2009; Wong, 2013; Gómez-Gélvez & Obando, 2014). For motorcycle use, individuals who are at an intermediate distance from the city center are more likely to use a motorcycle in Yogyakarta (Fevriera et al., 2021).

Previous research has documented that the built environment influences both car and motorcycle ownership and use. However, only a few built environment-travel studies have estimated its impact across different private modes of transportation. In Metro Manila, Rith et al., (2019) explored the socioeconomic and land use determinants of household car ownership. While this study extends their work to include motorcycle ownership, there are key data and methodological differences. First, the previous study sampled 1,795 households in 2017, gathered through various areas in Metro Manila excluding nearby provinces, while this study uses the official 2015 household travel survey which includes a sample of 51,188 households in Greater Metro Manila. Second, this study uses a different set of built environment features. As a measure of land use diversity, for example, the authors developed a mixed facility index using points of interests such as schools and colleges, hospitals, markets, and recreation centers. Other indicators in their study include public transportation density and the shortest distance to the nearest railway station.

Methodology

With data from the Metro Manila Urban Transportation Integration Study (MMUTIS) database and OpenStreetMap, I developed six built environment measures to examine its influence on vehicle ownership and use. The metrics selected represent different aspects of the built environment. I used a binomial logistic regression and a Tobit model to estimate the relationship with vehicle ownership and use respectively.

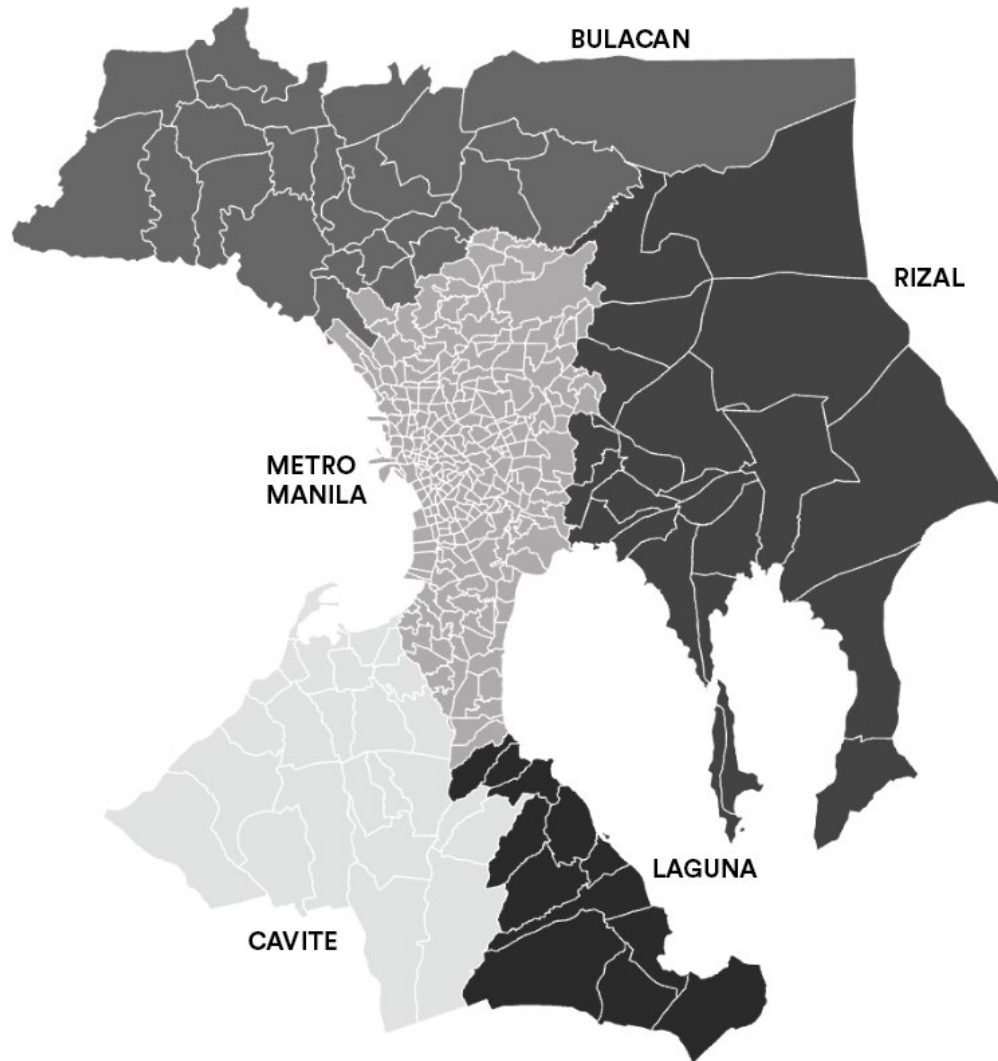
Data

This study uses data from the 2015 MMUTIS Home Interview Survey (MMUTIS-HIS), the Philippine government's official household travel survey data set, which was updated from the 1999 survey, with technical assistance from the Japan International Cooperation Agency. The MMUTIS-HIS covers the Greater Metro Manila region, which includes Metro Manila and its adjacent provinces—Bulacan, Rizal, Cavite, and Laguna (see Figure 2). The households were randomly selected at a sample rate of 1% of the population in the study area, or 51,188 households and 130,134 individuals (ALMEC, 2015). Each household member above 5 years old was interviewed.

This study uses three survey forms from the HIS. The Household Information questionnaire covers the socioeconomic characteristics of households, such as their family structure, vehicle ownership, income levels, and residence location. The Household Member Information questionnaire covers the socioeconomic characteristics of each household member. The Daily Trip Information form covers the characteristics of

weekday trips made by each household member and contains information such as trip origin and destination, trip purpose, travel mode, transfers made, as well as departure and arrival times.

Figure 2. Traffic Analysis Zones in Greater Metro Manila



Source: ALMEC (2015)

The built environment features included in this study are aggregated at the zone level. The household and trip information were geo-coded at the barangay level, the basic

administrative unit in the Philippines. There are 4,519 barangays in the study area, with around four households sampled in each (ALMEC, 2015). However, upon validation, some barangays did not have any sampled households. I aggregated the barangays into traffic analysis zones (TAZ) delineated by the JICA project team based on criteria including administrative boundaries, land use, and population distribution. There are 350 TAZs in the study area, 272 of which are in Metro Manila, with areas ranging from 0.098 sq km to 258 sq km.

The JICA project team also processed the HIS data further to adjust survey estimates that differed significantly from official statistics. For example, an expansion factor was applied to car ownership, which was unrealistically low, to match the registered number of vehicles. The number of single commuting trips per day, presumably due to those working night shifts, were also corrected. With only a small share of respondents in the 5 to 9 years old age group, an expansion factor was used so the survey data is commensurate with census data (ALMEC, 2015).

Model Specification

Vehicle Ownership

To determine the impact of the built environment on the likelihood of vehicle ownership, I develop a binomial logistic regression model of household vehicle choice for each mode. Households with no vehicles are assigned a value of zero, while households

with at least one vehicle have a value of one. I included ten built environment and socioeconomic variables in my model, which will be discussed in the succeeding sections.

Vehicle Ownership

$$= \beta_0 + \beta_1 \text{ Built Environment Measures} \\ + \beta_2 \text{ Socioeconomic Variables} + \mu$$

Vehicle Use

For vehicle use measured by the passenger kilometers traveled (PKT), I used a Tobit model to estimate the impact of the built environment variables on the total distance traveled by a household. The Tobit model accounts for censoring in the dependent variable. Since the household passenger kilometer were aggregated by zones, 31% of households who made short intrazonal trips had zero PKT. This does not reflect the total distances traveled by a household, so the estimates could be biased if an ordinary least squares regression was used. Since the distribution of household PKT is skewed to the right, I took the natural log plus one of the PKT. I use the same built environment and socioeconomic variables as the vehicle ownership models.

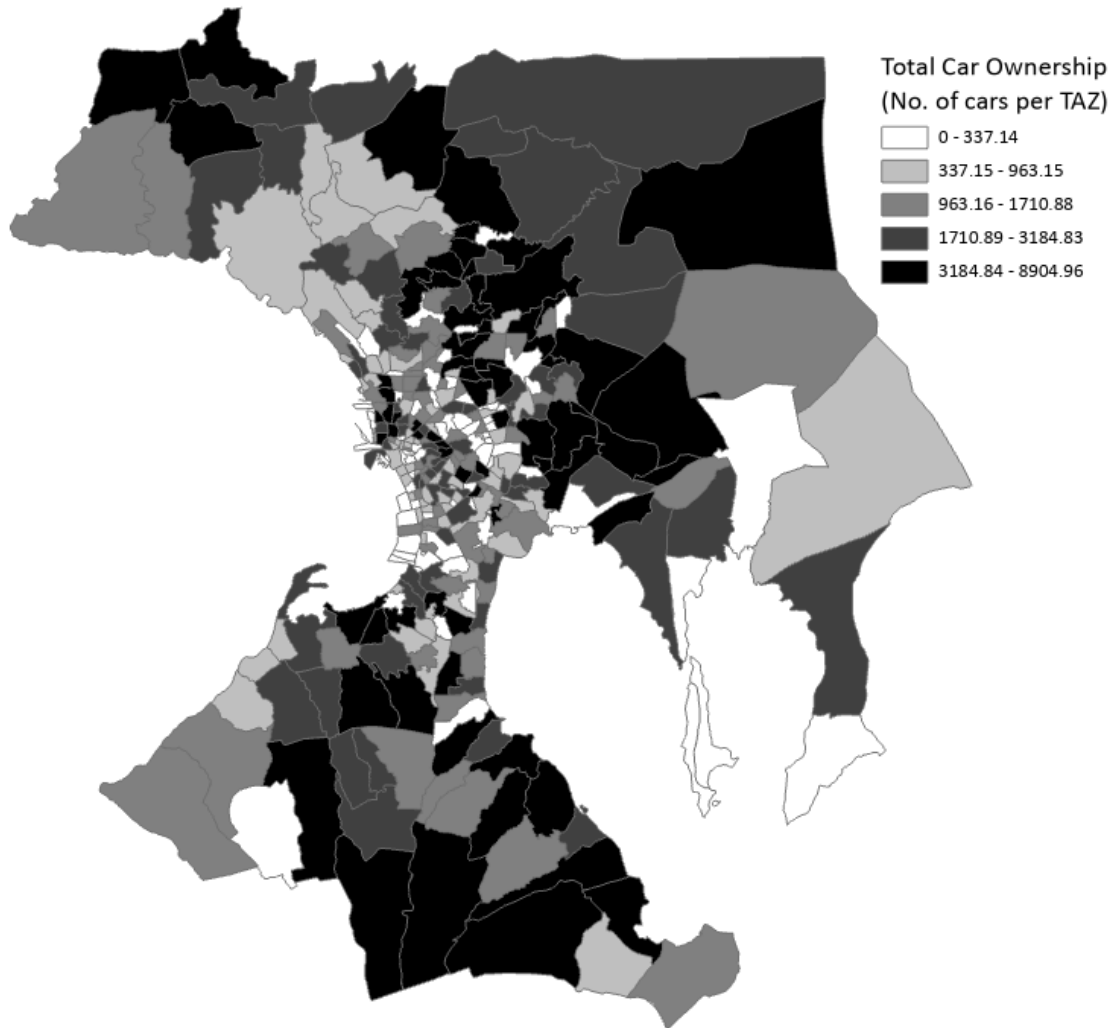
Log (Passenger Kilometers Traveled + 1)

$$= \beta_0 + \beta_1 \text{ Built Environment Measures} \\ + \beta_2 \text{ Socioeconomic Variables} + \mu$$

Dependent Variable

Vehicle Ownership

Figure 3. Total Car Ownership



Most households in the study area do not own cars or motorcycles. The share of households with no cars is 89% while those without motorcycles account for 80% of the sample, regardless of whether they own other types of vehicles. Households that own at least one of each mode account for only 3% of households. Figures 3 and 4 show the

spatial distribution of total car and motorcycle ownership by TAZ. Car ownership is higher in the urban core as well as in the peripheries of Metro Manila. In contrast, motorcycle ownership is generally low in the inner cities of the study area but higher at the peripheries.

Figure 4. Total Motorcycle Ownership

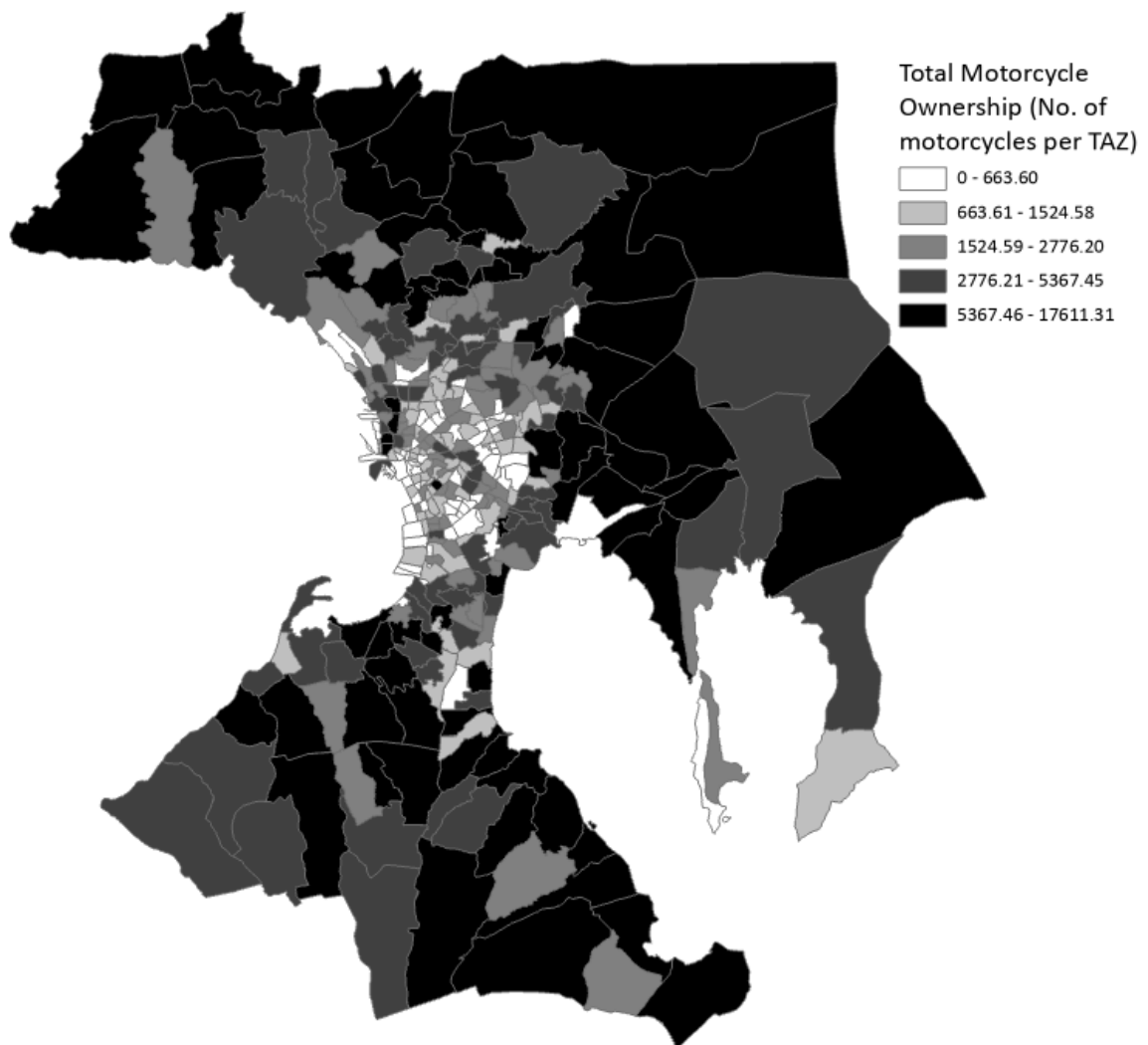
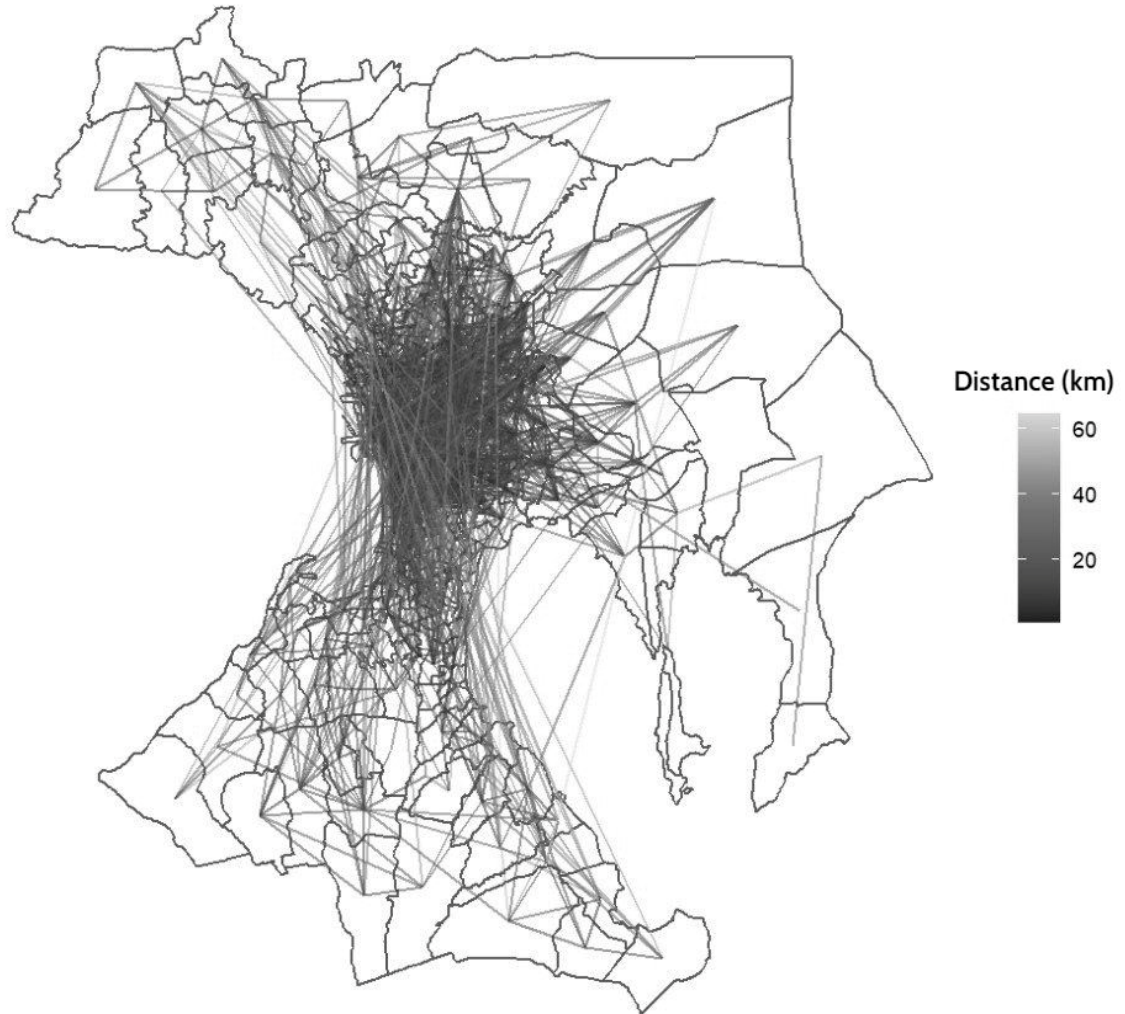


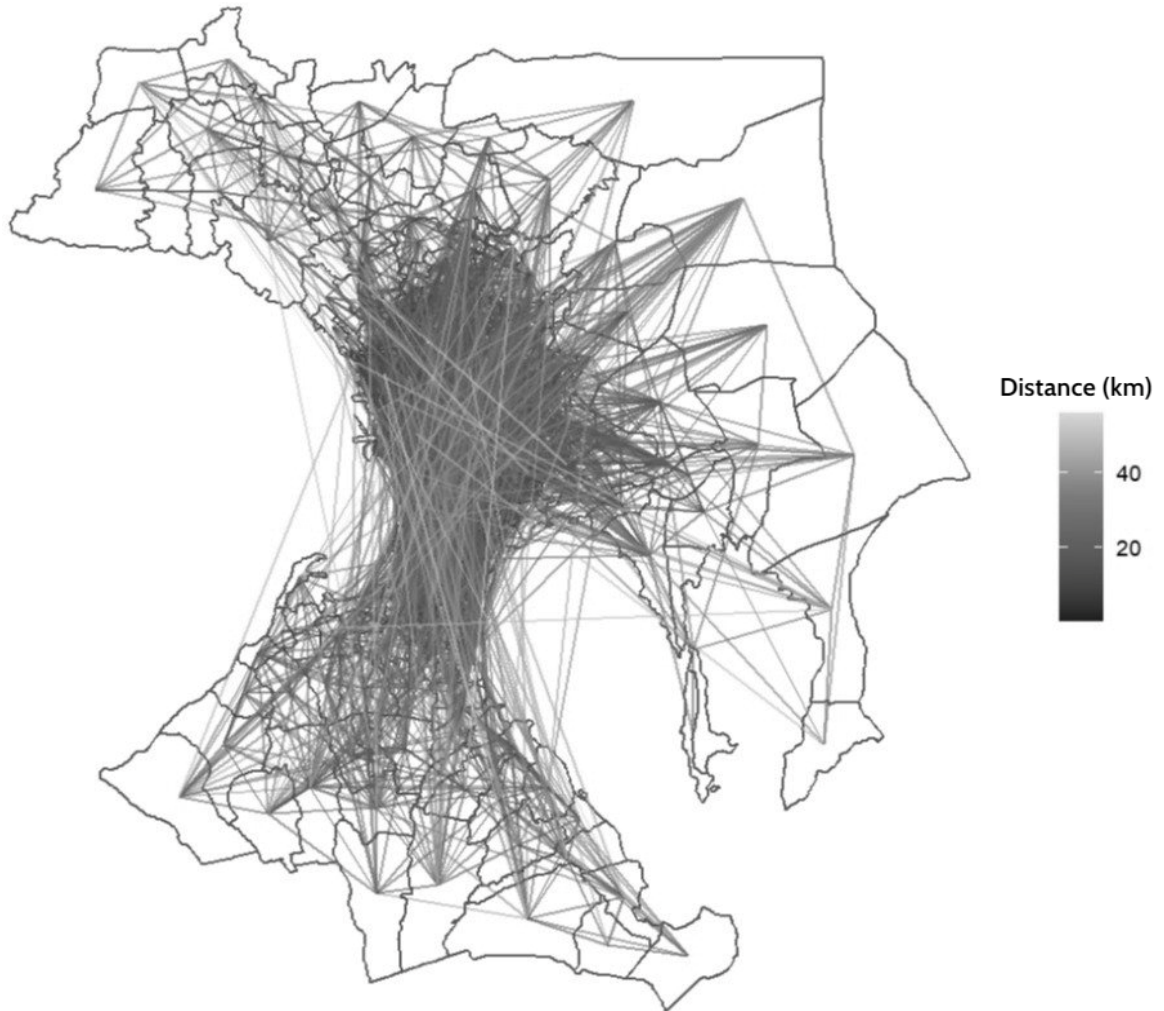
Figure 5. Passenger Kilometers Traveled of Car Trips



The PKT refers to the total distance traveled by households in cars and motorcycles. Because of the ease of calculation, a straight-line distance was used to calculate the PKT between the centroids of the origin and the destination zones. Figures 5 and 6 show the flow lines which represents the trips between the origin and destination TAZs unconstrained by the road network. The median distances for car and

motorcycle trips were almost similar at 6.7 km for car trips and 6.9 km for motorcycle trips. Figure 6 also illustrates that motorcycles are used for longer trips.

Figure 6. Passenger Kilometers Traveled of Motorcycle Trips



Independent Variable Selection

In their meta-analysis, Cervero and Ewing (2010) reviewed over 200 papers on the built environment and travel and included a list of the built environment variables used in each study. I use the same built environment measures in my research except when

the data is unavailable. All studies analyzed also controlled for confounding influences on travel behavior, including socioeconomic, attitudinal, crime, station, and level of service variables. With no reliable or granular data on these variables, I only controlled for socioeconomic characteristics in this study.

Measures of the Built Environment

I group these six built environment measures organized around the five Ds—density, diversity, design, destination accessibility, and distance to transit—discussed in the literature review. These built environment features are aggregated by TAZ.

Table 1. Built Environment Measures

Built Environment Measures	Variables
Density	Population Density
	Job Density
Diversity	Land use mix
Design	Road Density
	Intersection Density
Destination accessibility	Distance to the central business district
Distance to transit	Distance to railway stations

Using census data from 2012, the population density was computed by dividing the total number of respondents in a zone by its area in sq km. The population densities range from 0 people/sq km to 164,866 people/sq km. Fish ports and zones in the Port of

Manila do not have any resident population. Unsurprisingly, the TAZs within the Metro Manila region have higher population densities, with the City of Manila being the most densely populated.

Figure 7. Population Density

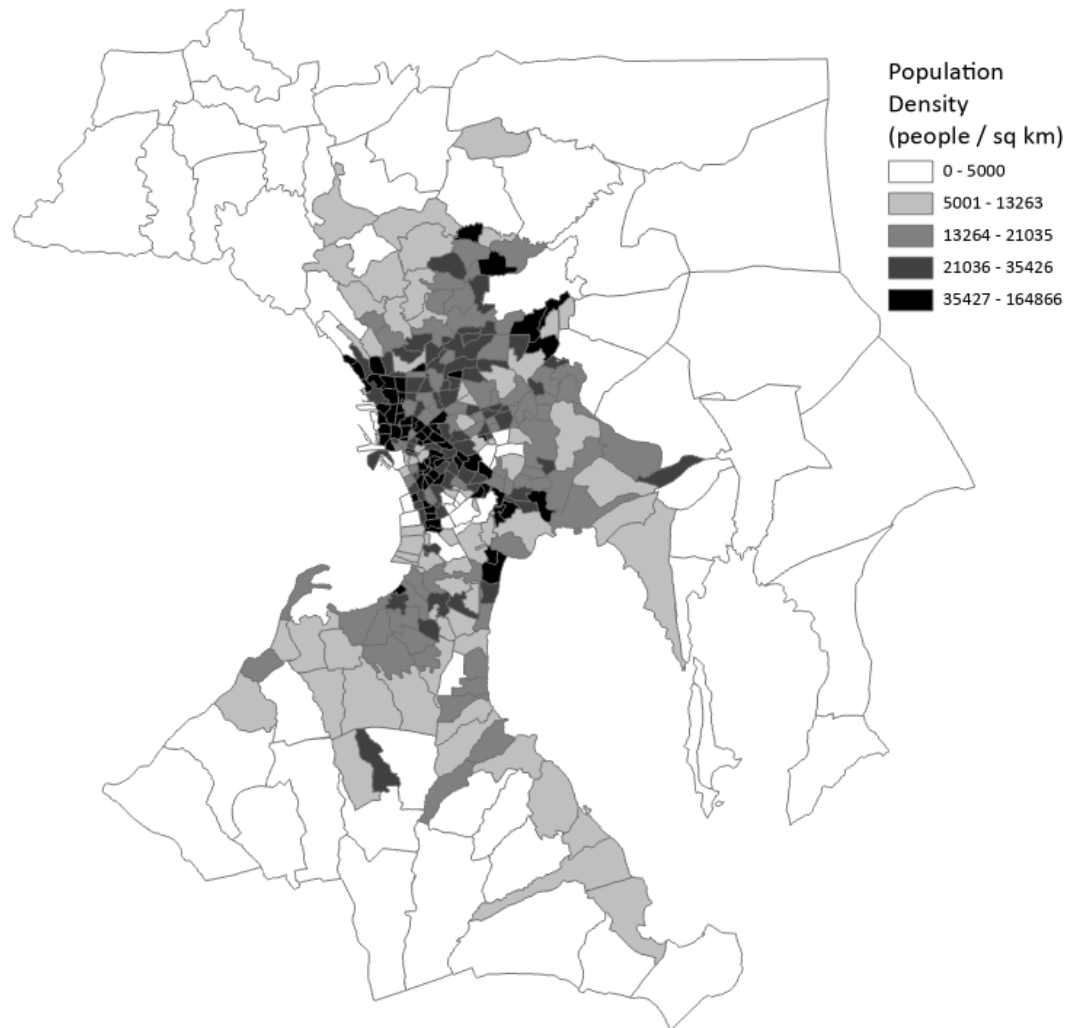
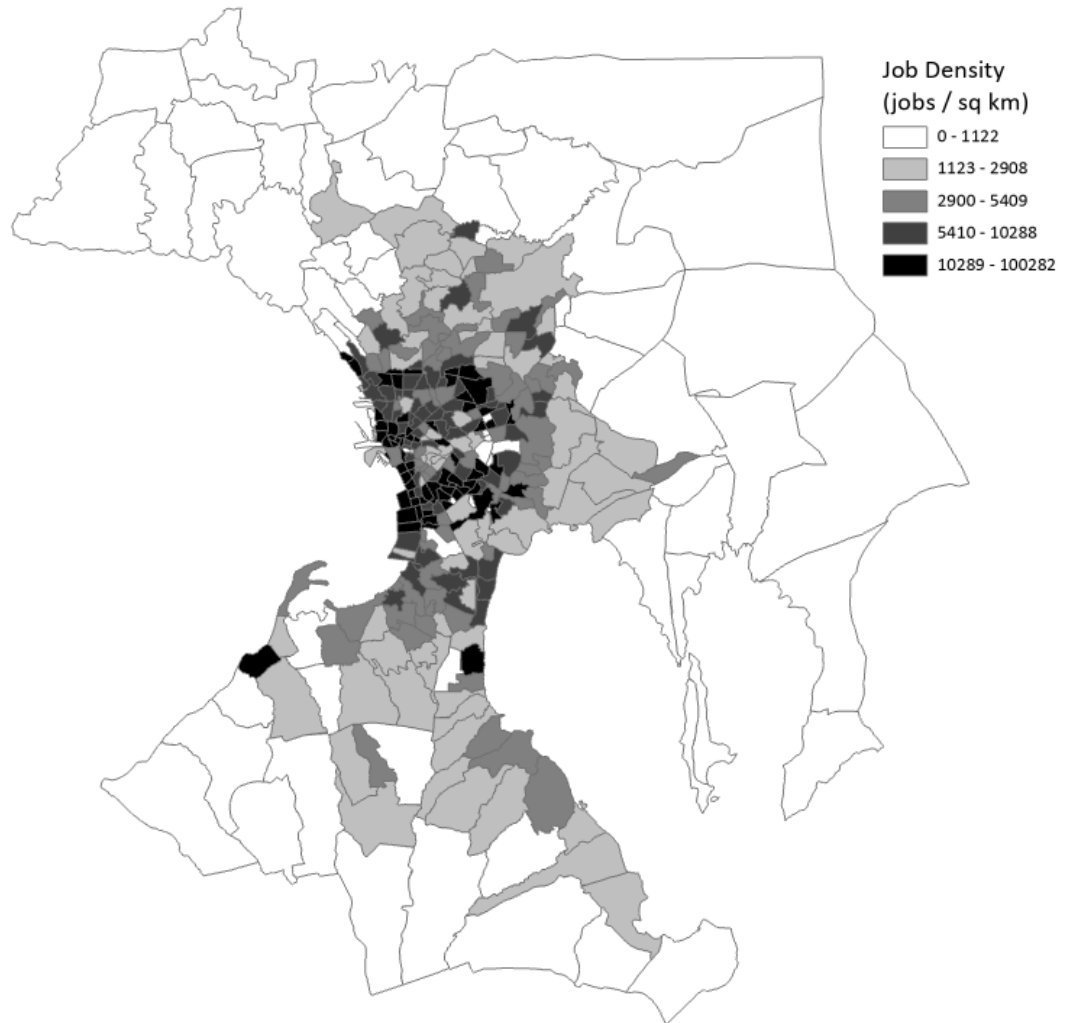
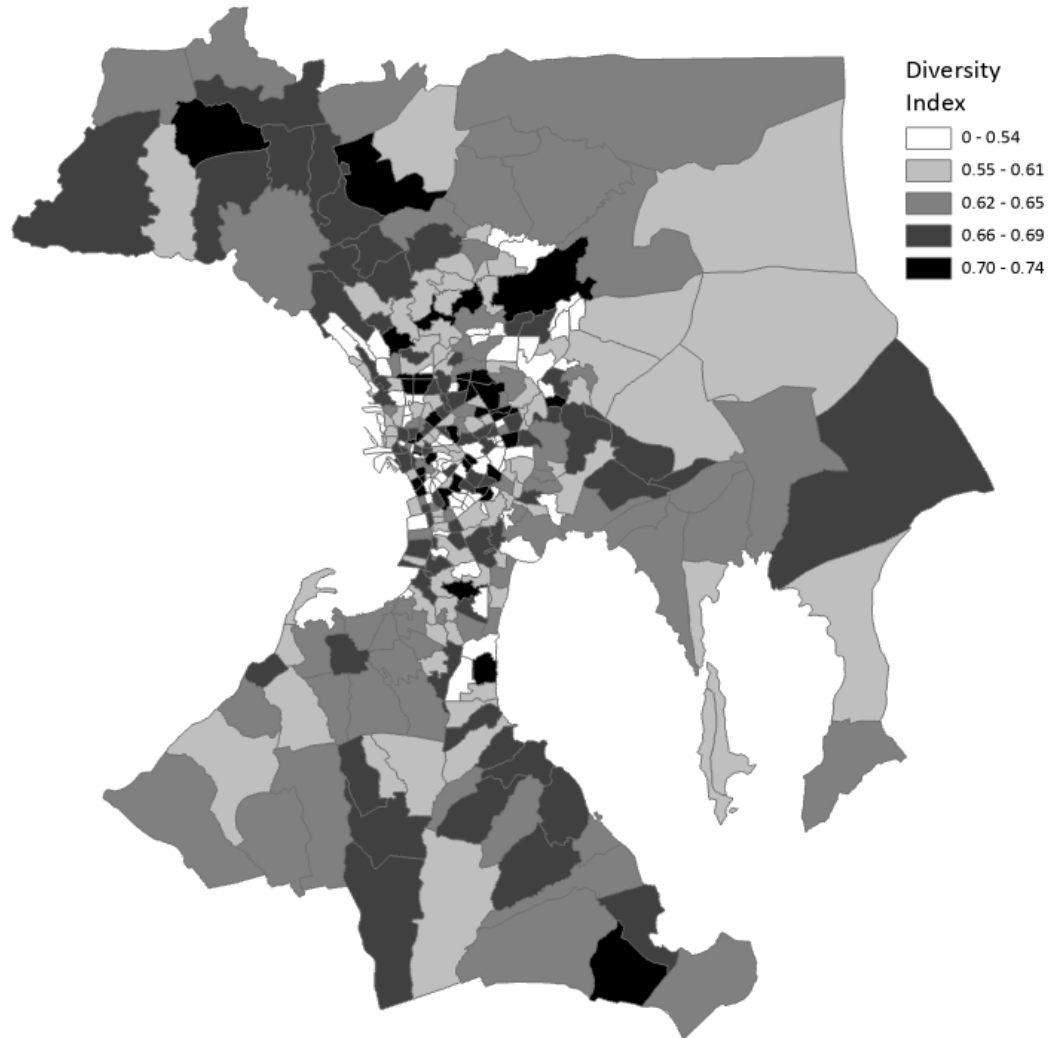


Figure 8. Job Density



Without data on the geographic distribution of jobs in the study area, I use the destination zones of work trips. The total number of work trips for each zone was divided by its area. Figure 8 shows a higher concentration of jobs in the inner core cities of Metro Manila. Since there were thirteen zones that were not work trip destinations, job densities range from 0 jobs/sq km to 100,282 jobs/sq km.

Figure 9. Destination Diversity



Due to data limitations, I am unable to measure land use diversity using an entropy index, which would require data on the different land use types within the study area. As a proxy for land use diversity, I use Simpson's Diversity Index to calculate this measure based on trip purpose. This diversity index was developed to measure species diversity but has since been adapted to measure land use and zoning diversity.

The zone destination diversity index is measured by the following equation:

$$D = 1 - \frac{\sum n(n-1)}{N(N-1)}$$

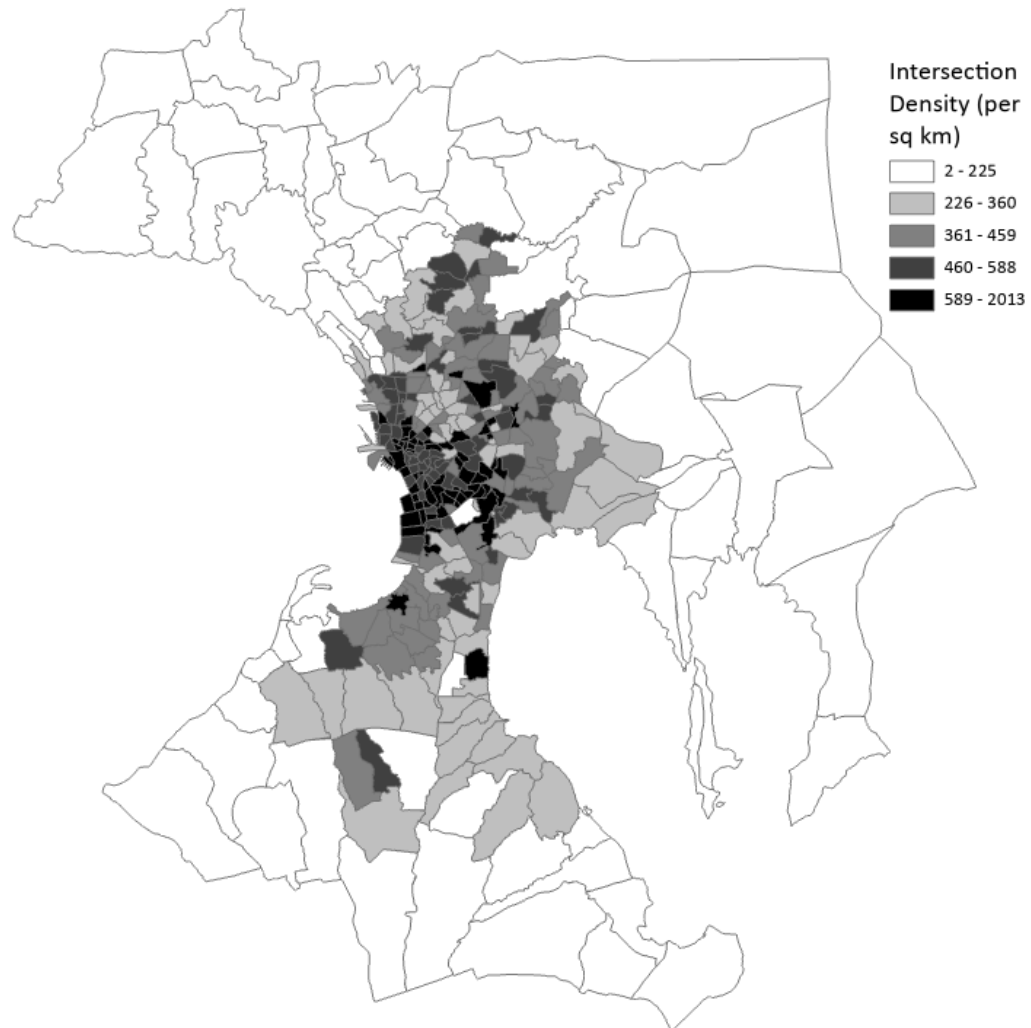
where DI is the diversity index in a zone, n is the number of trips for each purpose, and N is the total number of all trips. DI ranges from zero to one, where zero represents destinations in only one category, which indicates that the zone has less diversity, while a value of one represents an equal number of destinations for each trip purpose category.

In the MMUTIS-HIS questionnaire, respondents can choose from 13 different trip purposes. The share of work trips accounted for 16.6% of the total, while school and home trips made up 17% and 49.9% respectively. I grouped the remaining categories as private trips, which constitute 14.3% of total trips. Private activities include private business (1.3% of the total trips), employer's business (0.1%), medical (0.4%), social (0.7%), eating (0.2%), shopping (9.3%), worship (0.7%), recreational (0.4%), pick-up and drop-off (1.8%), and other (1.3%) trips. Since some zones only had one type of trip purpose, the diversity index scores range from 0 to 0.74. Zones with the most diverse destinations were spread throughout the study area. However, contrary to expectations, the least diverse zones were in Metro Manila.

Intersection density measures the number of intersections per sq km in each zone and provides information on the street design and connectivity. A higher density of intersections indicates more walkable zones and a smaller VKT. For this indicator, I included the primary, secondary, and tertiary links, as well as smaller street networks

including residential streets, footways, paths, and pedestrian roads downloaded from OpenStreetMap.

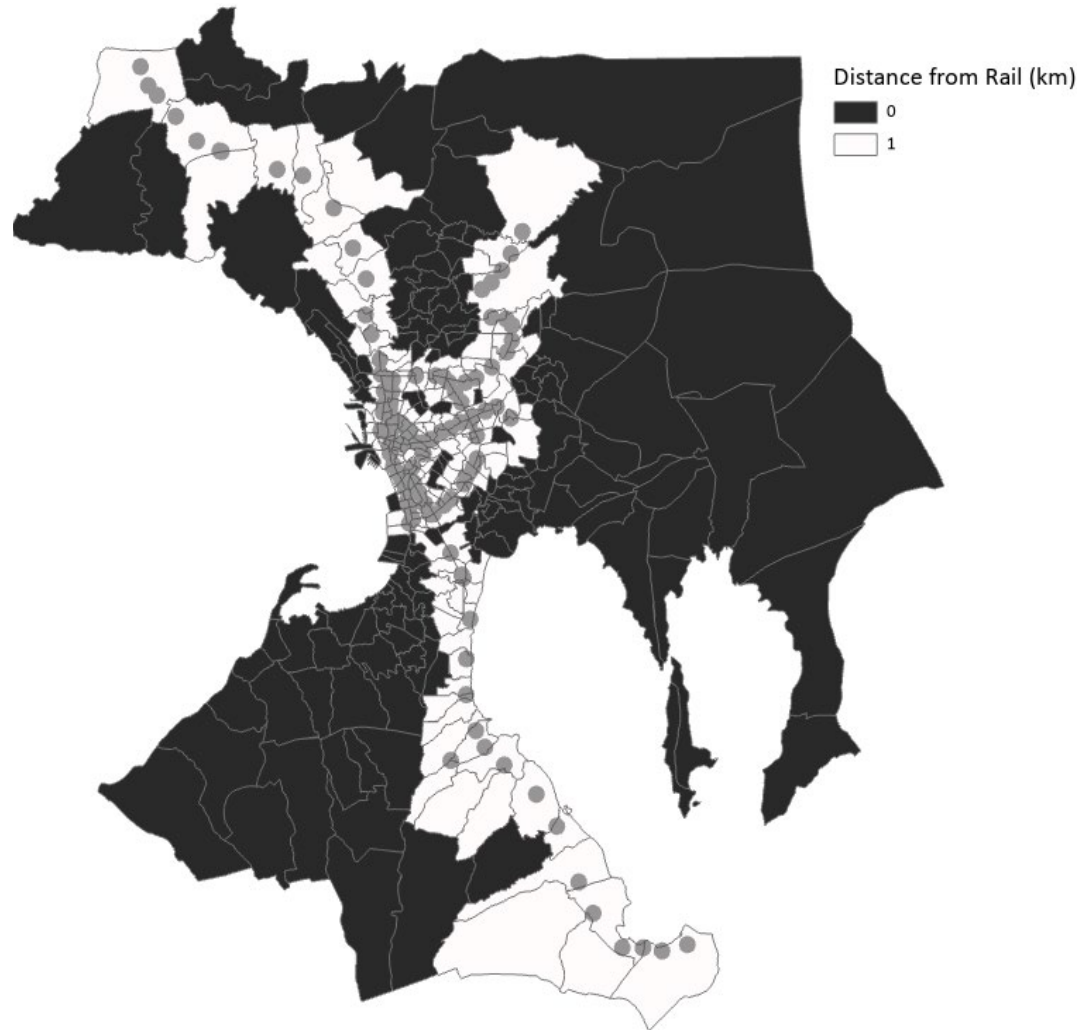
Figure 10. Intersection Density



Using railway stations data from the MMUTIS database, I created a half-mile buffer around each station. The half-mile distance from the rail stop has been the accepted standard for planning Transit Oriented Development. I created a binary variable, wherein zones that are within a half-mile distance from a railway station are

assigned a value of one and zones that are outside the catchment area have value of zero. There are 200 zones within the catchment area of the railway stations.

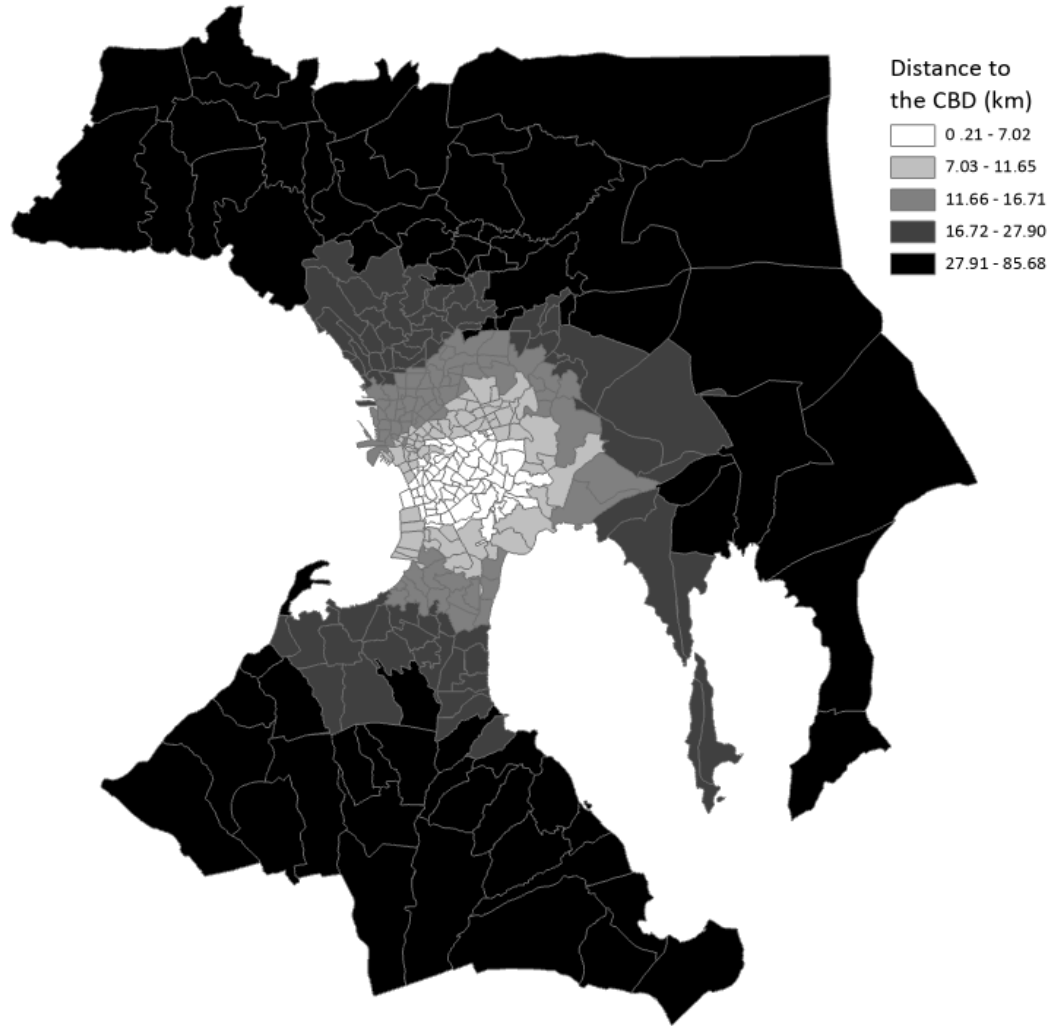
Figure 11. Distance from the Railway Station



Distance to the central business district (CBD) provides a measure for accessibility. Although there are several commercial hubs in the study area, I only calculated for the straight-line distance to the Makati CBD, the country's main financial hub. There is no official boundary that delineates where the CBD starts and ends, but for

this research, I combined the following TAZs: Legazpi Village, Ayala Center, and Salcedo Village.

Figure 12. Distance to the Central Business District



Socioeconomic Variables

To estimate the effect of the built environment on vehicle ownership and use, I included household socioeconomic characteristics in my model specification. The following variables were included in the model: mean age, income, number of working

adults, and household size. After testing for correlation, some variables were removed from the final model. For example, the number of children was highly correlated with the household size. Table 2 provides a summary of the socioeconomic and trip characteristics of the sampled households.

Table 2. Summary of Socioeconomic and Trip Characteristics

	1999	2015
<i>Socioeconomics</i>		
Average household income	PhP 11,109	PhP 10 – 15,000 ^a
<i>Demographics</i>		
Household population	13.6 million	18 million
Average Household Size	4.3	3.5
Average Number of Working Adults per Household	N/A	1.5
Mean Age	N/A	32.9
Car ownership by household	18.5%	11.5%
<i>Trips</i>		
Trip production rate ^b	2.3	2.23
To Work (share %)	17.3%	16.7%
To School (share %)	14.6%	14.7%
Private (share %)	22.4%	14.3%
To Home (share %)	45.7%	49.2%
<i>Mode share (% of motorized trips)^c</i>		
Motorcycle	0.7%	11.9%
Car	18.5%	11.7%
Public transport	69.8%	70.5%

Sources: Metro Manila Urban Integration Transportation Study (1999) & MMUTIS Update and Enhancement Project (2015)

^a The average household income falls within this range. Household incomes are grouped into categories in the 2015 survey.

^b Number of trips made by one person per day

^c Motorized trips accounted for 69% of total trips while walking trips made up 31% of total trips in 2015.

There is no official delineation of the different socioeconomic classes in the Philippines. The Household Questionnaire provides 18 monthly income ranges, which

were grouped into four classes – poor, low-income, middle-income, and upper-income – by aggregating the indicative ranges of monthly incomes based on the Family Income and Expenditure Surveys (Albert et al., 2018). Households with monthly incomes under PhP 9,999 (\$200) were categorized as poor, those earning below PhP 19,999 (\$400) were categorized as low-income, while those making under PhP 99,000 (\$1,980) and at least PhP 100,000 (\$2,000) were classified as middle income and upper income respectively. Poor households accounted for 38% of the sample, followed by lower income households at 36%. Middle income and upper income households comprised 25% and 0.35% of households respectively.

The average household incomes varied by zones. TAZs that had lower-income households were at the peripheries of Metro Manila, while zones near Makati CBD as well those that cover exclusive gated communities had higher income households.

In general, vehicle ownership is tied to income. Figures 13 and 14 provide the share of household vehicle ownership by income class. Car ownership rises with income. Higher-income households also tend to own more motorcycles. However, motorcycles primarily cater to the low and middle classes—income groups with the largest share of households that have one motorcycle.

Figure 13. Share of Household Car Ownership by Income Level

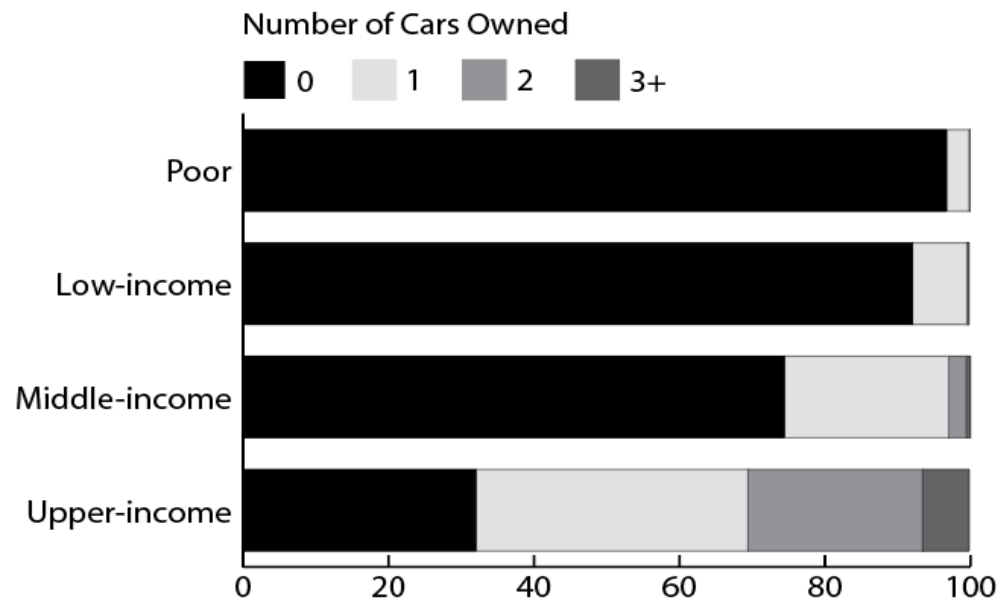
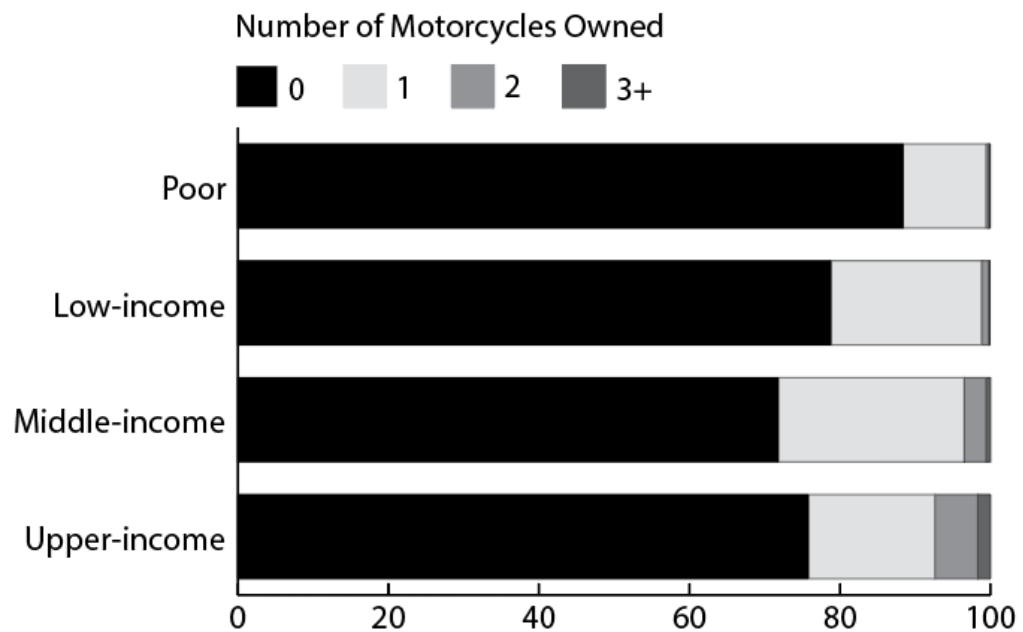


Figure 14. Share of Household Motorcycle Ownership by Income Level



Limitations

The built environment indicators used in this study could be refined with better data. For example, I used the trip data set to develop some of the built environment indicators. As a measure of land use mix, I used the trip purpose to calculate the destination diversity score. Since the share of activities such as private businesses, recreational, and social trips were small, I grouped them together under private trips, which meant that the diversity index scores may not reflect the mix of land uses in the TAZs. Figure 9 demonstrates this indicator's limitation, with zones in Metro Manila having low diversity scores. Similarly, without data on the spatial distribution of jobs, I used work trip destinations to calculate job density. However, some TAZs were not work destinations so their job densities were 0. These zones include Ayala Center, a major commercial center in the Makati CBD, as well as TAZs in the fisheries and port areas.

Results and Discussion

Model Estimation

Vehicle Ownership

Table 4 presents the model results and the odds ratios of car and motorcycle ownership. All built environment features for the car ownership model are statistically significant except for distance to the central business district. Since the coefficients are the log odds of vehicle ownership, I took the natural log to get the odds ratio. For example, for a unit increase in population density, the odds of owning a car is 0.9.

Households that are within a half mile from a railway station are associated with a 1.14 odds of owning a car. As expected, more diverse destinations and higher population densities lower the likelihood of owning a car. Socioeconomic characteristics such as household size, age, and income are all positively related to car ownership, while the number of working adults is negatively associated with car ownership. However, some of the variables also do not carry the expected signs. Higher job and intersection densities, and proximity to the railway station increase the likelihood of owning a car. Households that are farther from the CBD are less likely to own cars, but this indicator does not have a statistically significant influence.

For motorcycle ownership, only three built environment measures are significant. The probability of motorcycle ownership goes up for households living farther from the CBD and those in areas that are more densely populated. Households living in TAZs with higher intersection densities are less likely to own motorcycles. Although not statistically significant, land use diversity is positively correlated with motorcycle ownership, while areas with higher job densities and proximity to the railway station are associated with lower likelihood of motorcycle ownership. For the control variables, only income and age are statistically significant with motorcycle ownership.

Vehicle Use

Table 5 provides the model estimates of the Tobit model for the natural log of car and motorcycle use. Like the ordinary least squares regression coefficients, the Tobit regression coefficients also have a linear effect on the dependent variable, although this effect is limited to the uncensored latent variable. To interpret the change in outcome, I exponentiated the coefficient since the vehicle PKT was log transformed. For example, a kilometer increase in distance from the CBD is associated with a 0.6% decrease in the uncensored motorcycle PKT.

For car PKT, only the destination diversity and proximity to the railway station are statistically significant. As expected, households that live close to the railway station and in areas with a diverse land use mix are associated with lower car use. Although not statistically significant, higher population and job densities have a positive relationship with car use, while higher intersection densities and distance from the CBD are associated with lower distances traveled. Among the socioeconomic variables, only the number of working adults was not significant. Income, household size, and age are positively correlated with PKT.

For motorcycle trips, more built environment features have a statistically significant influence on PKT. Proximity to railway stations, land use diversity, and distance from the CBD are associated with lower motorcycle PKT, while higher population densities correlate with longer distances traveled. The household

demographics reveal that income and age are statistically significant with motorcycle use. Unsurprisingly, older households are less likely to use motorcycles. Larger households have higher motorcycle PKT and more working adults correlate with less motorcycle use, but these variables are not statistically significant.

Discussion

This research finds that the built environment influences vehicle ownership and use differently. Each of the built environment measures had the opposite relationship for cars and motorcycle ownership. For example, higher population densities lower the likelihood of owning a car but increases the probability of motorcycle ownership. Some built environment features, such as distance to the CBD, had a statistically significant effect on motorcycles but not on cars. Except for job and intersection densities, the built environment had a similar effect on car and motorcycle use. Finally, the results of the vehicle use models also reveal that vehicle ownership does not equate to vehicle use.

In line with previous research, destination diversity has a statistically significant association with both car ownership and use as well as with motorcycle use. In areas that have a more diverse land use mix, trips typically start and end in the same zone, reducing the distances that residents need to travel and making it easier to carry out activities on foot.

Proximity to a railway station is associated with lower motorcycle ownership and use, but contrary to expectations, this study finds that households within half a mile of

railway stations are more likely to own cars. This also runs counter to Rith et al.'s (2019) study, where they found that shorter distances to the railway station reduce vehicle dependency in Metro Manila. In Metro Manila, there are several high-rise apartment buildings near railway stations. The National Building Code of the Philippines requires property developers to provide a certain number of parking spaces. Previous research find that parking supply is an important determinant of car ownership (Guo, 2013; Millard-Ball et al., 2022).

Although households living near railway stations are more likely to own cars, they have lower PKT, indicating lower car use. This indicates that households prefer to have different transportation choices. Anecdotal evidence suggests that households would use transit if their destinations were easily accessible and connected to train routes.

While distance to the CBD is not statistically significant with car ownership and use, I find that households living far from the CBD have a higher likelihood of motorcycle ownership but tend to make shorter trips. As discussed earlier, motorcycle ownership is higher in TAZs at the peripheries of Metro Manila. This is also consistent with findings in cities such as Kuala Lumpur, Osaka, and Bogota (Yamamoto, 2009), where the distance to the city center had a positive effect on motorcycle ownership. The shorter distances traveled by motorcycles suggest the presence of subcenters in the peripheries.

Households living in more densely populated areas are less likely to own cars as expected but are more likely to own and use motorcycles. The results are similar to Yogyakarta in Indonesia where population density and motorcycle ownership had a positive relationship (Fevreira et al., 2021). Areas that have higher population densities also tend to be more congested (ADB, 2019). This could explain why population density impacts car and motorcycle ownership differently. Motorcycles have become popular largely because of their flexibility in navigating heavily congested roads.

Job densities are positively associated with car ownership, contrary to other studies. TAZs with higher concentration of jobs are typically located in financial and commercial areas where property values are higher and where wealthier households reside. Income levels are tied to car ownership and car owners make more trips. While not statistically significant, higher job densities unsurprisingly have a negative effect on motorcycle ownership and use.

Higher intersection densities correspond to smaller and more walkable blocks, but this study finds that it increases the likelihood of car ownership. In their meta-analysis on the built environment and travel literature, Cervero & Ewing (2010) observed that, compared to other built environment measurements, intersection density had the largest effect on walking. However, this indicator does not reflect the quality of the pedestrian environment. Leather et al. (2011) notes that although 35% of destinations in Metro Manila can be accessed in 15 minutes by walking or cycling, poor pedestrian infrastructure has forced commuters to shift to private motorized modes.

Table 3. Model Estimates and Odds Ratios from Car and Motorcycle Ownership Models

	Car		Motorcycle	
	Estimate (Standard Error)	Odds Ratio	Estimate (Standard Error)	Odds Ratio
<i>Built Environment</i>				
Population Density	-0.095*** (0.025)	0.909	0.039** (0.013)	1.039
Job Density	0.138*** (0.035)	1.148	-0.014 (0.026)	0.986
Destination Diversity	-1.529*** (0.311)	0.217	0.247 (0.186)	1.279
Intersection Density	0.131* (0.052)	1.140	-0.127*** (0.029)	0.881
Within a half-mile from a railway station	0.127* (0.050)	1.136	-0.011 (0.024)	0.989
Distance to the CBD	-0.002 (0.003)	0.998	0.005*** (0.001)	1.004
<i>Socioeconomic Characteristics</i>				
Household Size	0.139*** (0.021)	1.149	0.001 (0.011)	1.001
Mean Age of Household	0.039*** (0.002)	1.039	-0.016*** (0.001)	0.983
Working Adults	-0.316*** (0.029)	0.729	0.021 (0.017)	1.021
Household Income – Lower Income	1.077*** (0.085)	2.935	0.727*** (0.029)	2.069
Household Income – Middle Income	2.526***	12.501	1.134***	3.109

	Car		Motorcycle	
	Estimate (Standard Error)	Odds Ratio	Estimate (Standard Error)	Odds Ratio
	(0.082)		(0.035)	
Household Income – Upper Income	4.399*** (0.177)	81.353	0.810*** (0.188)	2.249
Intercept	-5.035*** (0.237)	0.007	-1.880*** (0.129)	0.152

*p-value<0.05; **p-value<0.01; ***p-value<0.001

Table 4. Model Estimates from Car and Motorcycle Ownership Passenger Km Traveled

	Car		Motorcycle	
	Estimate (Standard Error)	Percent Change	Estimate (Standard Error)	Percent Change
<i>Built Environment</i>				
Population Density	0.049 (0.029)	5	0.053* (0.022)	5.4
Job Density	0.013 (0.047)	1.3	-0.088 (0.048)	8.4
Destination Diversity	-1.536*** (0.351)	78.5	-3.055*** (0.320)	95.3
Intersection Density	-0.052 (0.062)	5.1	0.073 (0.051)	7.5
Within a half-mile from a railway station	-0.179** (0.058)	16.4	-0.239*** (0.042)	21.3
Distance to the CBD	-0.002 (0.003)	0.3	-0.006* (0.002)	0.6

	Car		Motorcycle	
	Estimate (Standard Error)	Percent Change	Estimate (Standard Error)	Percent Change
<i>Socioeconomic Characteristics</i>				
Household Size	0.061* (0.026)	6.3	0.026 (0.019)	2.6
Mean Age of Household	0.008** (0.003)	0.8	-0.005* (0.002)	0.5
Working Adults	-0.002 (0.035)	6.3	-0.034 (0.029)	3.4
Household Income – Lower Income	0.177* (0.080)	19.4	0.554*** (0.052)	74
Household Income – Middle Income	0.564*** (0.079)	75.8	0.702*** (0.0610)	101.8
Household Income – Upper Income	0.854*** (0.184)	134.9	0.748* (0.317)	111.3
Intercept: 1	2.251*** (0.265)	849.8	3.195*** (0.224)	2341.7
Intercept: 2	0.364*** (0.014)	43.9	0.613*** (0.009)	84.7

*p-value<0.05; **p-value<0.01; ***p-value<0.001

While intersection density had a positive association with car ownership, it had the opposite effect on motorcycle ownership. That is, households that live in areas with a more compact and connected street network are less likely to own motorcycles. Interestingly, although not statistically significant under the vehicle use model, the probability of motorcycle use goes up with higher intersection densities, while the probability of car use goes down. It is likely that smaller, local streets are more conducive to motorcycle travel.

Conclusion

The built environment has the potential to influence travel and ownership behavior. While several studies have explored this relationship, research on how the built environment's effect varies across private motorized modes remain limited. To fill this gap, I sought to answer the following research questions: *What is the relationship between the built environment and car ownership and use in Metro Manila? How does this relationship differ for motorcycle ownership and use?*

I find that the built environment influences vehicle ownership and use differently. More diverse land uses and proximity to a railway station have the potential to lower both car and motorcycle use. Households residing in areas with high concentrations of jobs tend to be wealthier car owners who drive more. Although motorcycle ownership is higher in the peripheries of Metro Manila, the presence of

subcenters shorten trip distances. Smaller and more connected street networks lower the likelihood of motorcycle but not car ownership.

Since the urban form varies for each city, the results of this study are not generalizable for other urban contexts. This thesis provides a foundation for future research, especially in rapidly motorizing cities where the share of motorcycle trips is competing with car trips. Future studies could focus on using different analysis methods and refining the built environment indicators. A multinomial logit with several outcome variables could provide more insights on a household's decision to own one, two, or more cars, motorcycles, or both. With access to better data, there are several opportunities to explore and develop other built environment indicators. For example, using zoning data instead of trip purposes would better capture the diversity of land uses.

Future household travel surveys should consider including ride-hailing services as its own travel mode category, separate from car and motorcycle passenger trips. The data for the MMUTIS-HIS was mostly collected in 2014, the same year that ride-hailing services were introduced to the Philippine market, and half a decade before the pilot implementation of motorcycle taxis. These ride-hailing services have become increasingly popular. In several US cities, studies have shown that these services have led to reductions in the utilization of public transportation modes (Rayle et al., 2016; Ngo et al., 2021).

The findings of this study highlight the need for decisionmakers to focus on strategies that promote more compact and connected urban development and prioritize investments in mass transit. The government should expand and improve pedestrian infrastructure, especially since walking accounts for almost a third of trips in Metro Manila. Railway expansion plans should focus on connecting and improving accessibility in motorcycle dependent areas. Motorcycles largely cater to the low- and middle-income classes and mass transit improvements would benefit them most. The share of motorcycle trips has already surpassed that of cars and until public transportation and alternative modes of travel become more reliable, this trend will likely continue over time.

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