

Article

Is Built Environment Associated with Travel Mode Choice in Developing Cities? Evidence from Hanoi

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Abstract: This paper examines the association between the built environment (BE) and travel behavior in Hanoi, Vietnam. A multinomial logit model is used to analyze individuals' choice of travel mode from a dataset collected via a questionnaire-based household travel survey in 2016 and the geospatial data of BE variables; the dataset contains 762 responses from local residents in ten districts of the Hanoi Metropolitan Area about their daily travel episodes. It also examines a spatial aggregation effect by comparing model performances among four buffering distances and ward-zones. The results showed that (1) a higher population density around an individual's home is associated with more bus use and less motorbike and car use; (2) mixed land use around the home, average tax revenue near the home, and bus frequency at the workplace have positive relationships with bus ridership; (3) senior people, students, or unskilled laborers tend to use the bus; (4) the spatial aggregation bias significantly affects the estimation results; and (5) new immigrants tend to choose to reside in areas designed for automobile users. Finally, there are several policy implications for transit-oriented development (TOD) in Hanoi, including: (1) parking regulations and/or control strategies should be jointly incorporated into the Hanoi's TOD policy; (2) Hanoi's TOD policy should be carefully designed in terms of its scope of development site and type; and (3) a polycentric structure strategy only may not be sufficient for increasing public transit ridership.

Keywords: built environment; travel mode choice; transit-oriented development; Hanoi

1. Introduction

Many developing cities have suffered from serious traffic congestion, which prevented cities from achieving sustainable development [1–5]. The serious traffic congestions in cities of the developing world are caused by a combination of rapid motorization, rising incomes, urban sprawl, undeveloped road systems, and spatial mismatches [6]. Cervero [7] suggests that integrated transportation and land-use planning needs to be elevated in importance in developing cities before it is too late. Meanwhile, over the past decades, the idea of urban sustainable development has been discussed in the developed world in terms of the “good city” and desirable urban planning policy [8]. It includes many urban concepts such as New Urbanism, mainly in US, where the movement began as an environmental and aesthetic critique of suburban sprawl [9,10] and Compact Cities, which are characterized by high density, mixed land use, pedestrian-oriented habitation, the utilization of development reserves for construction projects, and the structural transformation of former industrial areas or fallow land into service or residential areas of high quality [11–14]. One of them is transit-oriented-development (TOD),

which is “a push from practitioners, academics and some governments towards more transit-connected, compact, and mixed-use cities, and neighborhoods that are more walkable, more bikeable, and more complete” [15,16]. Recently, many developing Asian countries, such as India, China, and Thailand have begun to examine the feasibility of introducing TOD in order to deal with their urban problems [17–21].

The introduction of TOD policy has been debated in Vietnamese cities, especially in Hanoi [22], the capital, with an area of 3324.52 km² and a population of 7.2 million as of 2014. Hanoi has been urbanized and extended its margins, incorporating agricultural and multi-activity villages since the introduction of Doi Moi (renovation) reforms in 1986 [23–28]. Registered cars and motorbikes increased at 10.2% and 6.7% per year from 2011 to 2016, respectively, while the total length of road networks increased at a yearly average of 1.54% in the same period, leading to serious traffic congestion in many parts of the city [29]. The high traffic volume in streets also damages the livability for local people [30]. In line with TOD policy, the Hanoi People’s Committee (HPC) has been improving the public transit service by, for example, enhancing the bus system, introducing a new bus rapid transit (BRT) line, and constructing three new metro lines [31]. Hanoi’s TOD plan was first introduced in 2011, following the “Hanoi Capital Construction Master Plan up to 2030 and Vision to 2050,” which was approved in 2010. As a part of this project, the TOD guidelines were introduced in November 2015 and were regarded as the most detailed TOD plan in Hanoi as of June 2018. Although the plan has expected possible TOD effects, its effects have rarely been examined empirically in Hanoi, which is characterized by extremely high population density (nearly 30 thousand people per km² in the central districts) and poor public-transportation use (its modal share in 2016 accounts for only 5.7% in Hanoi).

This study thus aims to analyze empirically the associations between TOD planning factors, especially the density and diversity of the built environment (BE), with individuals’ choice of travel mode, using household travel data for Hanoi, Vietnam, in 2016. This analysis also pays attention to spatial units of BE measures in terms of their relationship with travel behavior. Detailed geospatial data for Hanoi measured in 2010 were installed into a GIS database to compute the BE variables in different geographical units. The paper is organized as follows: a summary of the existing literature is mentioned below, followed by a description of data characteristics and methodology. Then, the results are summarized, and further research directions are discussed.

2. Literature Review

A number of studies have empirically investigated the relationship between the BE and travel behavior since the 1990s. The BE was first classified by Cervero et al. [32] into three Ds: density, diversity, and design, and later extended to five Ds including destination accessibility and distance to transit [33]. Following their classification, many researchers have presented empirical evidence about the association of BE elements with travel behavior. BE variables examined in the past studies include population density [34,35]; job/business density [36,37]; land use mixture (diversity) [38–40]; design for walkability, street connectivity, or intersection density [41]; transit access such as proximity to transit stops and stations [42,43]; and distance from the central business district [44]. Empirical findings from those studies are quite mixed. Some studies showed that transit ridership depends on local densities more significantly than mixed land use, while walking depends primarily on mixed land-use and secondarily on local densities [45]. In addition, both transit and walk modes are found to be more dependent on employment densities at destinations than on population densities at the origins. However, these conclusions might be inconsistent with a TOD approach based on the residential density and neighborhood design. Meanwhile, Frank and Pivo [46] found that work and shopping trips to destinations with high employment densities took longer, probably because of traffic congestion or low accessibility. Handy [47] found that it was not the density itself that matters but what comes with this density. They also suggested that density might be an influential factor in automobile reduction, although its importance is still unclear.

One of the issues in the empirical studies about BE effects on travel behavior is a self-selection [48]. The relationship between “residential self-selection” and travel behavior has gradually been gaining

more attention from researchers. Residential self-selection in this context refers to “the tendency of people to choose locations based on their travel abilities, needs and preferences” [49]. The residential self-selection is affected by people’s attitudes and sociodemographic characteristics, for example, people who usually use public transit tend to reside in an area that has better accessibility to the public transit. In such a case, it is not the service quality of transit but rather households’ socio-economic status that directly affects the travel mode choice. As presented by Cao et al. [50], studies regarding residential self-selection fall into nine groups, including: direct questioning, statistical control, instrumental variables, sample selection, propensity score, joint discrete choice models, structural equation models, mutual dependent discrete choice models, and longitudinal designs. Research studies using longitudinal datasets are preferable for directly accessing residential self-selection; however, it has been so far applied by few studies due to the poor data availability.

From a methodological viewpoint, administrative boundaries, or traffic analysis zones have been used as geographic units in most previous studies due to data availability or time restrictions. However, the BE measured in such fixed spatial areas cannot avoid spatial aggregation bias, so-called Modified Areal Unit Problem (MAUP) bias [51]. Several studies have shown that land-use patterns computed at different geographic sizes can produce different empirical estimates [52]. To deal with the MAUP bias, many researchers have calculated the BE at different geographic sizes, usually at different buffering distances or grid sizes, and test these BE in their models to choose the most preferable buffering or grid size [53,54].

It should be noted that many of the abovementioned studies have focused on developed cities, mostly in US, where the BE characteristics are different from cities in developing countries. Cervero [7] summarized that major differences in spatial forms and land-use characteristics in cities of the developing world from those of the developed world are primacy, levels of monocentric city, population densities and trends, roadway designs, and geographic locations of the poor. Cervero et al. [55] conducted one of the earliest studies to analyze the situation in developing countries, which studied the influences of BEs on walking and cycling in Bogotá, Colombia, assuming that the BE variables are expressed with the five Ds. The results showed that the association between the BE and travel behavior that had been found widely in the developed world was not observed in Bogotá.

Asia’s developing countries, including Vietnam, have recently been exploring the relationship between the BE and travel behavior in the same way as the developed world; however, difficulties in data collection have enabled few studies to challenge this relationship so far. One of the recent exceptional studies is that of Ho and Yamamoto [56], who analyzed the roles of attitudes and public-transportation services on vehicle ownership in Ho Chi Minh City (HCMC). They investigated the impact of the BE on the number of vehicles with respect to personal attitudes using a Generalized Nested Logit model with data collected through a large-scale urban household interview survey in HCMC. Their dataset contains household and individual attributes, travel diaries, perceived characteristics, and attitudinal data. The BE was measured as one of perceived characteristics as well as objective measures of accessibility. They found that mixed-use developments induced people to use alternative modes to the private car and that the change in the BE, regarding improving walking/cycling conditions, may have resulted in a lower level of motorized vehicle ownership. Public transportation service in term of bus coverage and ease of use had strong negative influences on the propensity for owning vehicles. Transportation supply conditions also affected household vehicle ownership. Negative traffic externalities had negative effects on motorcycle and bicycle ownership. Besides, the effect of household socio-demographics appeared to play an important role in explaining household vehicle ownership behavior. They found that high income households were more likely to own vehicles and to have more than one vehicle, households with children younger than 6 years old always owned at least one vehicle, and house area affected vehicle ownership since large houses were more inclined for parking a car or more than one motorcycle. Their research contributed to the hypothesis that there is a connection between the BE and travel behavior in developing countries. However, the BE variables in their model were measured using perceived characteristics, which may be highly dependent on

personal perceptions and, thus, may not reflect accurately the BE features in HCMC. Another recent study of the relationship between the BE and travel behavior in Vietnam is that of Tran et al. [57], which investigated the roles of land-use attributes in travel modal choice for two types of workers in Hanoi. They found that knowledge-intensive workers were less likely to use motorbikes or bicycles if they resided in areas with a higher population density, but were more likely to use motorbikes if they worked in areas with a higher employment density; meanwhile, unskilled-workers were less likely to use motorbikes or bicycles if they resided in areas with more land-use diversity, but were more likely to use motorbikes and bicycles if they worked in areas with more land-use diversity. However, they assumed that Hanoi was geographically divided into only three zones of urban core, urban fringe, and suburb, which may have distorted the unique features of Hanoi city, and thus, may have led to a serious spatial aggregate bias. Besides, respondents in their study had a set of three modal options of walking, bicycles, and motorbikes, which may not sufficiently reflect the practice of urban trips in Hanoi. Additionally, their study did not show evidence on the effects of commuting costs (time) and did not take account of transit mode—the main component of the future TOD concept in Hanoi. To address these shortcomings, we compute all BE variables based on GIS digitalized data from Hanoi current maps and analyze a modal choice of four modes: motorbikes, cars, bus, and bicycles, which can represent better the travel patterns in Hanoi.

In summary, a question about whether the BE affects Hanoian's choice of transit mode is still unanswered. This study adds new evidence about the possible relationship between the BE and travel behavior using an empirical dataset from Hanoi.

3. Materials and Methods

3.1. Questionnaire Survey

This study uses a dataset collected through a local questionnaire survey, which was designed and conducted by a study team from the University of Tokyo and Vietnam Japan University, from 1 December 2016 to 25 December 2016. The respondents were chosen randomly in the southern part of Hanoi Metropolitan Area, which consists of eight urban inner districts and two suburban districts: Hoan Kiem district, Ba Dinh district, Tay Ho district, Hai Ba Trung district, Dong Da district, Hoang Mai district, Cau Giay district, Thanh Xuan district, Bac Tu Liem district, and Nam Tu Liem district. All districts are located on the southern side of the Red River, which is the most developed area in Hanoi Metropolitan. Six interviewers chose the households randomly and interviewed them at their houses or at the public places in target areas. The survey team obtained support from a local professional survey company to implement the face-to-face interviews. The respondents were requested to provide their basic information, such as age, gender, marital status, occupation, home address, work address, motorbike license, motorbike ownership, car license, and car ownership in line with the details of their daily travel behavior such as commuting mode, commuting time, and how many vehicle kilometers they traveled on weekdays and weekends, and their household attributes such as the number of household members and of those in the household who worked, the total monthly household income, number of vehicles owned by the family, the width of the road to access the house, and length of residence. The survey collected answers from 1000 respondents aged over 18 years old through a random sampling process, of which 762 valid respondents were used for our empirical analysis. Figure 1 illustrates the study area and the geographical distributions of the respondents' houses and workplaces.

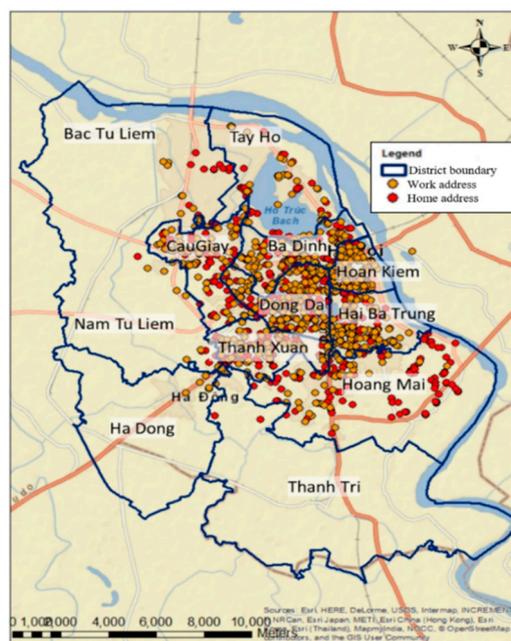


Figure 1. Locations of Respondents' Homes and Workplaces (Source: Created by the authors, using source map from Open Street Map).

3.2. Socio-Economic Characteristics of Respondents

Tables 1 and 2 summarize the socio-economic profiles and the descriptive statistics of the sample dataset, respectively. Male respondents account for 50.39% of the total, reflecting the gender distribution in Hanoi. Although most of the respondents are married (67.59%), the average age of respondents is only 36 years of age, which reflects the fact that the young generation is dominant in Hanoi. The most common job type involves knowledge-intensive labor (54.98%), including government officer (14.3%), private-company officer (31.5%), university researcher (2.1%), doctor (1.57%), and schoolteacher (5.51%). Service workers, unskilled workers, and street vendors/shopkeepers account for 9.45%, 6.56%, and 6.69%, respectively while housewives/unemployed/retired people and pupils/students account for 4.86% and 11.55%, respectively. In relation to motorbikes, 92.52% of respondents are owners, and 95.54% have motorbike licenses. These results reflect the fact that most Hanoians use motorbikes for commuting. In addition, 11.02% of respondents own cars, and 22.18% of respondents have car licenses, which may mean that the number of cars will grow in the future. The results also show that the average number of household members is 3.23 while the average number of working members is 2.09. This means that most respondents belong to quite small families, typically nuclear families. The average monthly household income is around VND 20,000,000, which is slightly higher than the average household income in Hanoi. The average numbers of motorbikes and bicycles owned by respondents' households are 2.19 and 1.26, respectively. The average width of the road accessing their place of residence is 3.78 m (one-lane road). This reflects the poor condition of the streets in Hanoi, with narrow lanes and substandard road space, which could be one of major factors leading to the dominant share of motorbikes in the city. Next, the data about commuting mode indicates that 75.98% of respondents choose motorbikes to commute to work/school every day, followed by walking (6.3%), bus (5.91%), car (5.91%), bicycle (4.2%), and other modes such as taxi (1.71%). These results reflect the truth that motorbike is the most popular commuting mode in Hanoi. The share of bus ridership in this survey is slightly lower compared to other previous values about bus ridership, at about 9%. A possible reason for this situation is due to the respondents' occupation and high-income level. In addition, when comparing the percentage of respondents using motorbikes for commuting (75.98%) with the motorbike ownership of respondents (92.52%), there are nearly 20% of respondents who own motorbikes but do not use them for commuting. Too short or too long commuting distance may be one

of the reasons for this situation. Another reason for this situation might be the dual ownership of a car and a motorbike. According to the data on a household's vehicle ownership, there are more than 99% of households who own cars and motorbikes, while only 1% of households owning a car do not have any motorbikes.

Table 1. Socio-economic Profiles of Respondents ($N = 762$).

Characteristics		Percentage of Respondents	Characteristics		Percentage of Respondents
Gender	Male	50.39%	Marital status	Single	32.41%
	Female	49.61%		Married	67.59%
Occupation	Government officer	14.30%	Shopkeeper/street vendor		6.69%
	Private-company officer	31.50%	Student		11.55%
	University researcher/teacher	2.10%	Service worker		9.45%
	Doctor	1.57%	Dependent		4.86%
	Schoolteacher	5.51%	Other		3.15%
	Unskilled worker	6.56%	Refused		2.76%
Motorbike license owner	Yes	95.54%	Motorbike owner	Yes	92.52%
	No	4.46%		No	7.48%
Car license owner	Yes	22.18%	Car owner	Yes	11.02%
	No	77.82%		No	88.98%
Commuting mode	Walk	6.30%	Bus		5.91%
	Bicycle	4.20%	Car		5.91%
	Motorbikes	75.98%	Others		1.71%

Table 2. Descriptive statistics of attributes of respondents ($N = 762$).

Attributes	Min	Max	Mean	Median	SD
Age	18	71	36.95	36	12.11
Household size	1	10	3.23	3	1.22
Number of working people	0	10	2.09	2	0.97
Monthly household income (million VND)	1.5	52.55	20.01	17.55	11.58
Number of motorbikes	0	7	2.19	2	0.85
Number of bicycles	0	4	1.26	1	0.53
Width of road access to house	0.5	40	3.79	3	2.89

Note: VND 1000 = USD 0.044 as of 2016.

3.3. Methods

This study employs a simple multinomial logit (MNL) model for an individual mode choice among a bus, motorbike, car, and bicycle. It assumes that an individual maximizes her/his utility function when choosing a transportation mode. The utility function of each mode is assumed as follows:

$$U_{in} = V_{in} + \varepsilon_{in} = \beta_{i0} + \beta_{i1}X_{in1} + \beta_{i2}X_{n2} + \beta_{iBE}X_{nBE} + \varepsilon_{in}$$

where U_{in} is the utility function of mode i of an individual n , V_{in} is a systematic component of the utility function of mode i of an individual n , ε_{in} is an error component, X_{in1} is a vector of transportation-related variables of mode i of the individual n , X_{n2} is a vector of socio-economic variables of the individual n , X_{nBE} is a vector of BE variables of the individual n , and β_{i0} , β_{i1} , β_{i2} , β_{iBE} are the unknown coefficients. When the error component follows the independent and identical distribution of Gumbel, a probability of choosing a travel model i for the individual n is expressed as:

$$P_{in} = \frac{\exp(V_{in})}{\sum_j^{M_n} \exp(V_{jn})}$$

where M_n is a choice set of the individual n . The size of choice set could vary across respondents depending on the availability of transportation modes. Because all respondents are located in areas where public transit networks cover, we assume that everyone can access the bus network.

3.4. GIS-Based Database and BE Measurement

A GIS-based database was originally created by the authors' study team using the geospatial data sources from the Hanoi Urban Zone Planning, which was developed in 2010. The GIS-based database enabled us to produce five dimensions of BE measures: density, diversity, design, distance to transit, and destination accessibility. Each dimension was measured for four different buffering distances (100 m, 200 m, 500 m, and 1000 m) around both trip origin and destination. The "density" is computed both for population density and employment density; "diversity" is represented by an entropy index of land-use mix; "design" consists of street density and the number of four-way (or more) street intersections; "distance to transit" is represented by the bus frequency within the buffering area; and "destination accessibility" is measured by the number of public facilities or the number of schools inside the buffering area.

The population and employment densities in the different buffering zones are computed using data at the ward-scale (the smallest administrative boundary in Hanoi) due to the constraints of data availability, as shown below:

$$X_{nPD,R} = \frac{\sum_{k \in K_{n,R}} Z_{PDk} A_k}{A_{nR}}$$

$$X_{nED,R} = \frac{\sum_{k \in K_{n,R}} Z_{EDk} A_k}{A_{nR}}$$

where $X_{nPD,R}$ represents the population density in a buffering zone (R) for the individual n , Z_{PDk} represents the average population density in a ward k , A_k is the area in the ward k , A_{nR} is the area of the buffering zone (R) for the individual n , $X_{nED,R}$ represents the employment density in the buffering zone (R) for the individual n , Z_{EDk} represents the average employment density in the ward k , and $K_{n,R}$ represents a set of zones belonging to the buffering zone (R) for the individual n .

The entropy index is computed using a land-use map for 2010. The map categorizes the land-use patterns into six different types: residential, public-use (such as hospitals, department stores, markets, offices, etc.), school, green (such as parks and gardens), religious-purpose (such as churches, temples, and pagodas), and other purposes (such as transportation). The entropy index is estimated by the following equation:

$$X_{nEI,R} = -\frac{1}{\ln(m_{n,R})} \sum_l^{m_{n,R}} (q_{nl,R} \cdot \ln(q_{nl,R}))$$

where $X_{nEI,R}$ is the entropy index of the buffering zone (R) for the individual n , $q_{nl,R}$ is a share of land-use category l in the buffering zone (R) for the individual n , and $m_{n,R}$ is the number of land-use categories observed in the buffering zone (R) for the individual n .

The commuting travel time is estimated for four different types of transportation mode: bus, motorbike, car, and bicycle. It is computed on the basis of Hanoi's current street network with observed vehicle speeds during peak hours. The travel time for bus users is estimated by the following equation:

$$X_{Tbusn} = IVT_{busn} + NIVT_{busn} = \sum_{b \in B_n} \frac{D_b}{S_{bus,b}} + WT_n + FLT_n + TR_n + \theta_n DW$$

where X_{Tbusn} is the bus users' commuting travel time for an individual n ; IVT_{busn} is the in-vehicle travel time of a bus route from an originating bus stop to a destination bus stop for the individual n ; $NIVT_{busn}$ is other travel time than bus in-vehicle travel time of the individual n ; D_b is the distance of links b ; $S_{bus,b}$ is the average speed of bus during the peak hours of link b ; B_n is the set of links along the bus route from home to workplace for the individual n ; WT_n is the waiting time of the individual n ,

which is calculated with the frequency of the bus service; FLT_n is the first- and last-mile travel time of the individual n , consisting of the walking time from home to the nearest bus stop and from the arrival bus stop to the workplace; TR_n is the transfer time of the individual n ; DW is the average dwell time at each bus stop, which is assumed to be 30 s for each stop; and θ_n is the number of bus stops along the bus route for the individual n . The average travel speeds of buses and motorbikes during peak hours are estimated through observations made by one of the authors using GPS devices in Hanoi in November 2017.

The travel time for motorbike, car, and bicycle users is also estimated as follows:

$$X_{T\mu n} = IVT_{\mu n} + NIVT_{\mu n} = \sum_{c \in C_n} \frac{D_c}{S_{\mu,c}}$$

where $X_{\mu n}$ is the commuting travel time of travel mode μ (=motorbike, car, or bicycle) for an individual n , $IVT_{\mu n}$ is the in-vehicle travel time of travel mode μ in the shortest route from home to the workplace of the individual n , $NIVT_{\mu n}$ is travel time other than in-vehicle travel time of travel mode μ for the individual n , D_c is the distance of link c , $S_{\mu,c}$ is the average speed of travel mode μ during the peak hours of link c , and C_n is a set of links along the route from home to workplace for the individual n . To estimate the travel time of cars during the peak hours, 500 cases regarding travel speeds of cars and motorbikes were observed in Hanoi using Google in morning and evening peak hours for five working days in July 2019. Additionally, the average speed of bicycles is assumed to be 8 km/h at every street based on our observation results.

Table 3 shows the descriptive statistics of the travel time and the BE measures in different spatial units. “B100,” “B200,” “B500,” and “B1000” refer to the 100 m, 200 m, 500 m, and 1000 m buffering zones around the respondents’ homes or workplaces and “ward scale” refers to the measurement in the smallest administrative zone. The table shows that an average commuting duration by bus is 43.57 min while that by motorbike is 15.93 min. The shorter travel time by motorbike arises because motorbike users can avoid congested traffic along trunk roads by passing through many dense and complex “narrow-alley” networks during peak hours. Meanwhile, the longer travel time of a bus indicates that buses face serious traffic congestion on the trunk roads during peak hours, not to mention accessing time and waiting time mean it is an even more time-consuming mode of travel. The average commuting time for bicycles is nearly double than that for motorbikes, about 30.26 min, partly because the average speed of bicycles is nearly half that of motorbikes. The average commuting time for cars is 17.84 min. This value a bit higher compared to those for motorbikes, and much lower compared to those for bus. The reason may be that car drivers spend time only for driving from home to their workplace. They do not have to spend time for walking from/to the bus stops, transferring, or waiting for the buses. The average population density measured at the smallest scale (100 m) is the highest, 284.52 per hectare, followed by those at 200 m, 500 m, and 1000 m. On the other hand, the average population density measured at the ward-scale is slightly higher compared to those in 100 m-buffering. The average employment density measured at the scales of 100 m and 200 m is 274.72 laborers per hectare and 280.16 laborers per hectare, respectively, which is significantly higher than those at 500 m and 1000 m. The values measuring in the 100 m- and 200 m-buffer are nearly equivalent to the values measuring in the ward-scale. The average entropy index varies from 0.47 to 0.62 across the different spatial units. They indicate that the current land-use pattern in Hanoi is quite mixed and evenly distributed. It is the smallest at the 100 m scale, followed by 200 m, 500 m, and 1000 m. This is quite reasonable because larger areas are expected to contain more land-use types. The average bus frequencies are greater at both origin and destination when they are measured at larger spatial scales. They are simply because larger buffering areas can cover more bus stops. The average bus frequency at a destination is significantly more than that at the origin, indicating that many respondents work in the city center where a better bus service is available. In the scale of the 500 m buffering area, the average bus frequencies at the origin and at the destination are 652.09 and 811.44 per day, respectively, which means approximately 10 to 13 bus routes cross within the 500 m

buffering from the origin and the destination, respectively, under the assumption of four services per hour and bus operation from 5 a.m. to 9 p.m. The average number of public facilities at the destination is slightly more than that at the origin. The results also show that people have access to nearly one public facility within a 100 m distance of their origin and destination (0.83 for origin and 0.98 for destination), which reflects the Hanoi government's policy that every administrative ward must install its own public facilities, such as ward headquarters, ward-level medical stations, etc. The values measuring in the 1000 m buffer are mostly much lower or higher compared to those measuring in the ward-scale. The reason might be that the ward is the smallest administrative unit in Hanoi, with areas ranging from 6 to 10 hectares if the ward located in the old quarter or ancient quarter, and from 60 to 80 hectares if the ward is located in new urbanized zones or urbanized villages. They are equivalent to the calculating areas for the buffering distance 100 m, 200 m, and 500 m, respectively. Therefore, the buffering distance ranging from 100 to 500 m will be more suitable compared to the 1000 m buffer.

Table 3. Descriptive statistics of travel time and built environment (BE) variables measured for four spatial units.

Travel Time	Min	Max	Mean	Median	SD
Bus	0	126.49	43.57	42.24	22.43
Motorbike	0	54.43	15.93	14.37	9.85
Car	0	58.53	17.84	16.18	10.41
Bicycle	0	112.28	30.26	27.15	19.43

BE variables	B100		B200		B500		B1000		Ward scale	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Population density at home	284.52	167.89	279.90	157.29	267.94	132.19	250.47	109.17	285.38	179.42
Employment density at workplace	274.72	220.34	280.16	207.53	272.34	167.99	256.54	137.34	279.76	88.63
Entropy index at home	0.47	0.16	0.53	0.14	0.60	0.10	0.62	0.09	0.51	0.11
Bus frequency at home	35.62	83.19	122.20	143.81	652.09	439.93	2337.76	1185.88	645.56	605.42
Bus frequency at workplace	65.54	111.78	176.	161.66	811.44	454.49	2818.17	1149.83	787.43	576.65
Number of public facilities at home	0.83	1.43	3.03	3.76	16.36	17.27	55.68	48.75	11.47	6.32
Number of public facilities at workplace	0.98	1.52	3.77	4.86	19.37	21.53	68.74	61.66	12.39	8.88

4. Results

4.1. Relationship between Density and Bus Ridership in Hanoi

Table 4 shows the comparison of bus modal shares across the four levels of population/employment densities for the four types of geographic units regarding the buffering zones mentioned above. The table shows that the bus modal share of respondents residing in the buffering zones with higher population densities tend to be higher, since it has the highest modal share in the buffering zones with the highest population density in all types of geographical unit. It also shows that the relationship in employment density is consistent for the 100 m, 200 m, and 500 m buffering zones, in which the areas with 300 to 400 people per hectare have the highest bus modal shares. However, both relationships are so unclear under such a simple uncontrolled analysis that a multivariate analysis, including other control variables, may be required to understand the associations of these densities with modal share.

Table 4. Bus modal shares by population/employment density by buffering scale in Hanoi.

	B100		B200		B500		B1000	
	No. Sample	% Bus User						
Population density at home (people per hectare)								
Below 150	134	5.97%	126	6.35%	113	4.42%	105	4.76%
150 to 300	222	6.76%	234	5.98%	256	7.81%	301	7.97%
300 to 450	196	6.12%	202	7.43%	217	6.45%	229	5.24%
Above 450	93	9.68%	83	8.43%	59	8.47%	11	27.27%

Table 4. Cont.

	B100		B200		B500		B1000	
	No. Sample	% Bus User						
Employment density at workplace (people per hectare)								
Below 150	129	6.20%	122	6.56%	112	5.36%	139	5.76%
150 to 300	304	6.25%	313	6.07%	330	5.76%	315	6.35%
300 to 400	100	10.00%	104	9.62%	108	12.96%	191	8.38%
Above 400	111	6.31%	106	6.60%	95	5.26%	105	11.43%

4.2. Estimation Results

To examine the MAUP issues, multinomial logit models for travel mode choice were estimated with the BE variables as measured at the four different geographical scales and at the ward scale. The scale effect of the MAUP is examined, following previous research [53] in which statistical significance in explanatory variables and model fitness are compared across different geographic scales. Table 5 summarizes the estimation results. “Commuting time” is defined as the total travel duration from home to workplace (minutes); “population density” is defined as the number of residents divided by area (people/hectare) at home; “tax revenue” is defined as the average annual district-level tax revenue at home (million VND); and “bus frequency at workplace buffering 500 m” is defined as the average bus frequency across all bus stops covered by the 500 m buffering zone from the workplace.

Table 5. Estimation results of models with BE variables measured in different spatial scales (N = 690).

Explained Variables	B100	B200	B500	B1000	Ward Scale
Intercept (bus)	−8.807 ***	−10.309 ***	−6.174 *	−7.099 **	−5.580 ***
Intercept (bicycle)	−3.352 ***	−3.521 ***	−2.900 ***	−2.261 **	−3.329 ***
Commuting time (bus, MB, bicycle, car)	−1.873 *	−2.405 *	−2.892 **	−1.131	−1.722
Population density at home (bus)	1.198 **	1.412 *	1.251	1.856 *	1.373 ***
Tax revenue at home (bus)	1.365 ***	1.423 **	1.170 *	1.069 *	0.540 *
Population density at home × Tax revenue at home (bus)	−0.0057 ***	−0.006 **	−0.005	−0.005 *	−0.0067 ***
Population density at home (MB, car)	−0.295 *	−0.396 *	−0.343	0.041	−0.299 *
Entropy index at home (bus)	4.508 **	5.22 **	−0.318	1.579	4.101 *
Bus frequency workplace buffering 500 m (bus)	0.091	0.13 **	0.140 **	0.0005	0.060
Number of public facilities at workplace (MB, car)	0.534 **	0.173 *	0.035 *	0.007	0.039
Adjusted ρ^2 (McFadden's R^2)	0.685	0.678	0.671	0.665	0.673
L0	−536.506	−536.506	−536.506	−536.506	−536.506
LL	−158.471	−162.552	−166.023	−169.402	−165.467
−2 (L0−LL)	756.07	747.908	740.966	734.207	742.078

Notes: ***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$, $p < 0.1$. “MB” represents motorbike. L0 means the initial log-likelihood, and LL means the optimum log-likelihood.

The model fitness represented by adjusted ρ^2 is sufficiently high in all models, while the likelihood ratio tests in all models also show that we can reject the null hypothesis that all coefficients are equal to zero at a high level of significance. The model with a 1000 m buffering distance has a quite high adjusted ρ^2 , but it contains few BE variables with statistically sufficient significance. By contrast, all BE variables appear to be statistically significant in the models with a buffering distance of 100 m and 200 m. As the model fitness is better in the model with a 100 m buffering zone than that with a 200 m buffering zone, our results may suggest that the 100 m buffering zone is most favored with respect to MAUP issues.

Second, the estimation results of the B100 model show that “commuting time” is estimated to be significantly negative, as suggested by previous studies. This means that a longer travel time reduces the individual’s utility level, which should lead to a lower probability of choosing a travel mode regardless of the type of travel mode.

The “population density at home (bus)” is significantly estimated to positively affect the bus’s utility level. The estimated coefficient of the cross-term of “population density at home (bus)” and “tax revenue at home (bus)” is significantly negative, but our dataset revealed that population density (bus) still has a positive effect even at the highest level of tax revenue in our observed data. This means that an individual residing in an area with a higher population density is more likely to choose the bus. This is consistent with the findings from other studies in developed cities.

The “tax revenue at home (bus)” is estimated significantly to affect positively the utility level of the bus. Again, this is still positive even if the highest population density in our dataset is assumed, incorporating the cross-term. This can be interpreted as meaning that an individual with a higher income chooses the bus more. This may be because rich people prefer to use environment-friendly travel modes or because they avoid dangerous travel modes such as motorbikes or bicycles.

The estimated coefficient of “population density at home (MB, car)” is significantly negative. This implies that a commuter tends to use a motorbike or a car less if they reside in an area with a higher population density. This contrasts with the effect of population density on bus use.

The “entropy index (bus)” is significantly estimated to positively affect the bus’s utility level. This may suggest that an individual residing in an area with more mixed land-use patterns tends to choose the bus more. This result may offer evidence to support TOD policy even in the case of a developing city like Hanoi.

The “bus frequency workplace buffering 500 m (bus)” is positively estimated. This means that a commuter whose workplace is located in an area with a higher bus service frequency tends to choose the bus more, which sounds reasonable.

The estimated coefficient of “number of public facilities at workplace (MB, car)” is significantly positive. This means that an individual whose workplace is located in an area with more public facilities, such as hospitals, department stores, and markets, tends to choose the private motorized vehicles more. This may conflict with the strategy of TOD policy, but it sounds reasonable because many Hanoians use private vehicles to engage in other non-work activities after work.

Table 6 presents the estimation results of the MNL models with a 100 m buffering distance, which introduces other explanatory variables in addition to the BE variables, such as socio-demographic and other variables that mitigate the residential self-selection bias. “Total duration of residence” is defined as the duration (years) of residence at the current location up to the present. If the respondent was born and raised in their current home, then the duration is equivalent to her/his age.

Table 6. Result of full models with BE variables measured for the buffering distance of 100 m.

Explanatory Variables		Model 1	Model 2	Model 3
BE variables and travel time	Intercept (bus)	−8.604 ***	−7.873 ***	−7.145 ***
	Intercept (bicycle)	−2.976 ***	−3.604 ***	−3.691 ***
	Commuting time (bus, MB, bicycle, car)	−1.659	−2.072 *	−1.823
	Population density at home (bus)	0.927	1.181 **	1.222 *
	Tax revenue at home (bus)	1.201 ***	1.144 **	1.128 *
	Population density at home × Tax revenue at home (bus)	−0.0049 **	−0.0062 ***	−0.0065 ***
	Population density at home (MB, car)	−0.303 *	−0.353 *	−0.348 *
	Entropy index at home (bus)	4.902 **	4.759 **	3.819 *
	Bus frequency at workplace buffering 500 m (bus)	0.087		
Number of public facilities at workplace (MB, car)	0.456 *	0.58 *	0.556 *	
Socio-demographic variables	Over 50 years old (bus)	1.222 *	1.471 **	1.11 *
	Male (MB, car)	0.881 *		1.107 *
	Marital status (MB, car)		0.944 *	
	Student, dependent (bus)	1.200 *	0.882	0.985
	Unskilled laborer (bus)	1.883 **		1.523 *
	Child pick-up (bus)	−2.001 *	1.357	−2.471 *
Self-selection variables	Total duration of residence (MB, car)		−0.058 *	−0.065 *

Table 6. Cont.

Explanatory Variables	Model 1	Model 2	Model 3
Number of observations	690	563	563
Adjusted ρ^2 (McFadden's R^2)	0.711	0.687	0.698
L0	−536.506	−442.249	−442.249
LL	−139.606	−124.319	−118.344
−2 (L0−LL)	793.800	635.860	647.810

Notes: ***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$, $p < 0.1$. “MB” represents motorbike. L0 means the initial log-likelihood, and LL means the optimum log-likelihood.

Model 1 represents the estimation results incorporating the socio-demographic variables in addition to the B100 model shown in Table 5. The estimates of the BE variables in Model 1 have similarities to those in the B100 model in Table 5. The results show that individuals aged over 50, students or dependents, and unskilled workers tend to choose the bus. Such people are less wealthy, physically unfit to drive a car/motorbike/bicycle, and/or are less likely to own a car/motorbike/bicycle, which could motivate them to use the bus. The results also show that “Male” is significantly positive with the choice of cars or motorbikes. This is also quite reasonable because females tend to prefer safer travel modes than the dangerous modes represented by cars and motorbikes. Besides, “Child pick-up (bus)” is significantly negative. It is quite reasonable in the context of Hanoi because Hanoians usually drive their children from/to school every day.

Models 2 and 3 represent the estimation results including the variables relating to residential self-selection in addition to Model 1, although “bus frequency workplace buffering 500 m (bus)” is removed due to poor significance. “Marital status” and “Child pick-up” are highly correlated so we introduce them separately. Both models have estimation results regarding the BE and socio-demographic similar to those in Model 1. “Marital status” is significantly positive, married people tend to use motorbikes rather than other modes. This is reasonable because married people typically need to use motorbikes to pick up and drop off their children at school. As for the residential self-selection variable, “total duration of residence (MB, car)” has a significantly negative estimated coefficient in Model 2 and Model 3. This may imply that new immigrants tend to choose motorbikes and cars more than those who have lived in their current homes for a longer period. This could mean that newcomers typically choose newly developed urban areas, which have been often designed for private vehicle users rather than public transit. This probably reflects local people’s preferences for residential location, which could cause the residential self-selection bias even in the context of Hanoi.

5. Discussion

The results of our analysis have implications for the Hanoi’s TOD policy. First, regarding the “Density” feature of TOD, the results unveiled that the population density near home has significantly positive influences on bus ridership while it also has significantly negative influences on motorbike use. These results support the TOD theory that a higher population density might induce the use of public transportation. The negative impact of population on motorbike use is mainly because parking spaces for motorbikes are poorly available at high population-density residential areas, which motivates people to choose the bus; whereas the parking spaces are more available at business districts even with a high employment density, which may motivate them to use the motorbikes. They suggest that the residential development in the vicinity of bus stops could work for better bus ridership while regulations and/or control strategies of motorbike parking should be jointly incorporated into the Hanoi’s TOD policy.

Second, regarding the “commercial development,” the estimation results found that the number of public facilities, such as department stores and markets near the workplace, might induce motorbike use. This may imply that commercial development near the business areas could negatively influence the bus ridership. It may also suggest that the Hanoi’s TOD policy should be carefully designed in

terms of its scope of development site and type, highlighting residential development at the residential areas rather than commercial development at the business districts in the context of Hanoi.

Third, regarding the “mixed-use development,” our results confirmed that the land-use mix could attract bus users. This suggests that monotonic land-use patterns such as residential- or business-only areas are not suitable for sustainable urban development. As old Hanoi’s urban areas have been developed in a mixed land-use pattern, such traditional styles of urban development should be respected even in new developments under the Hanoi’s TOD policy.

Lastly, regarding the public transit, the quantity and quality of transit services should be highlighted to fascinate public transit users in Hanoi’s TOD policy. Although the bus is the only transit service available in Hanoi until now, the Urban Mass Rapid Transit (UMRT) and Bus Rapid Transit (BRT) systems are under construction and will be operated soon. It raises a question to policy makers about how to connect these systems into an efficient intermodal transit network. Along with the appearance of the new UMRT and BRT systems, the current bus network, which has long routes (usually over 60 min per tour) passing through the city center should be reorganized and integrated into the UMRT and BRT systems, in which local buses serve mainly first/last-mile services to/from transit stations. This is expected to improve the average speed and service reliability of the public transit system. Additionally, the quality of bus vehicles should be upgraded so as to attract knowledge-intensive laborers in addition to students, dependents, unskilled laborers, and senior people as passengers of the bus service.

6. Conclusions

This study presented empirical evidence on the association between the BE and travel behavior in Hanoi. It found similar effects for BE variables in a developing Asian city to those in the developed world. This could encourage a more compact and higher mix of land use, as well as better transit services, to shift local people from private vehicles to public transit in Hanoi. It also has implications for the Hanoi’s TOD policy that highlights residential development near bus stops rather than commercial developments in the central business district. These findings should be valuable because the data availability for developing cities is quite poor for empirical analyses.

One of the challenges for the Hanoi’s TOD is the introduction of new public transit systems in the near future. Although the bus is currently the only mode of public transit, the UMRT and BRT systems are newly operated or under construction and will be in operation soon. Thus, further analysis is needed to incorporate these new public transit systems into analysis of the association between TOD planning elements and travel demand. Another challenge is the implementation of Hanoi’s TOD policy. Urban redevelopment with higher density and diversity and better transit services may attract more people to public transit use, but it is also expected to raise property prices near public transit stops, which could lead to so-called “gentrification” [58,59]. For instance, Venter et al. [60] reported the equity impacts from BRT through a literature review. In Hanoi, low-income unskilled people typically live under poor conditions in the urban core, where they work in jobs with motorbikes, such as street vendors and small privately-owned shops; those people could be easily displaced by gentrification. To reduce the negative impacts from gentrification, a fair transportation system should be developed, which is beneficial to any economic or social group. Policy actions reducing the dominance of private automobiles, such as traffic calming, may help the poor to have a safer, walkable, and livable commuting environment. Additionally, although many resettlement projects have tried to relocate these people into other areas of Hanoi with better living conditions, they have failed because the affected people refused to move due to their fixed daily-life routines. Even if the government could resettle these affected people in the same TOD area, there would be no guarantee that these people would continue the same jobs as before. They may suggest that the Hanoi’s TOD policy should be carefully designed to integrate job security for existing low-income residents.

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References

1. Fujiwara, A.; Zhang, J. *Sustainable Transport Studies in Asia*; Springer: Minato, Japan, 2013. [\[CrossRef\]](#)
2. Ieda, H. *Sustainable Urban Transport in an Asian Context*; Springer: Minato, Japan, 2010. [\[CrossRef\]](#)
3. Kato, H. Development assistance to transportation in Asian developing countries. In *Routledge Handbook of Transport in Asia*; Routledge Handbooks Online; Zhang, J., Feng, C.-M., Eds.; Routledge: Abingdon, UK, 2018.
4. Morichi, S.; Acharya, S.R. *Transport Development in Asian Megacities*; Springer: Berlin, Germany, 2013.
5. Zusman, E.; Srinivasan, A.; Dhakal, S. Low carbon transport and co-benefits in Asia: An Overview. In *Low Carbon Transport in Asia: Strategies for Optimizing Co-Benefits*; Zusman, E., Srinivasan, A., Dhakal, S., Eds.; Routledge: London, UK, 2012.
6. Suzuki, H.; Cervero, R.; Iuchi, K. *Transforming Cities with Transit: Transit and Land-Use Integration for Sustainable Urban Development*; Urban Development, World Bank: Washington, DC, USA, 2013.
7. Cervero, R. Linking urban transport and land use in developing countries. *J. Transp. Land Use* **2013**, *6*, 7–24. [\[CrossRef\]](#)
8. Drilling, M. Planning sustainable cities: Why environmental policy needs social policy. In *Environmental Policy is Social Policy—Social Policy is Environmental Policy*; Wallimann, I., Ed.; Springer: New York, NY, USA, 2013.
9. Trudeau, D. Sustaining suburbia through New Urbanism: Toward growing, green, and just suburbs? *Urban Plan.* **2018**, *3*, 50–60. [\[CrossRef\]](#)
10. White, S.; Ellis, C. Sustainability, the environment, and New Urbanism: An assessment and an agenda for research. *J. Archit. Plan. Res.* **2007**, *24*, 125–142.
11. Jim, C.Y. Green-space preservation and allocation for sustainable greening of compact cities. *Cities* **2004**, *21*, 311–320. [\[CrossRef\]](#)
12. Lang, U. Cultivating the sustainable city: Urban agriculture policies and gardening projects in Minneapolis, Minnesota. *Urban Geogr.* **2014**, *35*, 477–485. [\[CrossRef\]](#)
13. Tappert, S.; Klöti, T.; Drilling, M. Contested urban green spaces in the compact city: The (re-)negotiation of urban gardening in Swiss cities. *Landsc. Urban Plan.* **2018**, *170*, 69–78. [\[CrossRef\]](#)
14. Zimmerman, J. The “nature” of urbanism on the new urbanist frontier: Sustainable development, or defense of the suburban dream? *Urban Geogr.* **2001**, *22*, 249–267. [\[CrossRef\]](#)
15. Calthorpe, P. *The Next American Metropolis: Ecology, Community, and the American Dream*; Princeton Architectural Press: New York, NY, USA, 1998.
16. Duany, A.; Speck, J.; Lydon, M. *The Smart Growth Manual*; McGraw Hill: New York, NY, USA, 2010.
17. Bakker, S.; Contreras, K.D.; Kappiantari, M.; Tuan, N.A.; Guillen, M.D.; Gunthawong, G.; Zuidgreest, M.; Liefferink, D.; van Maarseveen, M. Low-carbon transport policy in four ASEAN countries: Developments in Indonesia, the Philippines, Thailand and Vietnam. *Sustainability* **2017**, *9*, 1217. [\[CrossRef\]](#)
18. Iamtrakul, P.; Zhang, J. Measuring pedestrians’ satisfaction of urban environment under transit oriented development (TOD): A case study of Bangkok Metropolitan, Thailand. *Lowl. Technol. Int.* **2014**, *16*, 125–134. [\[CrossRef\]](#)
19. Suzuki, H.; Murakami, J.; Hong, Y.-H.; Tamayose, B. *Financing Transit-Oriented Development with Land Values: Adapting Land Value Capture in Developing Countries*; World Bank: Washington, DC, USA, 2015.
20. Xu, W.; Gurhrie, A.; Fan, Y.; Li, Y. Transit-oriented development in China: Literature review and evaluation of TOD potential across 50 Chinese cities. *J. Transp. Land Use* **2017**, *10*, 743–762. [\[CrossRef\]](#)

21. Zhao, P.; Li, S. Suburbanization, land use of TOD and lifestyle mobility in the suburbs: An examination of passengers' choice to live, shop and entertain in the metro station areas of Beijing. *J. Transp. Land Use* **2018**, *11*, 195–215.
22. Hoa, T.Q. Study on transit oriented development (TOD) to promote green growth and sustainability for Hanoi city. *J. Sci. Technol. Civ. Eng.* **2016**, *10*, 58–63.
23. van Horen, B. City profile Hanoi. *Cities* **2005**, *22*, 161–173. [[CrossRef](#)]
24. Leducq, D.; Scarwell, H.-J. The new Hanoi: Opportunities and challenges for future urban development. *Cities* **2018**, *72*, 70–81. [[CrossRef](#)]
25. McGee, T.G. The urban future of Vietnam. *Third World Plan. Rev.* **1995**, *17*, 253–277. [[CrossRef](#)]
26. Quang, N.; Kammeier, H.D. Changes in the political economy of Vietnam and their impacts on the built environment of Hanoi. *Cities* **2002**, *19*, 373–388. [[CrossRef](#)]
27. Smith, D.W.; Scarpaci, J.L. Urbanization in transitional societies: An overview of Vietnam and Hanoi. *Urban Geogr.* **2000**, *21*, 745–757. [[CrossRef](#)]
28. Surborg, B. Advanced services, the New Economy and the built environment in Hanoi. *Cities* **2006**, *23*, 239–249. [[CrossRef](#)]
29. Minh, N.Q. Application of “Car-Free City” and “City of Short Walks” to living quarters in Hanoi towards sustainable mobility and logistics. *Procedia Eng.* **2016**, *142*, 284–291. [[CrossRef](#)]
30. Sanders, P.; Zuidgeest, M.; Geurs, K. Liveable streets in Hanoi: A principal component analysis. *Habitat Int.* **2015**, *49*, 547–558. [[CrossRef](#)]
31. Nguyen, M.H.; Pojani, D. Why do some BRT systems in the Global South fail to perform or expand? In *Preparing for the New Era of Transport Policies: Learning from Experience*; Elsevier: Amsterdam, The Netherlands, 2018; pp. 35–61.
32. Cervero, R.; Kockelman, K. Travel demand and the 3Ds: Density, diversity, and design. *Transp. Res. Part D Transp. Environ.* **1997**, *2*, 199–219. [[CrossRef](#)]
33. Ewing, R.; Cervero, R. Travel and the built environment: A meta-analysis. *J. Am. Plan. Assoc.* **2010**, *76*, 265–294. [[CrossRef](#)]
34. Rajamani, J.; Bhat, C.R.; Handy, S.; Knaap, G.; Song, Y. Assessing impact of urban form measures on nonwork trip mode choice after controlling for demographic and level-of-service effects. *Transp. Res. Rec.* **2003**, *1831*, 158–165. [[CrossRef](#)]
35. Zhang, M. The role of land use in travel mode choice: Evidence from Boston and Hong Kong. *J. Am. Plan. Assoc.* **2004**, *70*, 344–360. [[CrossRef](#)]
36. Boarnet, M.G.; Joh, K.; Siembab, W.; Fulton, W.; Nguyen, M.T. Retrofitting the suburbs to increase walking: Evidence from a land use-travel study. *Urban Stud.* **2010**, *48*, 129–159. [[CrossRef](#)]
37. Chatman, D.G. How density and mixed uses at the workplace affect personal commercial travel and commute mode choice. *Transp. Res. Rec.* **2003**, *1831*, 193–201. [[CrossRef](#)]
38. Cervero, R. Built environments and mode choice: Toward a normative framework. *Transp. Res. Part D Transp. Environ.* **2002**, *7*, 265–284. [[CrossRef](#)]
39. Frank, L.D.; Bradley, M.; Kavage, S.; Chapman, J.; Lawton, K. Urban form, travel time, and cost relationships with tour complexity and mode choice. *Transportation* **2008**, *35*, 37–54. [[CrossRef](#)]
40. Strauss, J.; Miranda-Moreno, L.F. Spatial modeling of bicycle activity at signalized intersections. *J. Transp. Land Use* **2013**, *6*, 47–58. [[CrossRef](#)]
41. Miranda-Moreno, L.F.; Fernandes, D. Pedestrian activity modeling at signalized intersections: Land use, urban form, weather and spatiotemporal patterns. *Transp. Res. Rec. J. Transp. Res. Board* **2011**, *2264*, 74–82. [[CrossRef](#)]
42. Hankey, S.; Lindsey, G. Facility-demand models of peak-period pedestrian and bicycle traffic: A comparison of fully-specified and reduced-form models. *Transp. Res. Rec. J. Transp. Res. Board* **2016**, *2586*, 48–58. [[CrossRef](#)]
43. Schneider, R.J.; Hu, L.; Stefanich, J. Exploring the importance of detailed environment variables in neighborhood commute mode share models. *J. Transp. Land Use* **2018**, *11*, 921–938.
44. Parkin, J.; Wardman, M.; Page, M. Estimation of the determinants of bicycle mode share for the journey to work using census data. *Transportation* **2008**, *35*, 93–109. [[CrossRef](#)]
45. Cervero, R.; Gorham, R. Commuting in transit versus automobile neighborhoods. *J. Am. Plan. Assoc.* **1995**, *61*, 210–225. [[CrossRef](#)]

46. Frank, L.D.; Pivo, G. Impacts of mixed use and density on utilization of three modes of travel: Single-occupant vehicle, transit, and walking. *Transp. Res. Rec.* **1994**, *1466*, 44–52.
47. Handy, S. *Travel Behavior Issues Related to Neo-Traditional Developments: A Review of the Research*. In *Proceedings of the TMIP Conference on Urban Design, Telecommuting, and Travel Behavior*; Federal Highway Administration: Washington, DC, USA, 1996.
48. Chatman, D.G. Residential choice, the built environment, and nonwork travel: Evidence using new data and methods. *Environ. Plan. A* **2009**, *41*, 1072–1089. [[CrossRef](#)]
49. Litman, T. Impacts of rail transit on the performance of a transportation system. *Transp. Res. Rec.* **2005**, *1930*, 23–29. [[CrossRef](#)]
50. Cao, X.; Mokhtarian, P.L.; Handy, S. Examining the impacts of residential self-selection on travel behaviour: A focus on empirical findings. *Transp. Rev.* **2009**, *29*, 359–395. [[CrossRef](#)]
51. Openshaw, S. The Modifiable Areal Unit Problem. In *Concepts and Techniques in Modern Geography*; Geo Abstracts Ltd.: Norwich, UK, 1984.
52. Krizek, K.J. Residential relocation and changes in urban travel: Does neighborhood-scale urban form matter? *J. Am. Plan. Assoc.* **2003**, *69*, 265–281. [[CrossRef](#)]
53. Clark, A.; Scoot, D. Understanding the impact of modifiable areal unit problem on the relationship between active travel and the built environment. *Urban Stud.* **2013**, *51*, 284–299. [[CrossRef](#)]
54. Mitra, R.; Buliung, R.N. Built environment correlates of active school transportation: Neighborhood and the modifiable areal unit problem. *J. Transp. Geogr.* **2012**, *20*, 51–61. [[CrossRef](#)]
55. Cervero, R.; Sarmiento, O.L.; Jacobi, E.; Gomez, L.F.; Neiman, A. Influences of built environments on walking and cycling: Lessons from Bogotá. *Int. J. Sustain. Transp.* **2009**, *3*, 203–226. [[CrossRef](#)]
56. Ho, C.Q.; Yamamoto, T. The role of attitudes and public transport service on vehicle ownership in Ho Chi Minh City, Vietnam. In *Proceedings of the Australian Transport Research Forum 2011*, Adelaide, Australia, 28–30 September 2011.
57. Tran, M.T.; Zhang, J.; Chikaraishi, M.; Fujiwara, A. A joint analysis of residential location, work location and commuting mode choices in Hanoi, Vietnam. *J. Transp. Geogr.* **2016**, *54*, 181–193. [[CrossRef](#)]
58. Hwang, J. While some things change, some things stay the same: Reflections on the study of gentrification. *City Community* **2016**, *15*, 226–230. [[CrossRef](#)]
59. Smith, N. *The New Urban Frontier: Gentrification and the Revanchist City*; Psychology Press: New York, NY, USA, 1996.
60. Venter, C.; Jennings, G.; Hidalgo, D.; Pineda, A.F.V. The equity impacts of bus rapid transit: A review of the evidence and implications for sustainable transport. *Int. J. Sustain. Transp.* **2018**, *12*, 140–152. [[CrossRef](#)]



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